Handbook of Research on Energy and Environmental Finance 4.0

Abdul Rafay
University of Management and Technology, Pakistan

A volume in the Advances in Finance, Accounting, and Economics (AFAE) Book Series

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Great things are done when men and mountains meet; this is not done by jostling in the street - William Blake in "Great things are done" (c. 1807-1809)

This book is dedicated to *Dr. Umar Saif*, a person of impeccable reputation and a visionary practitioner of computer sciences in Pakistan. His scholarly and practical contribution in the respective fields made him a person of great depth and integrity.

He holds a PhD from the University of Cambridge (UK) and a postdoc from Massachusetts Institute of Technology (USA). He served as the Chairman Punjab Information Technology Board (2011-2018) in Pakistan. His work led to a radical digital transformation of the government in Punjab. He established the Information Technology University in Pakistan and served as the founding vice chancellor. He became known for introducing the startup culture in Pakistan when he established Pakistan's first technology incubator "Plan 9" in 2012. In 2018, he was appointed UNESCO Chair for using ICT for Development. He brought MIT Technology Review to Pakistan and served as its founding Editor-in-Chief (2014-2018) to promote high-quality science and tech journalism in Pakistan.

He was awarded numerous awards such as Digital Inclusion Award from Microsoft Research (2006), MIT Technovator Award (2008), Mark Weiser Award (2008), IDG CIO Technology Pioneer Award (2008), Young Global Leader by the World Economic Forum (2010), Google's Faculty Research Award (2011), Sitara-i-Imtiaz (2014) by Government of Pakistan and the British Council Outstanding Alumni Award (2017). Dr. Saif was named as one of the top 35 young innovators in the world by the MIT Technology Review (TR35). He was named among "The 500 Most Influential Muslims" (2015-2019).

Currently he is the Founder and CEO, SurveyAuto.com, Chief Digital Officer of Jang/Geo Media Group and Chief Investment Officer, Khudi Ventures.

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The energy assessment in any industrial/engineering project is an important aspect of project identification in the environmental impact assessment (EIA) plan. It figures out the efficiency of projects through data envelopment analysis (DEA) in comparison with revenue, prior to the establishment of full-scale industries. This study assessed eight groups of Iranian small and medium-sized industries (ISMSI) for the energy stream/revenue. The DEA model is supported by weighing systems of Friedman test, criteria importance through intercriteria correlation (CRITIC), analytical hierarchy process (AHP), and entropy Shannon to assess the efficiency of industries. Four weighing systems of the multi-criteria decision-making (MCDM) model revealed no significant differences among findings of industrial groups, keeping in view the sensitivity analysis conducted and good reliability of Cronbach's Alpha ($\alpha = 0.858$). Therefore, the application of the DEA model is highly recommended for managing energy streams in the EIA plan.

This study examined the distributional effects of energy subsidy reduction in Kuwait. A computable general equilibrium (CGE) model was calibrated on a Kuwaiti social accounting matrix (SAM). A simulation experiment was conducted by applying a 25% energy subsidy reduction. The SAM consisted of 10 household groups, categorized into nationals and expatriates, and subsequently classified into five income levels. The employed labor force was classified into two groups (nationals and expatriates), each disaggregated by four skill levels. Industries were disaggregated into 65 branches. The CGE model was specified in such a way that it would be possible to quantify welfare effects on each household group and then trace the changes to distributional effects, factor income, and employment by industrial origins. When accompanied by compensation, the energy subsidy led to an aggregate efficiency (increase in GDP) and welfare gains. The welfare gains among Kuwaiti nationals were progressive; the lower-income groups gained more than higher-income groups.

This study, using the local projections, investigates linear and nonlinear impulse responses of the United States (US) household income inequality to oil price shocks. Oil price shocks are disaggregated according to the origin to test the dynamic response of income inequality to oil price structural shocks which are contingent on the status of oil dependence in individual US states. The results, based on the linear projection model, show that oil supply shocks lead to higher income inequality in the short term, but lower-income inequality in the medium and long terms. Moreover, economic activity shocks and oil inventory demand shocks mainly exert negative impacts on income inequality over time. Both positive and negative effects of oil consumption demand shocks on income inequality are observed. The nonlinear impulse response results reveal some evidence of heterogeneous responses of income inequality to oil price shocks between high- and low-oil-dependent US states.

Being economic boosters, foreign direct investment (FDI) and financial sector development (FSD) are highly recommended for developing countries. It is therefore critical and important to examine the impact of both FDI and FSD on energy consumption. This chapter examines the link between FDI, FSD, and energy consumption in Africa and also the role of institutional quality in this context. The results establish that both FDI and FSD have a significant positive impact on energy consumption. It is also established that there is an inverse relationship between institutional quality and energy use. Finally, it is proved that quality institutions moderate the link between FDI, FSD, and energy use in Africa.

The goal of every company should not be profit exclusively but also public welfare and social responsibility. Traditional financial reporting of companies was not sufficient to monitor the sustainable development of companies and their impact on the wider community. The Global Reporting Initiative (GRI) was introduced to provide global guidelines to report social and environmental information. The emphasis is on reporting and measuring the level of corporate social responsibility (CSR). Reporting on CSR is necessary because companies need to be responsible for the implementation of its principles, aimed at protecting the interests of stakeholders. Mandatory GRI reporting increases social responsibility due to reduced business risk and enhanced business performance.

Legislation regarding renewable energy became significant during the last few years. For this purpose, several international regulations have been adopted to regulate the environmental and energy policies of countries. These regulations are formulated in a wide range of binding instruments and soft laws. However, the proliferation of international instruments coupled with the uncertainty of the principles/rules of international law regarding the development of renewable energy sources necessitates the consideration of an international law approach. In this chapter, the author intends to examine the principles and rules of international law considering the importance of the development of renewable energy as an issue with global dimensions.

China has been one of the largest global emitters of carbon dioxide (CO2). As a result, the country is committing itself to implement the 2030 Agenda for Sustainable Development. The attention that is being paid to the serious problem of climate change has increased manifold. Corresponding policies are introduced in relation to the financing of carbon. In particular, in the wake of the announcement that China would be going carbon neutral before 2060, concrete efforts are being consistently made towards carbon emission reduction. Policies and measures related to carbon finance are being continuously promulgated, and a national carbon emission trading market too has been established on July 16, 2021. This chapter gives a brief overview of the carbon market, carbon finance, and its policies in the context of sustainable development. It also examines the approach towards the future development of the carbon finance market by discussing in detail the existing deficiencies and areas of improvement.

This chapter examines the asymmetric link between technological innovation and financialization in Pakistan for the period 1980-2019. The non-linear autoregressive distributed lag (NARDL) model proposed by Shin et al. is applied to achieve the research objective. The numerical estimates based on annual data explain that an asymmetric relationship exists between financialization and environmental degradation and between technological innovations and environmental degradation in the long run. An increase in financialization and regression in technology stimulates environmental degradation while a decline in financialization and progress in technology improves environmental quality in Pakistan. Based on empirical evidence, the research emphasizes the suitable channelization of financial institutions towards environmentally friendly projects and formulation of those policies that encourage energy-efficient technologies.

Carbon emission allowances are considered an important policy instrument to prevent an undesirable increase in the Earth's temperature caused by the excess of greenhouse gases in the atmosphere. Most of the existing literature modeled the behavior of allowance prices before the implementation of regulatory measures such as the market stability reserve mechanism. In this chapter, the main determinants of the carbon emissions allowance prices in the European Union are examined, applying econometric

This chapter explains the drivers for carbon prices related to institutional decisions, energy prices, and weather events. The study focuses on price changes in the EU as being the most liquid carbon asset. In this regard, the daily spot price of the EU is highlighted to demonstrate the daily changes, given the high volatility in this carbon financial market. The CO2 prices depend on several determinants. This chapter constitutes an introduction to emission trading and an overview of the regulations of carbon financial markets. First, the price changes in the EU and primary energy prices are discussed. Second, the characteristics of emissions trading are introduced in terms of spatial and temporal limits, clean dark spread, and switch price. Third, a global analysis of atmospheric variables, structural variations, the subprime crisis, and the COVID-19 crisis is presented.

Preface

The editing of a handbook of research on Theory and Practice of Energy and Environmental Finance (EEF) is more exciting and challenging than ever before. The past few decades have been eventful for the EEF, especially for Carbon Emissions, Sustainability, Environmental Pollution, Carbon Markets, Energy Pricing to name a few. These terminologies have become a buzzword from G20 to World Economic Forum to global and national economic agendas. Today tackling the problems of EEF is being considered a key issue in developed and developing countries alike.

INTRODUCTION

"We have met the enemy and they are ours" - Oliver Hazard Perry, 1813

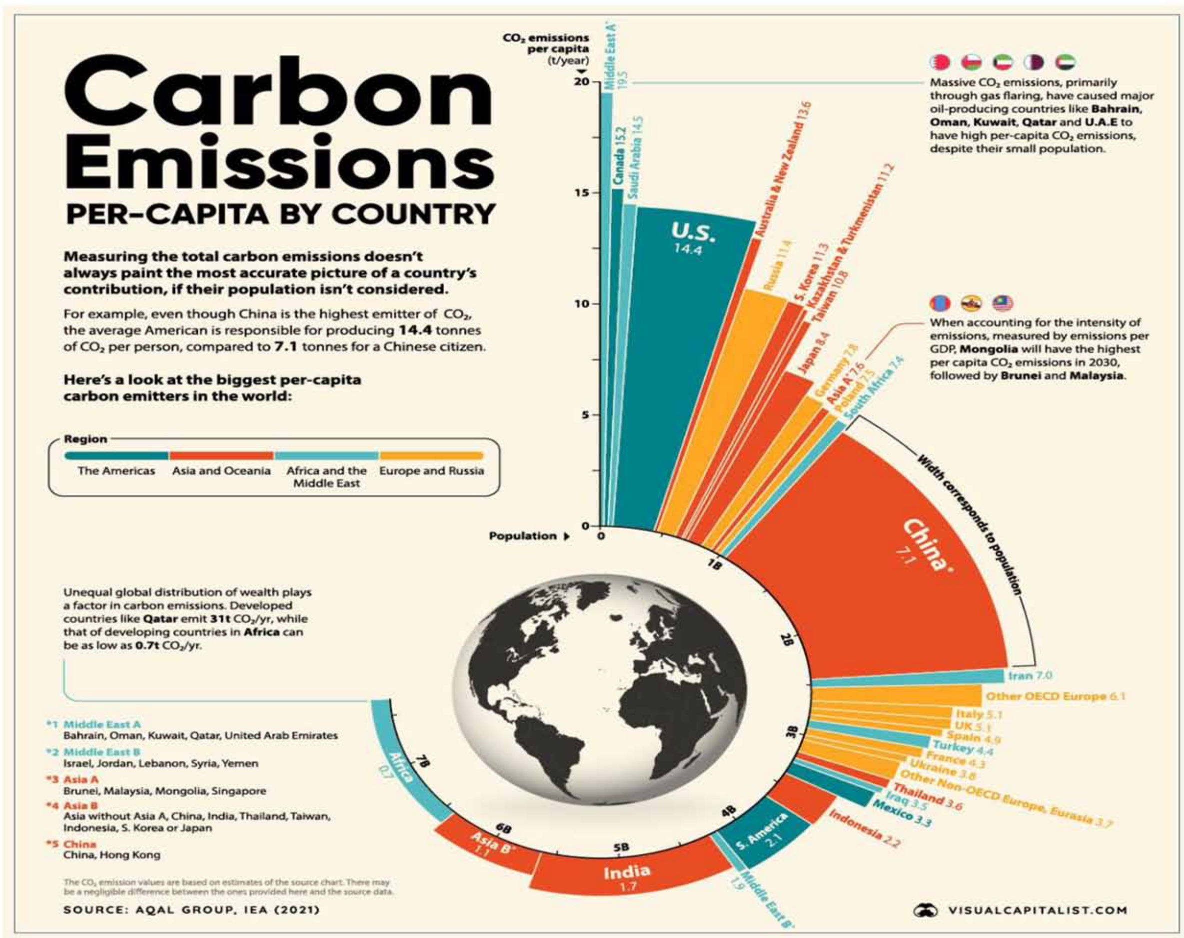
Mankind is witnessing disastrous effects of climate change that are continuing to wreak havoc. The ecosystems are affected by human interventions that include the use of fossil fuels, industrial emissions, waste dumping into oceans, deforestation to name a few (Olayungbo *et al.,* 2022). All these interventions are resulted in devastating floods, melting of glaciers, rise in temperature, droughts, cyclones, hurricanes, degradation of ecosystems, reduction in wetlands, loss of biodiversity, air pollution etc. The frequency, scale and severity of all these climatic hazards are increasing day by day.

POLLUTION AND HEALTH

"Environmental Pollution is an incurable disease. It can only be prevented" - Barry Commoner

A large number of countries are relying on fossil fuels (oil, gas and coal) based energy resources (which represents 80% of the energy consumed) for their economies. Energy Sector Coal-fired based energy is one of the biggest reasons for CO_2 emissions. Coal burning is not only contributing to the ongoing climate catastrophe but also harming the health of the people (Rehman *et al.*, 2022). Air pollution is the leading cause of deaths and disabilities. Polluted air contains carbon dioxide, carbon monoxide, lead, sulphur dioxide and other pollutants. In developing countries around 42 percent of all stroke cases, cardiovascular diseases and lung ailments are due to poor air quality (Bhatti, 2021). For example, annual coal-related air pollution deaths in South Africa (which is the 12th largest CO_2 emitter in the world) is about 2300 as reported by environmental justice NGO groundwork.

Figure 1. Carbon emissions per capita by country
Source: Visualcapitalist.com (2021)

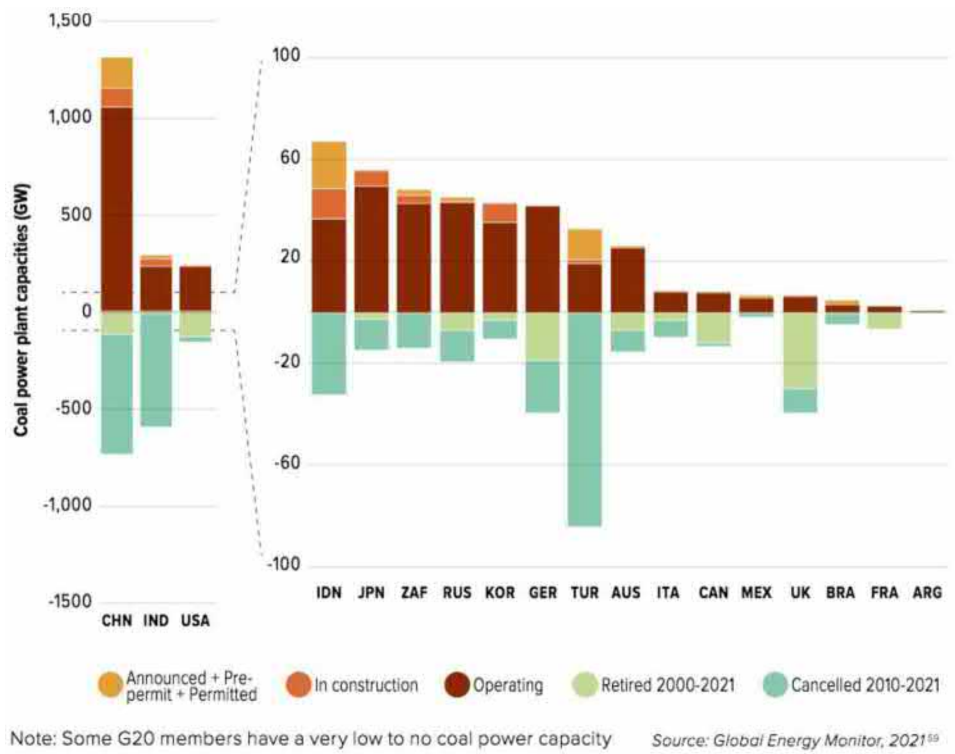


Despite the climate crises, many coal-producing countries (especially Africa and the Global South) are of the view that they should have their turn in benefiting from their coal reserves. In this regard, Zimbabwe is going to open its new coal mines to meet its energy needs (Mwareya, 2021). Despite all these facts, many countries are pledged to reduce coal usage. These countries include China, Chile, India, Poland and Vietnam (Ali *et al.*, 2021).

MIGRATION AND DISPLACEMENT

Climate-driven migration is also an emerging issue. In 2020, around 40.5 million people were displaced due to climate-driven events like floods, droughts, hurricanes, sea level rising, extreme wildfires with high temperatures etc. Global resiliency strategies for climate change and resettlement pathways for climate-displaced persons are also in discussion. ProPublica and Pulitzer Center are developing models to estimate the effect of climate change on migration.

Figure 2. Coal power plant capacities
Source: Visualcapitalist.com (2021)

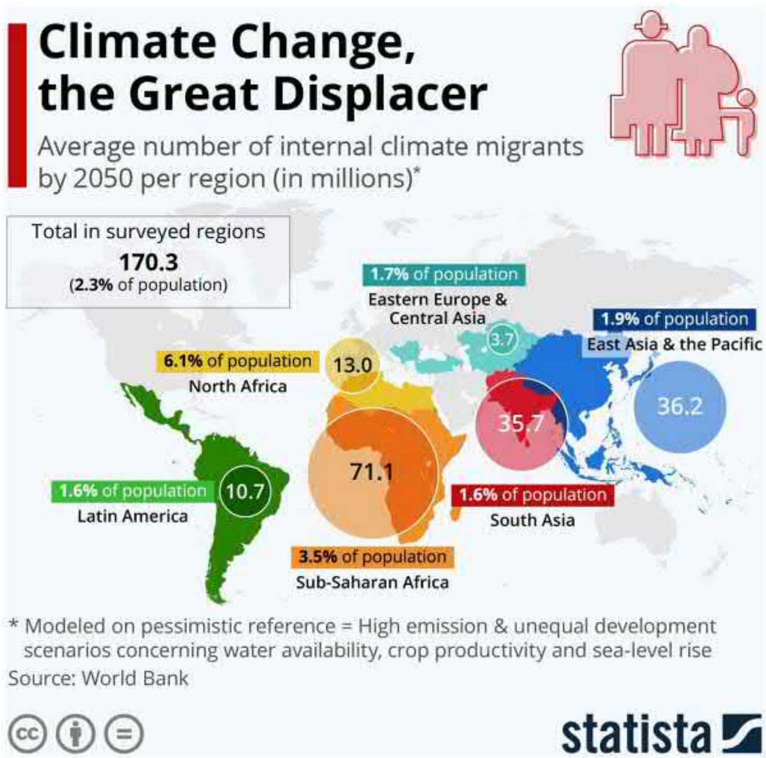


DAMAGES CONTROL PLANS

Environmental Conventions/Accords/Indices

Eradication of environmental pollution and all of its forms through a holistic approach of awareness, prevention and enforcement is the need of the hour. For a few years, national and international organizations based in different countries positioned themselves in the global fight against environmental pollution. Coastal cities are also planning to build sea walls due to rising sea levels due to the reduction in thickness of multi-year ice sheets of the Arctic (Hunziker, 2022). These bodies have been working with the governments to streamline the legal frameworks, regulatory institutions, capacities of the states and standardization (Rafay, 2021). Similarly, many international Conventions/Treaties/Standards for the environment have been signed and implemented. Various indices are used to measure the performance of energy and the environment.

Figure 3. Expected climate migration by 2050
Source: Statista (2021)



Conservation

Conservation policies for a sustainable environment are important in order to maintain a natural balance in the ecosystems. Many developing countries are trying hard to focus on nature-based solutions to restore eco-system. An ideal example is the efforts of Pakistan, which has gained global recognition for the projects like “10 billion tree tsunami” (which is expected to sequester 148.76 $MtCO_2$ by 2030), “Recharge Pakistan”, REDD+, Sustainable Forest Management, Generating Global Environmental Benefits (GGEB), “Clean and Green Pakistan”, Ecosystem Restoration Fund, Protected Area Initiative (Ahmed, 2021). The Nationally Determined Contributions (NDCs) of Pakistan submitted before the beginning of the 26th Conference of Parties (COP26) of the United Nations Framework Convention on Climate Change (UNFCCC) shows that the country has already led to an 8.7% decrease in emissions during 2015-2018. The government of Pakistan has plans to increase the number of protected areas from 12% to 15% by 2023 and initiate 20 years program to reduce flood risk in the Indus Basin (Ali *et al.*, 2021). Under the umbrella of the Glacier Lake Outburst Flood (GLOF-II) Risk Reduction Project, five artificial glaciers are developed in the Gilgit-Baltistan province of Pakistan to mitigate the effect of climate change (Abbasi, 2022). However, the downside of forced conservation may result in ignorance of fundamental rights, deprivation of livelihood, displacement from ancestral lands, loss of cultural values, the conflict between state and people and commodification at the expense of conservation (Shimshali, 2021). Other issues are the burning of agriculture field residues, brick kilns and vehicular and industrial emissions. Moreover, limiting global warming to 1.5° C, as decided in Glasgow Climate Pact, is not an easy task. Renewable energy systems like solar panels, wind turbines, electric cars need a lot of metals like graphite, lithium and cobalt. The renewable systems will require about 3 billion tons of these metals to keep the temperature at 1.5° C by 2050 (Dunbar *et al.*, 2022). Until all of the above-said issues are addressed, the world will continue to lag behind in sustainable energy and the environment.

Table 1. Important environment related frameworks/treaties and accords

Frameworks/Treaties/Accords	Year of Adoption	Purpose and Main Features
United Nations Framework Convention on Climate Change (Signed by 150 countries)	1992	• Foundational climate agreement that has provided the platform for most subsequent international climate agreements (Kuh, 2018)
Kyoto Protocol	1997	• Reduction of Greenhouse gases concentration
Intergovernmental Panel on Climate Change (IPCC)	2007	• Projects the increase in global mean temperature
Paris Agreement	2016	• Keep 1.5° C temperature by the end of the century • Adaption to Climate Change Effects • Mobilization of sufficient Climate Finance
EU taxonomy	2020	• Purpose is to meet the EU's climate and energy targets for 2030 • A classification system, establishing a list of environmentally sustainable economic activities • Create security for investors and protect private investors from greenwashing, • Help companies to become more climate-friendly, mitigate market fragmentation • Help shift investments where they are most needed
European Green Deal	2020	• No net emissions of greenhouse gases by 2050 • Economic growth decoupled from resource use • No person and no place left behind
Glasgow Climate Pact	2021	• Keep alive the Paris agreement target of 1.5° C temperature • Phase-down the coal usage • Availability of climate finance for developing countries
Glasgow Leaders Declaration on Forests and Land Use (Pledged by 120 countries)	2021	• Halt and reverse de-forestation by 2030
Beyond Oil & Gas Alliance (BOGA) (Pledged by 23 countries)	2021	• Oil & Gas Phase–out • Inclusion of climate education in national curriculums
The Global Methane Pledge - US & EU (Pledged by 100 countries)	2021	• Reduce global methane emissions by at least 30% by 2030

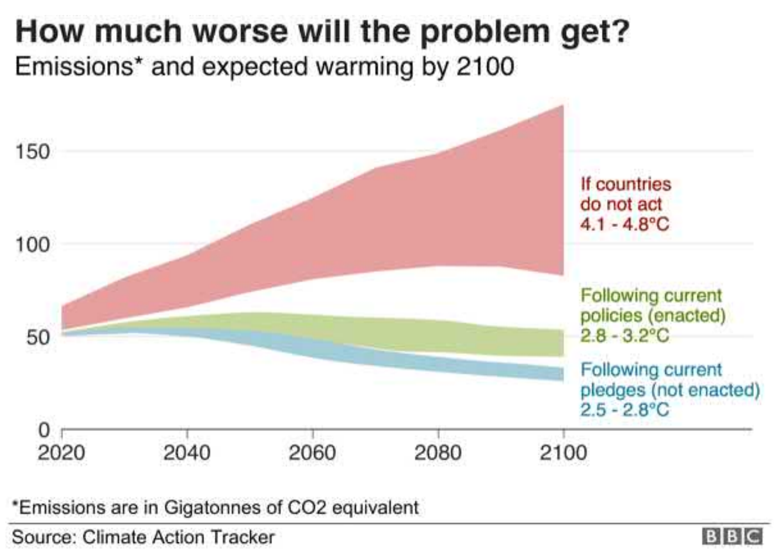
Source: Authors Compilation

Table 2. Important energy and environment related indices

Index	Organization	Main Features
Energy Transition Index (ETI)	• World Economic Forum	• Benchmarks 115 countries on the performance of their energy systems
Environmental Sustainability Index (ESI)	• Yale Center for Environmental Law and Policy • Center for International Earth Science Information Network (CIESIN) • World Economic Forum • Joint Research Centre European Commission	• A measure of overall progress towards environmental sustainability • Provides a composite profile of national environmental stewardship based on a compilation of indicators derived from underlying datasets
Environmental Performance Index (EPI)	• Yale Center for Environmental Law & Policy	• provides a data-driven summary of the state of sustainability around the world • offers a scorecard that highlights leaders and laggards in environmental performance • provides practical guidance for countries that aspire to move toward a sustainable future

Source: Authors Compilation

Figure 4. Emissions and expected warming by 2100



Technology

Clean Energy portfolios are combinations of renewable energy, efficiency, demand response and battery storage (Stone, 2022). In this regard, technology is also playing a significant role (Rafay, 2019). There is a dire need to invest in innovative technologies to manage environmental pollution. Emerging technology like Direct Air Capture (DAC) is used to suck CO_2 out of the atmosphere. Currently, ORCA plant in Iceland is the world's largest carbon-capturing plant capturing 4000 tons of CO_2 annually. Another alternative technology is Bio-Energy with Carbon Capture Storage (BECCS). But these technologies are facing issues like scarcity of freshwater, large-scale plants and high capturing cost (Whalley, 2021; Reza

& Tularam, 2022). Talks are in progress about finding ways of shifting from fossil fuel to investments in renewable (wind, solar) and carbon-neutral energies (Garcia, 2022). Recently Belgian government decided to shut down seven of its nuclear plans by 2025 in favour of other energy resources. Instead, the government shall invest Euro113 million on new-generation small modular reactors which are climate-friendly. In order to improve the energy system performance and sustainable outcomes, Sweden, Norway and Denmark are putting in place regulatory environments, diversified energy mix and cost-effective energy pricing methodologies (Shah, 2021). Eco-innovations like Green Hydrogen and Floating wind turbines are also in focus as a carbon-free source of energy (Lane, 2021). In order to de-carbonization of the industrial process especially cement, UK researchers developed a low-temperature process of limestone decarbonization to drastically cut the carbon emission of cement manufacturing (Hanein *et al.*, 2021). In a similar move, researchers of RMIT Australia have developed a carbon dioxide utilization technology to capture carbon dioxide and convert it to solid carbon (Kaszubska, 2022).

Climate Finance

Climate finance takes a center stage in all global climate meetings. This terminology is broadly used to describe funding for activities that help to slow the climate change (Telle, 2021). Climate Finance may be generated bilateral/multilateral concessional lending from the Public and Private sectors. In order to enhance the adaption capacities of developing countries without collapsing their economies, the developed countries should commit climate adaption funds (Kiranmai, 2022). For example, at least USD750 billion are required annually by the "Global South" to switch to sustainable energy resources (Mwareya, 2021). Over USD100 billion pledged by the developed countries during Paris Agreement 2015 is still not fulfilled. In April 2021, the US President asked congress for USD861 million in aid to Guatemala, Honduras and El Salvador for resilience to climate change (Moss, 2021).

Another issue is the availability of finance to build seawalls due to rising sea levels. For example, in the US, the estimated costs to build Charleston seawall (8 miles), Miami-Dade seawall (1 mile), New York-New Jersey Harbor seawall (6 miles) are USD2 billion, USD4.6 billion and USD119 billion respectively (Hunziker, 2022). A cost of USD400 billion is required to build seawalls in every coastal community in the US (CCI, 2022).

Trillions of dollars are required to avoid climate catastrophe (Baraldi *et al.*, 2021). The role of private capital is essential to slow climate change. International financial institutions agreed to align USD130 for this purpose. Climate tech innovations to reduce emissions require approximately USD150 trillion over the next thirty years (BCG, 2021). Venture Capitalists are required to drive breakthrough clean technologies (Pitchbook, 2021). Blended sources of public and private capital are necessary to achieve a "Net Zero" future.

WHAT THE ENVIRONMENTAL GURU SAID?

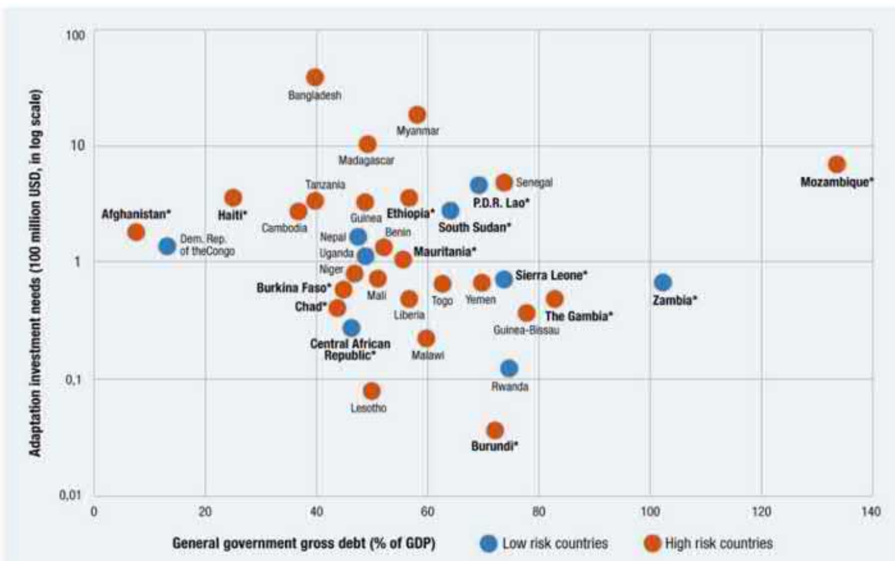
Berry Commoner (1917 – 2012), an American ecologist, is famous for primitive scholarly work on ecology. He was the father of the modern environmental movement, public campaigns against nuclear testing and chemical pollution. As reported by New York Times, he was a leader among a generation of Scientist-Activist. His outstanding book "*The Closing Circle: Nature, Man and Technology*", published in 1971, is one of the most cited books on the damage of the ecosphere. In the first chapter of this book, he described the four laws of ecology (Commoner, 1971):

1. Everything is connected to everything else;
2. Everything must go somewhere;
3. Nature knows best; and
4. There is no such thing as a free lunch

The final hypothesis of the book reads as follows:

"Restore to nature the wealth that we borrow from it"

Figure 5. Climate adaption investment
Source: UNCTAD (2021)

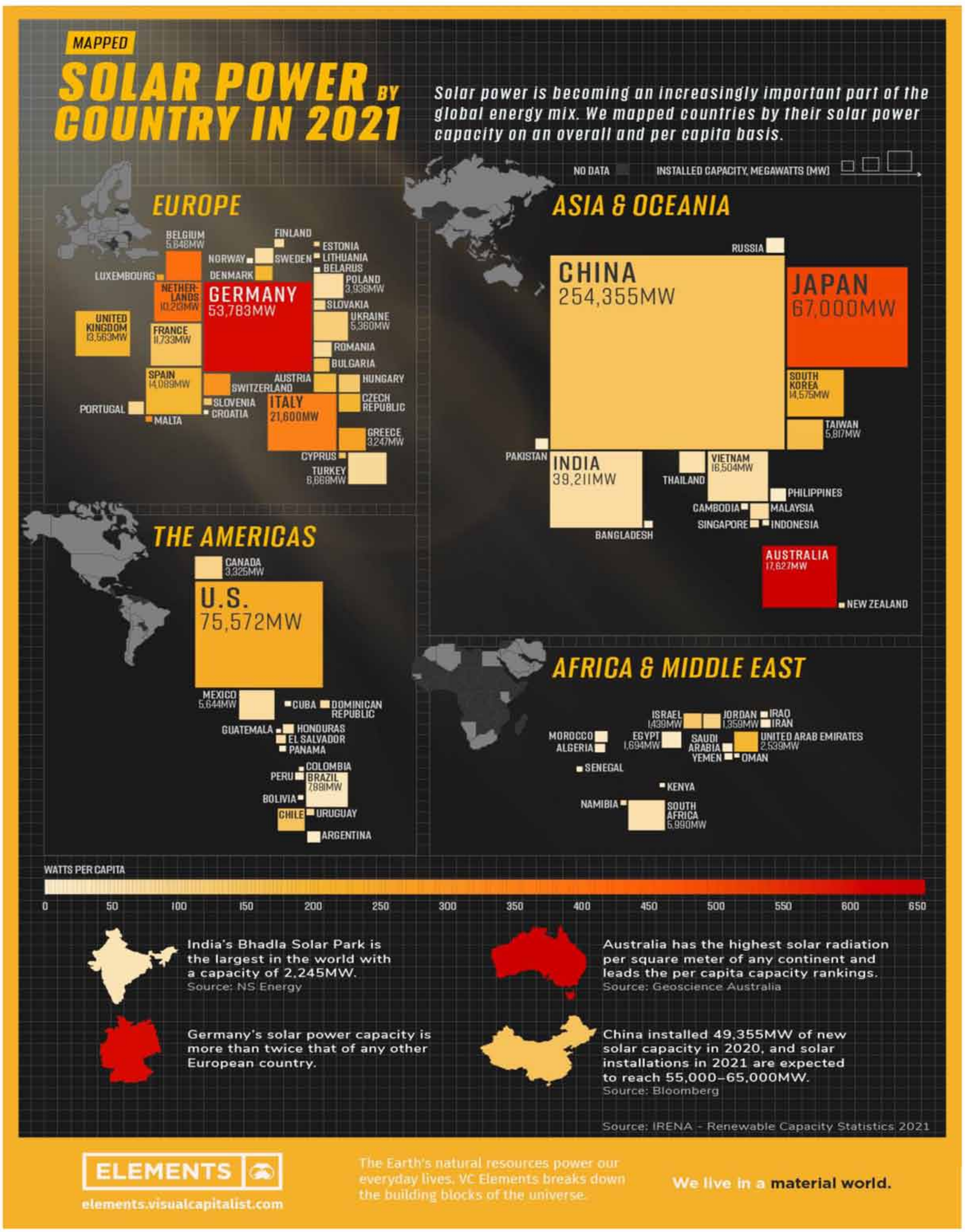


CONCLUSION

The transition to a green economy must be accelerated. Global governments are at the forefront to devise plans to manage the challenges of energy and the environment. Robust public-oriented green energy policies are being developed to reduce the climate-induced risks in a swift manner. In 2021, clean energy made up 46% of the Net Public Power Generation of Germany (Lewis, 2022). In order to move towards clean energy for a better and sustainable environment, various steps are required like investments in renewable energy (sunlight, wind, rain, tides, waves, and geothermal heat etc.), protection of natural eco-system, marine conservation, climate adaption, resilience building, re-forestation (reversal of deforestation), de-carbonization, mobilization of climate financing, end of fossil fuel subsidies, reduction in methane emissions, end the sale of fossil fuel-powered heavy-duty vehicles (by 2040), reach net zero-emission (by 2050), promotion of zero-emission cars and vans, phasing out or phasing down coal, put a price on carbon and promotion of eco-tourism (Talpur, 2021). As per International Energy Agency, if the world has to reach net-zero carbon emissions by 2050, an immediate halt to investment in the extraction of hydrocarbons is required.

In a nutshell, the transition to a carbon-neutral future is on the active agenda. Worldwide awareness regarding all the above-said issues is important. In this regard, UNO's flagship "World Environmental Day" takes place every year on 5th of June. In 2021, the UN decade on Ecosystem 2021-2030 is also launched.

Figure 6. Solar power in global energy mix
Source: Visualcapitalist.com (2021)



CONTEXT AND ORGANIZATION OF THIS VOLUME

Regardless of whether you are a beginner or a seasoned researcher, this handbook of research will deepen the discourse about energy and environmental finance. I am hopeful that this handbook of research is a fascinating and invaluable guide for understanding the theory, practice and cases of energy and environmental finance.

This handbook of research is organized into two sections that consist of eighteen chapters by writers from seventeen countries. Forty-six authors contributed from disparate parts of the world:

- **Europe**: UK, Spain, Germany, Croatia
- **Americas**: Brazil
- **Middle East**: Turkey
- **Asia**: Taiwan, China, India, Pakistan, Kuwait and Malaysia
- **Africa**: South Africa, Nigeria, Tanzania, Ghana, Morocco

Section 1 addresses Energy Finance with a set of ten chapters authored by writers from the UK, Tanzania, India, Kuwait, South Africa, Ghana, Croatia, Turkey, Malaysia and Nigeria. Section 2 addresses Environmental Finance with a set of eight chapters contributed by authors from Spain, China, India, Pakistan, Brazil, Taiwan, Turkey, Germany, Morocco, Pakistan and Nigeria.

In Section 1, the first chapter, "Investor-State Dispute Settlement (ISDS) in Energy Sector: A Poisonous Gift for Developing Countries," by Delphine Defossez of Northumbria University, UK, elaborates that in order to palliate any abuse towards the foreign investors, a strong protection framework was developed; the so-called investor-state dispute settlement (ISDS) coupled with the arbitration, which is currently, puts the interests of private corporations above the needs of the population. The second chapter, "Microfinance, Energy Poverty, and Sustainability: The Case of Tanzania," by Pendo Shukrani Kasoga and Amani Gration Tegambwage of The University of Dodoma, Tanzania, discuss the use of modern energy sources for other purposes, but not for cooking, is significantly influenced by household size. Microcredits customized for contemporary energy sources should be implemented to combat energy poverty. The third chapter, "Financial Assessment Model for Energy Streams: Evidence From the Middle East," by S Jithender Kumar Naik and Malek Hassanpour of Osmania University, India, contends that the energy assessment in any industrial/engineering project is an important aspect of project identification in the Environmental Impact Assessment (EIA) plan and the application of the DEA model is highly recommended for managing energy streams in the EIA plan. The fourth chapter, "Distributional Effects of Reduction in Energy Subsidy: Evidence From Kuwait," by Ayele Ulfata Gelan and Ahmad Shareef AlAwadhi of Kuwait Institute for Scientific Research, Kuwait, examines the distributional effects of energy subsidy reduction in Kuwait. The study concluded that the welfare gains among Kuwaiti nationals were progressive; the lower-income groups gained more than higher-income groups. The fifth chapter, "Oil Price Shocks and Income Inequality: Evidence From the US," by Xin Sheng (Anglia Ruskin University, UK) and Rangan Gupta (University of Pretoria, South Africa) investigates linear and nonlinear impulse responses of the United States (US) household income inequality to oil price shocks. The nonlinear impulse response results reveal some evidence of heterogeneous responses of income inequality to oil price shocks between high- and low-oil-dependent US states. The sixth chapter, "FDI, Energy Consumption, and Institutional Quality: The Case of Africa," by Joseph Dery Nyeadi, Kannyiri Thadious Banyen of SDD-UBIDS, Ghana and Simon Akumbo Eugene Mbilla (University of Education, Ghana), highlights that foreign direct investment (FDI) and financial sector development (FSD) are highly recommended for developing countries. It is therefore critical and important to examine the impact of both FDI and FSD on energy consumption. The seventh chapter, "Corporate Integrated Reporting: An Overview of GRI Standards," by Valentina Vinšalek Stipić of Polytechnic Nikola Tesla, Croatia), explains that the goal of every company should not be profit exclusively but also public welfare and social responsibility. Reporting on CSR is necessary because companies need to be responsible for the implementation of its principles, aimed at protecting the interests of stakeholders. The eighth chapter, "Renewable Energy: An Overview for International Legislation," by Nima Norouzi of Yasha Holdings, Turkey, discusses that the proliferation of international instruments coupled with the uncertainty of the principles/rules of international law regarding the development of renewable energy sources, necessitates the consideration of an international law approach. The ninth chapter, "FDI and the Gap of Clean Power Finance: The Case of Africa," by Ahmed Rashed, Yong Chen and Siew-Voon Soon of the University of Malaya, Malaysia, discusses that twin deficits in energy and financing are extensively detrimental in Africa which in turn entails foreign direct investment (FDI) to be effectively promoted. Improving renewable energy education with the timely availability of data promotes awareness in society and thus may facilitate the development of the clean power industry in Africa in the near future. The tenth chapter, "Economic Growth, Energy Consumption, and Carbon Emissions: The Case of Nigeria," by David Oluseun Olayungbo (Obafemi Awolowo University, Nigeria) Ayodele Adekunle Faiyetole (Federal University of Technology, Nigeria) and Adenike Anike Olayungbo (Obafemi Awolowo University, Nigeria) examines the interactions among energy consumption, economic growth, and carbon emissions in Nigeria. It is recommended that the Nigerian government should continue pursuing emissions reduction policies, such as the Nationally Determined Contributions (NDCs).

In Section 2, the eleventh chapter, "Economic Valuation and Cost of Air Pollution," by Dolores Hidalgo and Sergio Sanz-Bedate of CARTIF Technology Centre, Spain, discusses that air pollution has huge economic consequences for society, including reduced work hours, increased health care costs, and lost household income. It is proposed to carry out a public policy strategy to internalize the costs of pollution. The twelfth chapter, "Carbon Financing and Sustainable Development Mechanism: The Case of China," by Poshan Yu (Soochow University & Australian Studies Centre, Shanghai University, China), YueWen Weng and Aashrika Ahuja, discusses China has been one of the largest global emitters of carbon dioxide. Policies and measures related to carbon finance are being continuously promulgated, and a national carbon emission trading market has been established. The thirteenth chapter, "Technological Innovation and Financialization for Environment: The Case of Pakistan," by Samia Nasreen, Lahore College for Women University, Pakistan, and Abdul Rafay, University of Management & Technology, Pakistan, examines the asymmetric link between technological innovation and financialization in Pakistan. Based on empirical evidence, the research emphasizes the suitable channelization of financial institutions towards environmentally friendly projects and formulation of those policies that encourage energy-efficient technologies. The fourteenth chapter, "Determinants of Carbon Emission Prices: Evidence From the European Union," by Solange Kileber, Javier Toro, Matias Rebello Cardomingo, Luciano da Silva, Marcio Issao Nakane and Virginia Parente of University of Sao Paulo, Brazil, explains that carbon emission allowances are considered an important policy instrument to prevent an undesirable increase in the Earth's temperature caused by the excess of greenhouse gases in the atmosphere. The results depicted that the most relevant variables affecting the allowances prices were the regulatory measures that mainly restrict the number of allowances available. The fifteenth chapter, "Environmental Performance and Capital Structure: Evidence From Asia," by Naiwei Chen (National Chiayi University, Taiwan) and Min-Teh Yu (National

Yang Ming Chiao Tung University, Taiwan) examines the effect of environmental performance (EP) on the capital structure of firms. A more in-depth analysis further reveals that the financial system plays a more important role than the legal system in determining the effect of EP on leverage. The sixteenth chapter, "Environmental Policy and FDI Inflows: Evidence From OECD Countries," by Muhammed Sehid Gorus (Ankara Yildirim Beyazit University, Turkey) and Erdal Tanas Karagol (Berlin Education Attaché of Turkey, Germany) explores the impact of environmental policy stringency index (EPS) on FDI inflows in 26 OECD countries. It was determined that environmental policies cause FDI inflows in 12 out of 26 countries. The seventeenth chapter, "Carbon Financial Market: The Case of EU Trading Scheme," by Adil El Amri, Salah Oulfarsi, Abdelhak Sahib Eddine, Abdelbari El Khamlichi, Yassine Hilmi of Chouaib Doukkali University, Morocco, Abdelmajid Ibenrissoul, Abdelouahad Alaoui Mdaghri of Hassan II University, Morocco, and Rachid Boutti (Ibn Zohr University, Morocco) explains the drivers for carbon prices related to institutional decisions, energy prices and weather events. The study focuses on price changes in the EU, as being the most liquid carbon asset. The eighteenth chapter, "FDI and Environmental Degradation: Evidence From a Developed Country," by Burcu Bahceci Baskurt (Izmir Katip Celebi University, Turkey), Saban Celik (Izmir Katip Celebi University, Turkey), Abdul Rafay (University of Management & Technology, Pakistan) and Tayo Oke (Afe Babalola University, Nigeria), highlights the factors affecting environmental quality. FDI inflows are found to affect ecological footprint negatively, meaning that it decreases the environmental deterioration in the long run.

I thank the contributors and also the external reviewers who have patiently critiqued these chapters to meet the minimum acceptable standard. While the publisher and the Editor (myself) have used their best efforts in preparing this book, they make no representations and warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. The strategies or suggestions or whatsoever contained in this book may not be suitable for any specific situation for which anyone should consult with a professional, where appropriate. Neither the publisher nor the Editor shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

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Section 1

Energy Finance

Chapter 1
Investor–State Dispute Settlement (ISDS) in the Energy Sector:
A Poisonous Gift for Developing Countries?

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ABSTRACT

The creation of an international energy market has brought along new challenges. In order to palliate any abuse towards the foreign investors, a strong protection framework was developed: the so-called investor-state dispute settlement (ISDS) coupled with the arbitration. Recent cases have, however, highlighted that private institutions are becoming so powerful that they can prohibit states from implementing changes without being threatened by arbitral proceedings. This threat works as a limitation of state sovereignty. Currently, the system puts the interests of private corporations above the needs of the population. ISDS in the energy sector has always been a poisoned gift for developing countries.

INTRODUCTION

The increasing liberalisation of markets coupled with more developed technologies and a decrease in trade barriers have led to an international energy market. To fulfil the need of this market, energy companies have to invest massively to extract minerals, oil, and gas. Those investments are often situated in developing economies with sometimes unstable political regimes. In order to mitigate any abuse towards the foreign investors on the part of the host state, a solid protection framework was developed, called the investor-state dispute settlement (ISDS) (Garcia, Ciko, Gaurav, & Hough, 2015).

As Zhan (2016) noted, "Originally, the ISDS mechanism was designed to ensure a neutral forum that would offer investors a fair hearing before an independent and qualified tribunal, granting a swift, cheap and flexible process for settling investment disputes". Indeed, ISDS allows the foreign investors

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to bypass national jurisdiction and solve the dispute before a tribunal of supposedly neutral arbitrators selected by the parties (AMES, 2015). To best fit those requirements, arbitration has been regarded as the ‘best option’ because it is a “speedy disposition of differences through informal procedures without resort to court action.” (Firmin vs. Garber, 1977). Arbitration is also regarded as fairer, as national courts could be biased towards the state. In addition to being considered more appropriate, arbitration is less expensive. However, this statement should be nuanced; arbitration is not always cheaper than litigation; it actually depends (Phelps Gay, 2018).

ISDS coupled with arbitration is regarded as providing strong protection for those foreign investors is necessary to avoid any unlawful exploitations and negative financial consequences (Gaitis *et al.*, 2017). Without such protection, states could easily expropriate investors without compensation and on dubious grounds. Indeed, those arbitral clauses are often found in bilateral investment treaties (BITs) or multilateral frameworks, such as the Energy Charter Treaty (ECT). Moreover, energy projects are characterised by complex and capital-intensive deals with long-term transactions and investments. Consequently, the energy sector has always been a fertile ground for investment disputes.

This standard protection has, nevertheless, sparked public outcry and opposition due to the outcomes it generates. Public perception is that foreign investors, which are often large corporations, are granted too much power. Additionally, private arbitral tribunals, which are often pro-investors, are not legitimate in balancing private profits with public interests. Consequently, the use of private arbitration in State-investors disputes is becoming increasingly questioned and faces great opposition, resulting in a legitimacy crisis.

In addition to being increasingly questioned, it is also regarded as disadvantageous, especially for developing countries and indigenous communities. The *Gold Reserve v. the Bolivarian Republic of Venezuela*[1] ruling probably best exemplifies this increasing problem. Similarly, the *Cosigo Resources v Colombia*, on mineral extraction, demonstrated the powerful nature of arbitration. In addition to being forced to pay millions in compensations, Colombia was prohibited from setting a natural reserve. These recent cases highlight that governments from developing states are in a weaker position compared to big international corporations. Additionally, those agreements put indigenous rights at risks because these native populations are often part of the contracts but are affected by them. In fact, private arbitration in investor-state dispute limits state sovereignty[2] in a hidden manner.

While protection of investors is necessary, such protection has evolved into a form of state sovereignty limitation as foreign investors can directly challenge a measure if such measure is believed to violate the said BIT (Salacuse, 2015). In fact, recent cases have highlighted that private institutions are becoming so powerful that they can prohibit states from implementing changes without being threatened by arbitral proceedings (Alvarez, 2011; Arato, 2015).[3] This phenomenon has been referred to as regulatory chill, whereby governments do not enforce or enact measures due to concern about potential litigations, therefore threatening the host state’s regulatory power (Thakur, 2021; Tienhaara, 2018; Bonnitcha, 2014; Tienhaara, 2011). This article goes a step further and claims that arbitral clauses in ISDS limit state sovereignty to revoke previously granted concessions without incurring a duty to compensate. The potential to interfere with state sovereignty flows from the limitation on regulatory powers, which are an integral part of sovereignty (Van Harten & Loughlin, 2006). Indeed, under international law, states have a right to implement their economic, social and political system.[4] By signing an IIA, states are bound by some obligations towards foreign investors; however, such obligations should not be so extensive as to restrain the right to regulate important aspects without having to compensate foreign investors. The *Vattenfall v*

Germany quite clearly demonstrates that it is not only about regulatory power but also limiting state's actions to meet the population expectations and, therefore, limits state's sovereignty.

At the same time, exploration contracts are extremely lucrative for countries, especially developing economies, and require security for investors. Normal litigation would not bring this kind of security and stability because it would mean that a dispute against a state would be determined by the courts of that state applying that country's laws. The chances of things going wrong are, therefore, very high. However, other dispute resolution mechanisms exist that might offer a better balance and avoid granting private companies' undue power to limit state sovereignty (Paldi, 2020). It is, therefore, time to review whether arbitration is really that advantageous for developing countries or whether it has always been a poisoned gift.[5]

WHY ARBITRATION IS THE PREFERRED METHOD OF DISPUTE RESOLUTION IN THE ENERGY SECTOR?

Compared to traditional court proceedings, arbitration is a less public dispute resolution scheme. Indeed, arbitration can be divided into two types; state-supervised model, where the voluntary character of arbitration can be removed, and private arbitration, where parties have complete freedom to engage in arbitration (Van Harten, 2007). The State's only role in a private arbitration model is to guarantee that agreements to arbitrate will be legally binding. The latest has been the prevailing method in the energy sector. It is often said that the energy sector is largely responsible for driving the growth of international arbitration (Rowley, 2020).

Arbitration requires a private third party to decide a dispute between two litigants, binding them on the outcome (Ashenfelter & Iyengar, 2009). As such, arbitration is a creature of consent because parties are only bound by it if they have agreed on its use to settle their dispute. Additionally, only matters authorized, or at least not expressly prohibited by law, can be arbitrated, meaning that not all disputes can be resolved using this mechanism. The inherent advantages of being flexible, confidential, autonomous, professional and enforceable means that arbitration might be beneficial for energy claims (Moses, 2012).

Some view arbitrations as a kind of *lex mercatoria*; however, the efficacy of an award depends on the legal framework where this award is to be enforced. As Reisman and Richardson (2012) noted, "[…] international commercial arbitration, no less than arbitration within nation-states, while conducted in the sphere of private law, is a public legal creation whose operation and effectiveness is inextricably linked to prescribed actions by national courts" (p. 17). As such, arbitration's legitimacy contains two components: first, the legal authorization allowing parties to empower a third party to decide their dispute, and second, the agreement between the parties to empower the third party.

Although arbitration developed as a private mechanism of dispute resolution, some mechanisms have evolved in a way that it becomes the only *de facto* method for solving disputes. As Lillich and Brower (1994) noted,

By and large, parties to international transactions choose to arbitrate eventual disputes not because arbitration is simpler than litigation, not because it is cheaper, not because arbitrators may have greater relevant expertise than national judges, although any one of those factors might be of interest; they arbitrate simply because neither will suffer its rights and obligations to be determined by the courts of the other party's state of nationality.

The increasing liberalisation of markets coupled with more developed technologies and a decrease in trade barriers have led to an international energy market. This international market has driven foreign direct investment and the need for complex agreements to protect those investments. Indeed, the energy sector features capital-intensive transactions involving multiple jurisdictions and often requiring a permit from states. Energy projects typically require a licence or concession from the host state because exploration involves sovereign resources. The international nature and intrinsic business complexity coupled with the high business risk also mean a higher risk of disputes. Disputes between States and companies can, therefore, involve multiple contracts and parties. Finally, projects are often long-term in nature and highly sensitive to regulatory changes, requiring extensive protection for investors. Since "energy investments are often made in countries providing less stability and security than the investor's host state," foreign investors are looking for certainty through the inclusion of arbitration clauses (Brueckner, 2020; Akgul, 2008).

To best adapt to the need of the parties and face the new challenges created by this international energy market, arbitration was regarded as the solution. Indeed, as Katharina Brueckner (2020) noted:

State courts are often not in the position to meet the demands of the international energy market community. They frequently lack the capability to handle complex cross-border disputes or cannot provide the required impartiality, technical knowledge or efficiency. Furthermore, the applicable law often differs from the law of the state court competent for potential disputes and, thus, constitutes the risk of a misapplication of the law.

The two main advantages traditionally ascribed to arbitration are flexibility and efficiency. However, it is questionable whether these are achieved in the energy sectors. Moreover, there is a (mis)conception that investors will have less chances of success in national courts (Sabahi, Rubins, & Wallace, 2019). Arbitration also helps to overcome the inefficiency of certain local courts and possible corruption.

In addition to being considered more appropriate, arbitration is said to be less expensive. However, as Phelps Gay (2018) argued, this statement should be nuanced -- arbitration is not always cheaper than litigation; it actually depends (p. 180). "Consequently, most contracts in the energy sector contain a dispute resolution mechanism resorting to arbitration, closely followed by mediation" (Brueckner, 2020).

Those clauses foster certainty for at least two reasons: the binding nature of the arbitration and its 'neutrality'. Investor-State arbitration has as its central tenet the financial investment principle enshrined in Article 25(1) ICSID:

The jurisdiction of the Centre shall extend to any legal dispute arising directly out of an investment, between a Contracting State (or any constituent subdivision or agency of a Contracting State designated to the Centre by that State) and a national of another Contracting State, which the parties to the dispute consent in writing to submit to the Centre. When the parties have given their consent, no party may withdraw its consent unilaterally.

This highlights the binding nature of arbitration. Second, foreign investors tend to avoid arrangements whereby disputes involving their investment in a country would be determined in that country's courts applying that country's laws. Whilst the principle of judicial independence may be entrenched, the system remains representative of the authority of the state and is, therefore, bound to apply national laws and procedures. As such, arbitration offers 'neutral' ground for dispute resolution due to the manner it has been structured. Moreover, parties have considerable control in determining the conduct of the proceedings and adapting the procedures according to their circumstances. For those reasons, international investment agreements (IIAs) mostly prescribe arbitration as a means of dispute settlement (Schill, 2017). Its costs, however, can easily outweigh any benefits.

According to the London Court of International Arbitration (LCIA) 2019 Report, 22% of LCIA disputes were related to the energy and resources sector. This percentage surged further in 2020, with energy dispute representing 41% of all the International Centre for Settlement of Investment Disputes (ICSID) cases (Calvert, Gilbert, & Meade, 2021). Fry and Bret (2019) report that "the mining and metals sector has emerged as one of the main users of international arbitration" (p.1). As Gaitis *et al.*, 2017 argued, the oil and gas industry has "long been a leader in promoting the resolution of industry disputes through the use of binding arbitration". Indeed, it is considered an important incentive for promoting international investment (Roberts, Bromund, & Dasgupta, 2015). As Rowley (2020) rightly pointed out, "bolstered by the advantages of party autonomy (particularly over access to a neutral forum and the ability to choose expert arbitrators), confidentiality, relative speed and cost-effectiveness, as well as near worldwide enforceability of awards, the system is flourishing." (p.1). However, the various recent cases in the energy field raise many questions regarding the wide use of arbitration clauses and whether such clauses are really advantageous for developing countries or if they are, in fact, a poisonous gift.

WHY IS THE RELIANCE ON ARBITRATION IN PUBLIC-PRIVATE SITUATION A PROBLEM?

The proliferation of international investment agreements and disputes generates public protest. While foreign investors deserve protection, the overreliance on arbitration has resulted in unfair outcomes and regulatory chill. The current system also grants private institutions way too much unrestricted power. Arbitrators are ill-equipped to balance human rights considerations with monetary considerations. The system limits state sovereignty and impacts local communities that were never consulted prior to concluding those agreements.

Regulatory Chill Effect and Limitation of State Sovereignty

Notwithstanding the benefits of arbitration, its use in public-private disputes is problematic for both developing and developed countries because it allows private companies to sue in private arbitral tribunals, which are not bound by the same rules as courts. In fact, Investor-State Dispute Settlement (ISDS) seems to be a very expensive gamble for developing states. Indeed, States are unable to be winners in the manner foreign investors do because treaties have been framed not to prohibit states from suing and recovering damages from foreign investors. States are only able to avoid losing, but even in this case, they are still required to pay proceeding costs. As Van Harten & Malysheuski (2016) pointed out, sadly, "ISDS has produced monetary benefits primarily for those companies or individuals at the expense of respondent states" (p.1). Putting it plainly, ISDS is very lucrative for investors at public expenses, which creates great incentives for private companies to start proceedings.

This incentive is even more present, knowing that the number of cases investors win is much higher than in the judicial process. According to UNCTAD (2019), most cases decided in favour of states were dismissed on the ground of jurisdiction, while 70% of the cases decided on merits were won by investors (p.102). This could result in very high costs for states both with regard to proceeding costs and compensation (Roberts & Bouraoui, 2018).

The ISDS was created to protect foreign investors by allowing them to sue states when they believe public decisions may have had a negative impact on their potential profits. However, it seems that such protection has turned against the states themselves by allowing foreign investors to directly challenge a measure taken against a said BIT. This means that States do no longer have the supreme power within their territories and have to justify their actions to foreign third parties. Moehlecke (2017) even demonstrated that ISDS is used to slow the host states' policy-making down. The system is also unfair as foreign investors are better protected than national investors who cannot rely on those provisions.

More importantly, recent cases have highlighted that private institutions are becoming so powerful that they can prohibit states from implementing changes without being threatened by arbitral proceedings, resulting in regulatory standstill or chill (Tienhaara, 2018; Bonnitcha, 2014; Tienhaara, 2011).[6] *Renco Group Inc v Republic of Peru*, explained in details below, is probably the best example whereby the private company was not complying with environmental norms for years, resulting in the local population being faced with several health issues. When the Government decided to close the mine, after years of non-compliance with environmental norms, it was sued for unlawful expropriation.[7] This case exemplifies the unfairness of the current system. Renco never complied with Peruvian environmental regulations, as such, negating Peru's sovereignty, and when Peru took the last option left, closing the mine, Renco started arbitration. In France, the 2017 Hulot law to phase out oil and gas extraction was watered down after France was threatened to be sued (Corporate Europe Observatory, 2019).

In addition to states being cautious in taking new measures due to the threat of arbitration, other countries could avoid formulating similar rules. For instance, if another country is facing a similar situation, the outcome of an arbitration proceeding against another state could influence its decision (Shekhar, 2016). This phenomenon is also called cross border chill (Tienhaara, 2018).

Biases and High Compensation

It seems that the narrative regarding the benefits of arbitration is only valid from a private company point of view. Although there are rules safeguarding impartiality and independence[8], the arbitration system has been criticised for being "designed in a way that systemic bias creeps in, due to the arbitrator's interest in being reappointed in future disputes and also because of frequent changing of hats – being appointed as arbitrator in one case and counsel in another" (Thakur, 2021). The so-called double hatting is a real problem as it creates a conflict of interests. It is not uncommon for arbitrators to work as counsel in one case and arbitrator in another regarding similar issues. In addition to creating a conflict of interest, it also can grant 'insider' information with arbitrators, knowing which arguments might be more impactful on the panel. Finally, it is also not uncommon for arbitrators to sit on company boards, which could influence their decisions.

Instead of being impartial, arbitrators are appointed by each party because they are sympathetic to their case. This could result in biased arbitrators, especially because those arbitrators are often drawn from the same small pool. While parties are free to appoint 'outsiders', they often refrain from doing so because those outsiders are less likely to have the power to influence co-panellists. Therefore, arbitrators enjoy exorbitant power. Part of the problem is explained by "the absence of conventional markers of judicial independence," which results in asymmetric biases (Van Harten, 2012).

Arbitrators have more power than judges as their decision is binding and often final even if the law or the facts are incorrectly interpreted (Moses, 2012). Linked to this issue is the findings of Norton (2018), who established that the reliance on precedents is mainly to legitimise the arbitrators' decision. Therefore, any biases can have far more reaching consequences than in the judiciary and can impact future cases.

These possible biases and the very small number of recognized arbitrators endanger the fairness of the awards. In fact, the perception of ISDS being more burdensome than advantages led to a backlash against it and attempts to reform the system (Waibel, Kaushal, Chung, & Balchin, 2010). Singh and Ilge (2016) noted that "Bolivia became the first country to denounce the Convention on the Settlement of Investment Disputes between States and Nationals of Other States (ICSID Convention)" (p.5). South Africa followed the trend by terminating agreements and replacing them with national legislation, which safeguards domestic policy space while affording protection to foreign investors (Singh & Ilge, 2016).

From a developing country point of view, these possible biases could lead to a very high amount of compensation and very little possibility of revisions. Singh and Ilge (2016) have reported that Ecuador claimed the system is biased towards investors (p.1). This claim has been strongly rebutted by ISDS promoters (European Federation for Investment Law and Arbitration, 2015). However, it was confirmed by Gerstetter & Meyer-Ohlendorf (2013), who concluded that arbitral tribunals tend to rule more in favour of investors compared to domestic courts. Such finding is in line with Moore & Perez Rocha's (2019) analysis, which highlighted that investors are often winning on merits. Although states have reportedly won more cases than investors, states are still often required to pay their legal costs (Moore & Perez Rocha, 2019; UNCTAD, 2019).

Additionally, the valuation techniques used by arbitral tribunals are highly controversial and speculative, resulting in financial wards that significantly burden public budgets and discourage Government from taking actions (Bonnitcha & Brewin, 2020). The *Exxonmobil v Venezuela* ruling probably best exemplifies this increasing problem. In addition to being totally disproportionate, the issue with high compensation is that those amounts are decided by arbitrators who are not linked to the system and without any possible oversight by domestic courts. In a sense, those arbitrators are deciding how public funds should be spent by awarding mind-blowing compensation while not experiencing that specific country's financial situation. This could also be regarded as a form of limitation of state sovereignty, as states are no more able to freely decide how public money is spent.

The Deficiencies of the Current System: Lack of Predictability and Consistency

The system lacks transparency, confidentiality, appellate mechanism and above all, predictability. Confidentiality is one of the key characteristics of arbitration, making it a popular choice to solve commercial disputes. While confidentiality makes perfect sense in private parties' dispute, when involving a state, it raises some objections. Indeed, when such matters are solved in a confidential manner, it generates public distrust in the integrity and fairness of the process (Menakeration, 2010). This distrust has resulted in a greater transparency in investment arbitration but also a greater knowledge of the issues it creates, resulting in greater public protest. At the same time, the system has considerably improved on the transparency and confidentiality aspects.

The major problem of the system is the lack of predictability. Indeed, no further express consent by the state is required before a claim is brought under ISDS, meaning that states are in the dark regarding when or which investor could bring a claim. As Thakur (2021) noted, "This situation of uncertainty provides the foreign investor with first mover's advantage in dispute resolution".

Moreover, arbitral decisions lack consistency (Jones, 2013; Johnson & Sachs, 2018; Nilsson & Englesson, 2013). It is not uncommon to find inconsistent findings by arbitral tribunals leading to "divergent legal interpretation of identical or similar treaty provisions, as well as differences in the assessment of the merits of cases involving the same facts. Inconsistent interpretations have led to uncertainty about the meaning of key treaty obligations and lack of predictability as to how they will be read in future cases" (Zhan, 2016). Inconsistencies also occur because a country can be sued in different arbitral tribunals for the same conduct (Johnson & Sachs, 2018). For instance, *TECO v Guatemala* and *Iberdrola v Guatemala*[9], two foreign shareholders of the same company, brought two different ISDS suits to challenge the same conduct. The tribunals interpreted the same provisions differently. While arbitration deliberately attempts to avoid precedent, interpreting the same provisions in a similar manner is necessary for legal certainty. The fact that consistency could defeat the purpose of arbitration demonstrates that arbitration is not adequate in energy disputes, as to enact policy agendas, states need predictability (Brown, Ortino, & Arato, 2019).

Balancing Human Rights and Economic Consideration: The Job of a Judge, Not Arbitrator

Recent cases have demonstrated that private institutions now have the power to limit State regulatory powers and, consequently, sovereignty. In fact, arbitration clauses seem attractive from the outset but are, in reality, limiting state sovereignty in a hidden manner. These limitations do not only concern health measures and endangering local populations for the benefits of private companies. Aalthough exploration contracts are extremely lucrative for countries, especially developing economies, they often significantly impact the local communities and the environment. These communities are often not part of the negotiations and have to face the consequences while they are the first affected by it.

The major problem is that private arbitration is mainly concerned with commercial or contractual agreements, which means that human rights protections or democratic concerns are not given priority. In fact, States find themselves in an awkward position of either maintaining democratic decisions and paying multinationals or endangering democracy to benefit private groups. Such type of questions would be best answered by impartial judges. ISDS is often criticised for the use of private arbitrators rather than judges that might be pre-disposed or biased and can be influenced by monetary incentives (Zhan, 2016). Indeed, private arbitrators do not seem most suited to assess the validity of States' acts that are not impacting those arbitrators directly.

The *Cosigo Resources v Colombia*, on mineral extraction, demonstrated the powerful nature of arbitration. Colombia was no longer able to set a natural reserve to preserve sacred places for the indigenous communities due to the threat of arbitration. The Colombian Government had to decide between giving way to foreign investors or protecting indigenous rights by setting a reserve. In this case, two obligations are in conflicts: indigenous rights protection, i.e., a form of human rights, against contractual obligations. Private arbitration is mainly based on commercial or contractual obligations meaning that human rights protections are not a priority. This approach and the threat of arbitration creates a *de facto* prohibition to set a natural reserve. Moreover, this case will create a precedent that could have disastrous consequences for indigenous ethnic groups.

Overlooking Changes in Circumstances or How ISDS Is Used as a Tool to Resist Changes

The international investment agreements (IIAs) and bilateral agreements have often been around for some time. They had been negotiated when environmental concerns were not such a hotly debated topic. While some licences require the abstention of an environmental impact assessment (EIA), some private companies have initiated proceedings for the revocation of a concession, although no EIA was obtained. In *Harken v Costa Rica*, the company's concession was put on hold over environmental concerns after a new legislation was passed to fulfil its obligation under a World Bank and International Monetary Fund (IMF) structural adjustment programme. Harken started proceedings for reparations for its aborted exploits. The case was submitted for the dispute to the Arbitration Centre of the Costa Rican Chamber of Commerce. Costa Rica challenged the Arbitration Centre's jurisdiction before the Supreme Court. In October 2006, the Supreme Court declared that the Arbitration Centre lacked jurisdiction. While this ruling is welcomed in a sense, it also demonstrates that national courts and arbitration centres might not be the best suited for hearing those disputes.

The changes of a situation are rarely considered by arbitral tribunals. For instance, Venezuela has been condemned to pay nearly three billion (2.883 million) in three proceedings brought by three different Canadian private investors (Moore & Perez Rocha, 2019). On top of that, it had to defend itself in six more proceedings, meaning that it had to pay legal costs and arbitration fees in those situations. The economic situation of Venezuela does not seem to have been taken into consideration. Similarly, when Argentina took some strict measures due to a severe economic crisis, it still faced various arbitration with each tribunal interpreting the term 'necessary' differently (Alvarez & Khamsi, 2009). Interestingly, in more recent cases against Spain, the tribunal recognised a right for States to adapt their framework. However, the tribunals also "concluded that the measures had to comply with the standards of protection established by the applicable international treaties, principally fair and equitable treatment (including legitimate expectations) and full protection and security and that the measures should not be unreasonable, arbitrary, disproportionate or discriminatory" (Magallanes & Barradas, 2020. This means that radical changes that are needed to mitigate the effects of climate change will never take precedent over private economic interests.

In fact, ISDS has been criticised for being a tool to resist climate actions by making it much more expensive. Energy transition measures can have direct impacts on investors by limiting extraction or combustion of certain energies to meet the objectives of the Paris Agreement, for instance. These measures could mean loss of sunk investment and/or expected future profits for companies, which are answerable to their shareholders (Tienhaara & Cotula, 2020). As Tienhaara and Cotula (2020) concluded, those businesses expect to be compensated. If States do not accept to compensate or the compensation is insufficient in the investors' view, they are threatened with arbitration. The greater good is left aside to comply with some economic interests of multinational companies. For instance, two claims have been initiated in 2021 under the Energy Charter Treaty (ECT) against The Netherlands (ICSID, 2021).

While foreign investors should be protected against unlawful expropriations and should be compensated for the losses they incurred from such expropriation, this right should not impede states from enacting necessary measures to avoid possible proceedings. Instead, countries are bound by sometimes old treaties which *de facto* refrains their regulatory power. The threat of arbitration is so real that it can lead to regulatory chill or standstill (Tienhaara, 2018; Bonnitcha, 2014; Tienhaara, 2011). The *Vattenfall v Germany* saga highlight that even developed countries are no more on the safe side.

Examples From Latin America and Other Developing Countries

Nearly 50 years ago, Galeano (1973), in his work 'The Open Veins of Latin America', described how foreign powers plundered Latin America's wealth. Little did he know that currently, it is even easier to do so. Since 1997, there have been at least 35 claims by investors involving Latin America and more than 15 awards granted since 2004 (Ali, *et al*. 2019). According to Ali *et al*. (2019), out of the 16 awards, only eight addressed the merits; "In seven of these cases, the investors were awarded monetary compensation; the eighth award rejected all of the investor's claims".

For instance, in 2016 alone, Colombia faced three arbitration requests. Two involved Canadian companies, and the final one a Swiss company, Glencore. The most interesting is probably the Cosigo Resources dispute. Cosigo Resources, a Canadian company, and Tobie Mining and Energy, an American company, submitted an arbitration request against Colombia under the Free Trade Agreements (FTAs) concluded by Colombia with the United States and Canada. The claimants argued that they were expropriated fraudulently and without compensation from the mining concession of Taraira South. This concession is located in the Amazon region and was the territory of indigenous communities. In 2009, Colombia passed a resolution that granted the status of 'natural park' to that specific region at the request of the indigenous communities. Renco spent years trying to overturn this decision in the Colombian court system. In 2014, the Constitutional Court in Bogotá ruled that the national park is lawful and that mining would not be permitted there (Corte Constitucional, 2014). The claimants started arbitral proceedings before an ISDS panel and asked for US$16.5 billion for expropriation and US$11 million for the costs incurred to acquire the concession. At the time of writing, the proceeding was still ongoing.

Endangering Democratic Decisions and Indigenous Rights

The opacity of the agreements is also generating problems from a democratic point of view. Indeed, the communities that are the most directly concerned by the exploration are often not involved in the negotiations. At least four cases related to community consent were heard by arbitral tribunals after permits were revoked.[10] Even more aberrant is the case of *Gran Colombia Gold v. Colombia*, whereby the company sued Colombia for a perceived lack of action over the need for further community consultation.[11]

Commercial arbitration has taken away the power of these local communities to protest and enforce their rights while they are the first impacted by those decisions. For instance, in the *Bear Creek v. Peru* award, the tribunal decided that the revocation was not justified by the social conflict, although this conflict quickly escalated to high levels of disruption. At the time of revocation, the project was still in the pre-feasibility stage and lack most permits and licences.[12] Nonetheless, the tribunal recognized from the magnitude of the social conflict that the project was no longer viable. Interestingly, the tribunal limited compensation to investors on the basis of their failure to secure community support. The investors were still awarded US$18.2 million. In another similar case, the tribunal reached a different outcome by stating that the state was justified in revoking the mining concessions because of the claimant's significant contribution to aggravating the social conflict sparked by the mining activities.[13] Although the expropriation was regarded as lawful, Bolivia was still condemned to pay damages for sunk investments worth US$18.7 million.

Indigenous rights are also greatly threatened by commercial arbitration, which often does not recognize these rights. These were also relevant in *Gold Reserve v. the Bolivarian Republic of Venezuela*.[14] In this case, the government revoked a construction permit due to the project's impact on the environment and indigenous communities. The tribunal ruled that Venezuela had breached the fair and equitable treatment (FET) standard under the Canada–Venezuela bilateral investment treaty (BIT) of 1996. Interestingly, while the social and environmental importance was argued by the parties, it was not decisive. In fact, the tribunal decided that "Venezuela's responsibility for the protection of the environment and the local communities did not release it from its commitment to international investors" (Ali *et al*., 2019).

Arbitration threatens not only indigenous rights but also some legal orders, for instance, in *Abu Dhabi* or *ARAMCO*, where the arbitral tribunals refused to apply Islamic law. The reasons for such refusal are not clear, but this raises further questions for countries where *Sharia* law form an integral part of the legal system (Alsaidi, 2004; El Kosheri, 2007). The power of a private arbitral tribunal to disregard an entire legal order is worrying.

Various cases demonstrate that environmental concerns are not a priority. Tribunals often stick to the words of BIT or FTA that have been decided decades ago and do no longer reflect the modern trend towards the environment. *Quiborax et al. v. the Plurinational State of Bolivia* best reflect this problem.[15] In this case, the concessions were located in the Salar de Uyuni without an environmental licence. In 2004, the investors were granted an environmental licence, but due to a wave of protests from civic organizations, it was soon cancelled. Although no licences were delivered for the concession at the time of revocation, the tribunal did not find it sufficient to justify the state's actions.

Finally, multinationals are able to attack democratic choices in front of private arbitral tribunals. In fact, Ecuador's Constitutional Court found the arbitration clauses of six BITs unconstitutional (Singh & Ilge, 2016). Moreover, although various Latin American countries have submitted a notice to terminate BITs, the regime is not fully dismantled because of the so-called survival clause found in most BITs (Singh & Ilge, 2016). This clause allows investors to still bring claims in front of arbitral tribunals in relation to investments that were made whilst the BIT was in force. This means that a country can still face arbitral proceedings for "an additional period of 10-15 years, depending on the treaty" (Singh & Ilge, 2016) yet again demonstrating the powerful nature of ISDS provision as well as how easily it can limit state sovereignty. This raises questions regarding the safeguards of democratic principles. Indeed, as already noted, some of those BITs are older agreements that might no more accurately represent the country's philosophy or situation. Venezuela is a very good example; when it entered those BITs, its economy was still flourishing.

As such, it can be said that ISDS mechanisms can be used to stymie human rights (Bradlow, 2018). Countries have been sued in arbitration for taking measures to protect the health of their citizens. In the *Renco Group Inc v Republic of Peru* dispute, for instance, although Renco did not comply with environmental norms for years, when the Peruvian government decided to close the mine, it was sued for unlawful expropriation.[16] This case shows how those major groups are playing with the inequality of powers. Indeed, the Peruvian government was unable to make the company comply with environmental norms due to power balance inequality. The arbitral tribunal dismissed Renco's claims based on a procedural error (DAC Beachcroft, 2017). The arbitral tribunal considered that the rule of the 'unsuccessful party' bears the costs was not applicable and required both parties to bear their own cost as well as half of the arbitration cost (DAC Beachcroft, 2017).

The Disproportionate Compensation

In addition to restricting state sovereignty by not allowing states to create new nature reserve and preserve indigenous rights, the amount of compensation claimed seems indecent (Moore & Perez Rocha, 2019, appendix 1). For instance, in a 2018 request for arbitration against Uruguay, the amount claimed was equivalent to nearly 6% of the country's GDP. Venezuela was also required to pay the largest amount awarded in a single mining case, US$1.2 billion, plus interest, to Crystallex, a Canadian mining company, for the cancellation of a mine operation contract. This means that private companies could lead to the bankruptcy of a state.

This possibility of bankruptcy is very well exemplified in the long-running dispute of *Crystallex International Corporation v. Bolivarian Republic of Venezuela*. In this case, after Crystallex was awarded $1.2 billion, plus interest, it converted the award into a US judgment in the DC District Court. The judgment was then registered "in the Delaware District Court where Crystallex successfully pierced the veil to reach Venezuela's assets, including PdVSA, Venezuela's national oil company, and the shares it holds in the US oil refining company Citgo" (Davidson *et al.*, 2020). As Davidson *et al.*, (2020) rightly pointed out,

Crystallex's attempts to enforce its judgment (as a single creditor) is somewhat in tension with the administration's policy to protect Venezuela's US assets for the interim government of Venezuela led by President Juan Guaidó. In the near term, the Supreme Court's decision to deny review is likely to incentivize enforcement actions by Venezuela's creditors and encourage creditors of foreign sovereign entities more generally to consider alter-ego claims as part of their enforcement strategies.

This also means that states' assets are at risks after arbitral decisions, which are not easily reviewable.

Questioning the Rationale of Investments Agreements

All of these downfalls have resulted in a number of developing countries questioning the rationale of investments agreements. Indeed, there is a lack of clear evidence that IIAs positively impact foreign investments (Webb Yackee, 2010). Such presumption seems to be confirmed when looking at the Brazilian situation. Brazil never ratified BITs containing the ISDS clause, nor did it adhere to the ICSID Convention, yet it has always been very attractive for foreign investments without ISDS (Vidigal & Stevens, 2018). In fact, developing countries have started to realize that such agreements are often not sufficient to attract foreign investments and that the arbitration clauses could have disastrous consequences on their economy. ISDS has turned into high stakes gambling from developing counties.

The perception of ISDS being more burdensome than advantages led to a backlash against it and attempts to reform the system (Waibel, Kaushal, Chung, & Balchin, 2010). Singh and Ilge (2016) noted that "Bolivia became the first country to denounce the Convention on the Settlement of Investment Disputes between States and Nationals of Other States (ICSID Convention)" (p.5). South Africa followed the trend by terminating agreements and replacing them with national legislation, which safeguards domestic policy space while affording protection to foreign investors (Singh and Ilge, 2016). Interestingly, already in 1973, Domke & Glossner (1973) noted, "developing countries no longer wish to see their disputed commercial relations determined by Western-oriented arbitral bodies outside their countries". However, it took much longer for countries to take the initiative to replace the existing agreements.

Other countries have questioned the reliance on private arbitration to solve state disputes. For instance, Belgium blockage of CETA due to the private arbitration clause in the deal (BBC News, 2016; Vidigal & Stevens, 2018). CETA was nonetheless signed. Some of its provisions have been challenged in front of the CJEU, which did not share Belgium's preoccupation with regard to arbitration (Kassoti & Odermatt, 2020). In fact, in Opinion 1/17, the Court established that Section F on Resolution of investment disputes between investors and states is compatible with EU law (Opinion 1/17 EU:C:2019:341, 2019).

The Problem Is Not Limited to Developing Countries: Examples From EU Countries

The use of private arbitration in energy disputes is not only a problem for developing countries. Indeed, traditionally, developed countries that did not host investments from their BITs counterparts have found their policies challenged through ISDS (Vidigal & Stevens, 2018). European states have been sued by private companies when passing legislation to protect the health of their citizens. For instance, Spain faced a large number of proceedings when enacting "a series of measures that effectively suppressed the economic incentives created to boost the renewable energy sector" (Magallanes & Barradas, 2020). These measures "had the effect of significantly reducing the level of economic incentivization for renewable energy producers and, thus, the rate of return for investors, lowering the value of their investments and the profitability of their projects" (Magallanes & Barradas, 2020). This resulted in Spain being the second most frequently respondent state in ISDS cases being ordered to pay €290.6 million so far (UNCTAD, 2020). One of the first cases was the so-called PV Investors disputes where claimants sought more than €1.9 billion in damages but only obtained €9.1 million (The PV Investors v Spain, 2020). This highlighted the lack of proportionality in the investors' claims, which are only trying to obtain a form of profit maximization through arbitral proceedings.

Similarly, Italy has been sued by Rockhopper following Italy's decision not to grant a concession for oil drilling because of concerns over earthquake risks and environmental damage (Ruggero Di Bella, 2018). Italy passed a law to prohibit oil drilling within 12 miles of its coastline after waves of protests regarding drilling in Abbruzzo (Red Carpet Courts, 2019). The amount claimed by Rockhopper is allegedly more than seven times what the company spent on Ombrina Mare, the Italian branch of the project. This means the lawsuit represented a real cash cow for the company. Once again, an arbitral tribunal will have to balance private interests against democratic decisions.

Germany has been involved in a long international arbitration proceeding launched by Swedish company Vattenfall in front of the International Centre for Settlement of Investment Disputes (ICSID) in Washington D.C. The dispute started when the German Parliament amended the Act on the Peaceful Utilisation of Atomic Energy and the Protection against its Hazards (the Atomic Energy Act) to phase out nuclear energy by 2022. Consequently, Vattenfall's licences to operate both plants were immediately withdrawn, and operations in both plants were shut down. Vattenfall's strategy to counter this enactment was two-fold: the filing of a challenge with the German Federal Constitutional Court and the initiation of an investment arbitration against Germany under the Energy Charter Treaty (Paez-Salgado, 2021). The court rendered two judgments, first in 2016 and second in 2020, both finding that Vattenfall's rights were violated due to a lack of adequate remedial provision.[17] The court ruled that compensation payments should be granted to the companies. Additionally, in 2021, the German government agreed to settle the arbitral claim (Sanderson, 2021).

Unlike developing countries, Member States face an additional problem: the compatibility of private arbitration with EU law. The tension derived from the coexistence of EU law and arbitration is well illustrated in the *Achmea* case.[18] Until that ruling, it was believed, "save in some exceptional circumstances, EU law and private arbitration constitute two legal orders traditionally deemed merely to coexist, functioning in parallel according to distinctive logics" (Penades Fons, 2020). However, in that case, the

Court of Justice of the European Union (CJEU) ruled that the Netherlands-Slovakia BIT was incompatible with EU law and confirmed the autonomy of the EU legal order. For the CJEU, the fact that arbitral awards are not subject to review by a Member State court to ensure compatibility with EU law made it unacceptable. Moreover, the Court established that an arbitral tribunal is not a court or tribunal of a Member State within the meaning of Article 267 TFEU (Fouchard & Krestin, 2018). Although the CJEU established that arbitration clauses in intra-EU BITs are incompatible with EU law, the ruling did not influence the *Vattenfall v Germany* saga. This decision could influence future decision as it constitutes an important precedent.

In 2021, *Uniper* has threatened to sue the Netherlands over its plan to phase out coal power by 2030 (Darby, 2020) In this case, ISDS can be viewed as a tool to resist climate actions by making it much more expensive. If this claim is successful, it will set a dangerous precedent that can water down future climate policies. The threat is very real and also shows that changes in situations are not given enough weight. Another proceeding was initiated in 2021 against the Netherlands by a German company (ICSID, 2021).

Currently, investment treaties are not aligning with the Paris Agreement. Consequently, European countries are facing a difficult choice between complying with the Paris Agreement and paying investors or honouring their private contracts and paying fines to the EU for not complying with the Paris Agreement. European countries are facing an important dilemma.

HOW DID WE GET THERE? AND POSSIBLE WAYS FORWARD

Investor-State Dispute Settlement (ISDS) is often included in bilateral treaties or free trade agreements. As Zhan (2016) noted, “Originally, the ISDS mechanism was designed to ensure a neutral forum that would offer investors a fair hearing before an independent and qualified tribunal, granting a swift, cheap and flexible process for settling investment disputes”. The assumption is that “ISDS acts both as a deterrent to states and as an insurance policy for investors” (Tienhaara, 2015). So, if States decided to change the rules of the game, the investors were still protected. However, ISDS has been gradually used to challenge state decisions and the regulatory capacity to protect other rights and interests different to foreign investors’, including the “public” interest. It allows private entities to sue States in private arbitration tribunals, which can render binding and globally enforceable awards.

The major issue with the current system is the extensive protections granted to foreign investors against government measures that might damage their investments. These measures include expropriation or the implementation of other policies that may affect their economic expectations or treat them unfairly. One of the main arguments to afford more protection to foreign investors is that energy projects are often long-term and capital-intensive in countries with political instability and different cultural background. This argument is, however, hard to sustain in the *Vattenfall v Germany* context. Indeed, Germany is quite stable politically with a quite similar cultural background to Sweden. This tends to show that the ‘protection’ for political instability is a non-argument and has been used to enforce a system that allows private companies to limit state sovereignty.

Moreover, the ISDS system is profoundly unfair, not only regarding states or indigenous communities but also regarding investors in general. First, they do not protect national investors. Second, only specific investors have standing under a treaty or have the ability to gain such standing through restructuration (Tienhaara, 2015). For instance, major multinationals use their foreign affiliates to gain standing. As argued by Aisbett, Karp, & McAusland (2010), “compensation also distorts investment and entry decisions" (p.381). This could lead to abuses. For instance, some foreign investors continued to invest in Spain even after bringing an ISDS case, which raises the question of whether ISDS is not regarded as an additional source of profit by investors (Olivet & Eberhardt, 2014).

While multinational and big companies are to blame for using the system to their advantage, states are often their accomplices. Indeed, states have created this system and are the only ones able to stop it. States often play ambiguous roles by, on the one hand, trying to attract foreign investors and, on the other hand, promulgate laws for the benefit of their population. Often, these laws that are promulgating the wellbeing of the population goes against the interests of the multinationals.

Furthermore, the IIAs have been traditionally kept vague with regard to the substantive obligations of states. The substantive protection provisions virtually always included in these agreements are the protection from uncompensated expropriation, fair and equitable treatment, national treatment, most-favoured-nation treatment and full protection and security. Although these provisions are somewhat similar in all IIAs, the interpretation of the provisions are dependent on the exact wording, scope, context and intent of the parties to the treaty. Compulsory arbitration combined with ambiguous substantive provisions resulted in arbitral "tribunals to increasingly rely on previous arbitral decisions for guidance as regards legal interpretation of the scope and content of the obligations set forth in IIAs" (Vidigal & Stevens, 2018). More importantly, although arbitration is a creature of consent, states' consent is regarded as implicit in the IIAs. Therefore, no further consent is required, even if the situation in a specific state changed over time.

The power given to these international companies is so important that it seems we are now facing two levels of power: the traditional power represented by the states and a new power dominated by money. Through these treaties or bilateral agreements, which often treat foreign investors much better than national ones, states have given those companies the impression to be above the laws. This is especially exemplified by two facts; first, the choice of forum, procedures and rules mainly lies with the foreign investors. Taking the *Vattenfall v Germany* dispute, all the connecting factors are in Europe. Despite this, the proceedings were started in the US. Second, IIAs allows for investors to bring claims against states but not the opposite (Thakur, 2021).

This impression of being above the laws and being more than just a tool to protect foreign investment is very well embodied in a quote by Echandi & Newson (2014). They argued that "the time has come to start visualising the international investment regime not merely as an instrument to protect foreign investments abroad, but rather as a tool of international economic governance" (Echandi & Newson, 2014). This statement demonstrates that for its proponents, ISDS serves a much greater purpose than its initial aim. If we accepted that ISDS is an international economic governance tool, it also means that we allow these major corporations to be above the laws by setting their own rules.

In a sense, the energy sector is to blame for the globalisation of arbitration because of the financial stakes which are involved. As Rowley (2020) noted, "if a single industry sector can lay claim to parental responsibility for the present universality of international arbitration as the go-to choice for the resolution of commercial and investor-state dispute, it must be the energy business. It is the poster boy of arbitral globalisation" (p.1).

While the system is definitively inadequate, various proposals have emerged to cure its defects. Some countries, such as the US and Japan, have advocated for the introduction of a code of conduct for arbitrators. The EU has debated the possible creation of a whole new institution, the Multilateral Investment Court (MIC). It is "one of the most ambitious procedural reform efforts to impact international investment law since the negotiation of the ICSID Convention" (American Society of International Law, 2020). The proposal seeks to avoid conflicts of interests by employing full-time judges (Torgal & Saavedra Pinto, 2019). Other proposals related to the establishment of domestic forum for dispute settlement. However, domestic forum faces the same critics as domestic courts, namely that they are biased towards states.

The best solutions so far are found in Brazil and South Africa, which have established state-to-state adjudication to replace ISDS.[19] The Brazilian system called Cooperation and Investment Facilitation Agreements (CIFAs) "combines dispute prevention mechanisms, creating institutions to ensure continued communication and foster cooperation, and state-to-state arbitration (inspired by dispute settlement provisions common in trade agreements and codified in the World Trade Organization's Dispute Settlement Understanding)" (Vidigal & Stevens, 2018). Under this system, investors are required to get an authorisation from their home state before any proceedings can be initiated.

Unfortunately, despite the recent restructuring of cross-border investments and supply chains, there is no sign that other means of dispute resolution will take precedence over the use of international arbitration in the energy sector. As a result, it seems important to "safeguard sufficient regulatory space in future IIAs to protect public health and to minimise the risk of ISDS proceedings, while protecting and promoting international investment for development" (UNCTAD, 2020).

CONCLUSION

Private arbitration is a poisonous gift, which often results in unfair decisions for developing countries. The growth in disputes also increases the power of commercial arbitral tribunals, rendering them more powerful than ever. The current system gives exorbitant jurisdiction to private companies and arbitral tribunals, which can, in effect, limit state sovereignty and results in regulatory chill.

Although the arbitral tribunal should perform a balancing exercise between the protection of the investors' legitimate expectations and the regulatory power of a state, many have reported a form of bias in the ruling. The simple inability of states to sue foreign investors in arbitration not only results in absurd outcomes such as in the *Renco* decision but tend to show an imbalance in the system. Moreover, errors in interpretation have much harsher consequences compared to litigation. Indeed, while domestic courts can also err in applying domestic, EU or international law, private arbitration is much more troublesome due to the very limited avenues of reviews. It is, therefore, time to reassess the use of arbitral tribunals.

States have created this system and are now facing the consequences. However, little did they know the difficulties they would be facing even after terminating BITs? The danger of the system and the need for reforms have been discussed for decades without much success. The EU MIC initiative is far from being ready. Similarly, there is no consensus on the introduction of a code of conduct for arbitrators. The best solution so far is probably found in Brazil and South Africa, which have established state-to-state adjudication to replace ISDS. As has been discussed, the Brazilian situation is very peculiar because it never ratified BITs containing ISDS clauses. Despite the recent restructuring of cross-border investments and supply chains, there is no sign that other means of dispute resolution will take precedence over the use of international arbitration in the energy sector.

While states are also to blame, multinationals have taken advantages of the system, resulting in the number of claims skyrocketing. ISDS is now used to water down legislation and is a tool to resist climate actions by making it much more expensive. ISDS is such a powerful tool and serious threat that it results in a *de facto* limitation of state sovereignty through regulatory chill. Climate change mitigation is an issue that must be urgently addressed and should not be restricted by private interests. It is, therefore, time to broaden the debate instead of keeping a narrow focus on the investment policy sphere.

The current system is very unfair for local populations, which are not part of the negotiation process. The unfairness of the system mainly stems from allowing private companies to challenge state measures and claim mind-blowing amounts of compensation. Even though the costs of explorations are often very high, investors also earn money through these explorations. The fact that future gains of major international companies weigh more than the health of the local populations, rights of indigenous communities or the conservation of the environment demonstrates a broken system. States are left at the mercy of wealthy private groups, which see themselves as above the laws. It might be time to change the system and investigate new forms of dispute resolutions that would be fairer for everyone.

DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints, and they are not responsible for any duty of care in this regard.

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ENDNOTES

1 ICSID Case No. ARB(AF)/09/1

2 Supreme authority within a territory or ultimate power within a specific territory. See: Article 2(4) an (7) of the Charter of the United Nations (done at San Francisco, United States, on 26 June 1945) (United Nations) 1 UNTS XVI, 59 Stat 1031, TS 993, 3 Bevans 1153, 145 BSP 805, 892 UNTS 119,

3 *Cosigo Resources, Ltd. v. Republic of Colombia*, Notice of Demand and Demand for Arbitration and Statement of Claim, UNCITRAL (19 February 2016); *Vattenfall AB and others v. Federal Republic of Germany*, Notice of Demand and Demand for Arbitration and Statement of Claim, ICSID Case No. ARB/12/12 (31 May 2012)

4 Article 1 of the Charter of Economic Rights and Duties of States adopted December 12, 1974, UNGA resolution 3281 (XXIX). Military and Paramilitary Activities in and Against Nicaragua (*Nicaragua v United States*), Merits, [1986] ICJ Rep 14; *Texaco Overseas Petroleum Company v Libyan Arab Republic*, Merits, (1978) 17 ILM 3.

5 To be clear, the question of whether investors should be compensated when negatively impacted by state measures is not part of the discussion. Instead, the focus is on demonstrating that arbitration is not the best forum for developing states, at least.

6 *Cosigo Resources, Ltd. v. Republic of Colombia*, Notice of Demand and Demand for Arbitration and Statement of Claim, UNCITRAL (19 February 2016); *Vattenfall AB and others v. Federal Republic of Germany*, Notice of Demand and Demand for Arbitration and Statement of Claim, ICSID Case No. ARB/12/12 (31 May 2012)

7 UNCT/13/1

8 Article 14(1) of the ICSID Convention on arbitrators; Article 11 of the 2010 UNCITRAL Arbitration Rules.

9 *Teco Guatemala Holdings v Guatemala*, ICSID Case No ARB/10/2, Award, December 19, 2013; *Iberdrola Energía v Guatemala*, ICSID Case No ARB/09/5, Award, August 17, 2012

10 *Dominion Minerals v. Panama* ICSID Case No. ARB/16/13; *Bear Creek Mining Corporation v. Republic of Peru*, ICSID Case No. ARB/14/21; *Copper Mesa Mining Corporation v. Republic of*

Ecuador, PCA No. 2012-2; *Cosigo Resources, Ltd., Cosigo Resources Sucursal Colombia, Tobie Mining and Energy, Inc. v. Republic of Colombia*

11 ICSID Case No. ARB/18/23

12 'had not received many of the government approvals and environmental permits it needed to proceed' and 'on the basis of the evidence before it, the Tribunal concludes that there was little prospect for the Project to obtain the necessary social license to allow it to proceed to operation, even assuming it had received all necessary environmental and other permits.'

13 *South American Silver Limited v. Bolivia*, PCA Case No. 2013-15

14 ICSID Case No. ARB(AF)/09/1

15 CSID Case No. ARB/06/2

16 UNCT/13/1

17 Judgment of 6 December 2016 - 1 BvR 2821/11; Order of 29 September 2020 - 1 BvR 1550/19

18 Case C-284/16, *Slovak Republic v. Achmea BV*, ECLI:EU:C:2018:158

19 Article 13(5) of Republic of South Africa Protection of Investment Act 2015

Chapter 2
Microfinance, Energy Poverty, and Sustainability:
The Case of Tanzania

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ABSTRACT

The role of microfinance in reducing energy poverty among Tanzanian micro-borrowers is examined in this chapter. A standardized questionnaire was used to conduct a survey of 490 micro-borrowers. The data was analyzed using the multiple regression technique. Micro-borrowers are eager to spend on modern energy sources for cooking and other activities, according to the findings. Affordability and willingness to spend on contemporary energy sources for cooking have a substantial positive impact on their usage. The willingness to utilize modern energy sources for other purposes has a significant positive impact on their usage. Age, marital status, and education have no bearing on the use of modern energy sources for cooking and other purposes. The use of modern energy sources for other purposes, but not for cooking, is significantly influenced by household size. Microcredits customized for contemporary energy sources should be implemented to combat energy poverty.

INTRODUCTION

Access to clean, affordable, reliable, and contemporary energy sources has been connected to the Sustainable Development Goals (SDGs) (Crentsil *et al.,* 2019). 2.5 billion People utilize traditional biomass for cooking, 120 million use kerosene, and 170 million use coal (IEA, 2017). Around 905 million people in Sub-Saharan Africa (SSA) do not have access to clean cooking fuels, while 578 million

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do not have access to electricity (IEA, 2020). Around 80% of all Tanzanian families rely on traditional energy sources like firewood and charcoal, with over 90% of rural and disadvantaged households doing so (World Bank, 2016).

The high prevalence of energy poverty has serious socioeconomic consequences for people's health, livelihoods, and social well-being (Churchill *et al.,* 2020a). As such, energy poverty can be seen as one of the drivers underlying extreme income poverty among households. Hence, lowering energy poverty serves as a catalyst for many other development goals through bolstering microfinance institutions' social aim of alleviating income poverty and improving the well-being of micro-borrowers (Rafay, *et al.,* 2020). Low purchasing power, on the other hand, is mentioned by Koomson and Danquah (2021) as one of the issues impeding households' exit from energy poverty. This implies that energy and income poverty are intertwined. In other words, energy poverty leads to income poverty and vice versa (Boutabba, 2020; Groh & Taylor, 2015; IRENA, 2019; PAMIGA, 2020; World Bank, 2019; Aziz *et al.,* 2020). Since microfinance has been identified as a way to alleviate income poverty and improve household wealth (Allet, 2016; Du Can *et al.,* 2018; Koomson & Danquah, 2021), it is also expected to relieve energy poverty among the poor (Yunus, 1999).

Despite increased access to microfinance among Tanzania's poor (Kasoga, 2020), the majority of Tanzania's poor still live in energy poverty (World Bank, 2016). This circumstance necessitates an empirical study of the effects of microfinance on energy poverty reduction, with a special focus on the following research questions: Are micro-borrowers willing to use and afford contemporary sources of energy? Is there a relationship between micro-borrowers' willingness and ability to use contemporary energy sources and the use of contemporary energy sources?

Adusah-Poku and Takeuchi (2019) argue that in order to alleviate energy poverty, households must be ready to spend on contemporary fuels as they become more widely available. Similarly, a home may be in energy poverty due to low income and high energy costs (WEO, 2017). Income poverty is a significant driver of energy poverty, but it is neither the only reason nor even a required condition for energy poverty (WEO, 2017). Because there is no universal consensus on the influence of microfinance on energy poverty reduction around the world, and because energy poverty is a context-specific phenomenon (Kumar, 2020), it is necessary to investigate the role of microfinance in eradicating energy poverty in Tanzania.

Boutabba *et al.* (2020), Groh and Taylor (2015), Levaï *et al.* (2011), Mohiuddin (2006), Morris *et al.* (2007), and Rao *et al.* (2009) are among the few research studies in the literature that has focused on microfinance and energy poverty. This chapter adds to the body of knowledge by presenting evidence of the impact of microfinance on the decrease in energy poverty among Tanzanian micro-borrowers. This was important because, while energy poverty is a context-specific problem, there is no general consensus on the influence of microfinance on the decrease in energy poverty around the world (Kumar, 2020). The findings are also crucial for policymakers working to alleviate energy poverty among the poor.

Specifically, the objectives of this chapter are to determine micro-borrowers' willingness and ability to use modern energy sources, as well as to investigate the relationship between micro-borrowers' willingness and ability to spend on contemporary energy sources and their use of contemporary energy sources. The chapter also looks into the impact of micro-borrowers' demographic characteristics (age, marital status, level of education, and household size) on their use of contemporary energy sources.

LITERATURE REVIEW

Energy Access and Poverty

One of the world's most pressing development concerns is poverty. Indeed, the United Nations' 2030 Agenda for Sustainable Development (UN, 2015) recognizes that "the biggest global challenge and an imperative condition for sustainable development is eradicating poverty in all its forms and dimensions, including extreme poverty." Despite the fact that the number of people living in extreme poverty decreased by more than half between 1990 and 2015 (from 1.9 billion to 836 million) (UNDP, 2016), many people still struggle to obtain the most basic necessities of life, such as food, shelter, clothing, health services, and safe drinking water (UNDP, 2016).

Many international organizations stress the relevance of energy access in poverty reduction (UNDP, 2016; WHO, 2018; World Bank, 2019; Rafay, 2022). As a result, ensuring that everyone has access to affordable, dependable, sustainable, and contemporary energy is a top priority in the 2030 Agenda for Sustainable Development. The IEA (2009) identified three degrees of access to energy services based on household energy demands and the services provided by energy sources. The first is the bare minimum of energy availability required by households to meet their basic human needs (electricity for lighting, health, education, and community services). Second, the level of energy access that families need to raise production (electricity and modern fuels); third, the level of energy access that households need to meet modern society's needs (modern services for domestic appliances, increased requirements for cooking and heating, and private transport). However, despite the broad availability of microfinance institutions, the majority of Tanzanians are at the first level of access to energy services, with only 32.8 percent of households having access to electricity (Tanzania Bureau of Statistics, 2017). Hence, it is critical to investigate the role of microfinance in eradicating energy poverty.

Households are severely hampered by energy poverty, which is characterized as a lack of access to modern energy services (Ambrose, 2015; Azpitarte *et al.,* 2015; Boardman, 2009; Churchill & Smyth, 2020; Hills, 2011; Moore, 2012). According to prior studies, energy poverty has an impact on the hours of production available to households, as well as economic activity and time available for schooling, homework, and other activities (Kaygusuz, 2011; Reddy, 2000). Insufficient energy, according to Sovacool (2012), causes serious and rising public health issues due to a lack of refrigeration and medical care. Energy poverty, he believes, has an impact on both gender roles in society and the educational opportunities available to children and adults. Hence, energy poverty is one of the causes of income poverty among households (Boutabba, 2020; Groh & Taylor, 2015; IRENA, 2019; PAMIGA, 2020; World Bank, 2019).

Biomass fuels are used by the majority of households in underdeveloped countries to meet their basic energy demands (Kaygusuz, 2011; Sovacool, 2012). Biomass use has a significant negative impact on household health, especially when it is burned inside without the use of a working stove or a chimney to help regulate smoke emissions (Kaygusuz, 2011; Sovacool, 2012). Aside from the expensive cost, using biomass fuel could result in higher medical bills and a reduction in the poor's ability to work productively. According to the WHO (2018), around 4 million people die prematurely each year as a result of illnesses induced by inefficient cooking methods, such as the use of polluting solid-fuel stoves and kerosene. The fact that biomass users are less likely to boil their drinking water for cost or tradition reasons exacerbates these effects (Kaygusuz, 2011; Sovacool, 2012). Because the use of biomass in cities causes deforestation, reliance on biomass in the future may tend to boost its price, further decreasing the poor's living standards and leading to income poverty.

Despite having access to electricity, Marufu *et al.* (1997) discovered that some urban Zimbabwean households choose not to use it due to the expensive cost. Homeowners in South Africa (Davis, 1998) and India have observed similar findings (Bhide & Monroy, 2011). As a result, energy access and affordability are closely intertwined (Du Can *et al.,* 2018). They also noted that energy-efficient equipment and supplies have higher initial prices, but less efficient devices are less expensive to install. However, the former is more cost-effective in the long run since they are more efficient (Du Can *et al.,* 2018). They go on to say that energy efficiency has numerous advantages, including lowering power plant fuel input, lowering hazardous pollutants, improving energy security, and serving the energy needs of a larger number of clients. A household may be in energy poverty for three reasons: low-income, high-energy expenses, and energy inefficient housing (WEO, 2017). In response to the question of whether energy poverty is just a result of poverty, WEO (2017) noted that while poverty is a major driver of energy poverty, it is not the only reason or even a necessary condition. Hence, the need to provide empirical evidence regarding the role of microfinance in eradicating energy poverty among micro-borrowers in Tanzania.

Microfinance and Energy Poverty

Microfinance is a method of delivering financial services to those who are too poor to be served by regular financial institutions (Yunus, 1999). Alternative collateral, such as shared liability borrowing, is commonly used by microfinance organizations to provide these services (Yunus, 1999). The World Economic Forum (2010) defines energy poverty as "the absence of access to contemporary energy services and goods." Energy poverty is described as a lack of appropriate, reliable, economical, safe, and environmentally suitable energy services (Awan *et al.,* 2013) and Reddy *et al*. (2000). In order to distinguish contemporary energy sources from traditional energy sources, Pachauri and Spreng (2004) define contemporary energy sources as clean energy with no negative environmental impact, whereas traditional energy sources are defined as energy with negative environmental and health impacts on households. This chapter defines energy poverty as the lack of sufficient choice in getting enough reliable, affordable, safe, and ecologically compatible energy services, as suggested by Awan *et al.* (2013) and Reddy *et al.* (2000).

The 2015 Sustainable Development Goals (SDGs) (number 7) intend to provide everyone with affordable, reliable, sustainable, and contemporary energy by 2030. This aim underlines the importance of providing all people in developing countries with contemporary and sustainable energy services, as well as adopting a wellness approach to energy consumption (Kiranmai, 2022). People's access to modern energy services can be significantly improved, according to Morris *et al.* (2007) if they also have access to microfinance loans to pay for them. Energy access is a catalyst for many other development goals, and its facilitation can support microfinance's social mission of eradicating poverty and enhancing the well-being of consumers (PAMIGA, 2020). Few research, however, has looked into the effect of microfinance on reducing energy poverty (Boutabba *et al.,* 2020; Groh & Taylor, 2015; Morris *et al.,* 2007; Rao *et al.,* 2009).

Boutabba *et al.* (2020) found that microfinance reduces energy vulnerability, with microfinance clients having higher energy poverty indices and energy expenditures than non-client households, in their study on understanding the impact of microfinance on energy access in the peripheral districts of Lomé, Togo.

They suggested that policymakers take steps to encourage and expand access to microfinance, as this has the potential to reduce energy poverty and improve access to high-quality, contemporary energy services.

Koomson and Danquah (2021) investigated the impact of financial inclusion on energy poverty in Ghana. According to their findings, financial inclusion has the ability to eliminate energy poverty. Similarly, Groh and Taylor (2015) discovered that microfinance plays a key role in reducing energy poverty in their study based on case studies from Bangladesh, Pakistan, and Cameroon, as well as lessons gained from experiences in Mexico, Peru, and the Philippines. While major microfinance programs are likely to improve rural communities' access to energy and, as a result, reduce energy poverty, they are rare, if not non-existent, according to them. They go on to suggest that solar must adapt to local needs if it is to become a viable option for energy access in rural areas.

In a similar vein, Mohiuddin (2006) addressed this issue by proposing a new strategy for developing countries to take the lead by expanding the role of microfinance programs in financing renewable energy generation and distribution, as well as outlining how affluent countries may assist. According to the author, microfinance institutions are a possible alternative to closing the energy gap since they can offset the high prices that limit the development of renewable energy generation. Microfinance institutions, according to the author, can aid in the commercialization of renewable energy technologies by making them more affordable for consumers and businesses. Allet (2016) corroborated this finding by examining a sample of rural financial institutions in Cameroon, Ethiopia, and Kenya that have begun to develop financial products to assist their poor rural consumers in obtaining excellent pico-solar systems.

Morris *et al.* (2007) discovered that having access to microfinance loans to pay for contemporary energy services improves people's access to them significantly. Their study shows that if individuals have access to appropriately designed loans in order to purchase contemporary energy services, the potential market for energy products can be transformed into effective demand. They looked at the experiences of selected microfinance institutions in Asia, Africa, Latin America, and the Caribbean that have energy-lending programs.

Furthermore, Ekouevi and Tuntivate (2012) examined the World Bank's funding operations as well as selected interventions by other institutions in the area of household energy access in order to identify success and failure variables that may be used to inform the next generation of interventions. They discovered that programs that incorporate microfinance options to assist families in obtaining better stoves are more successful. They recommend that the poor have a long-term plan in place to pay for the better stoves. Rao *et al.* (2009) presented energy-microfinance initiatives that provide low-income households with novel energy solutions such as clean lighting and upgraded cook stoves, as well as much-needed financing.

Generally, studies on the role of microfinance in reducing energy poverty are few and limited in the specific context. Since energy poverty is a context-specific phenomenon (Kumar, 2020), there is still a need for more work to be conducted in developing countries such as Tanzania.

Microfinance and Energy Poverty in Tanzania

Microfinance institutions began operating in Tanzania in the 1980s with the goal of providing financial services to those who were not served by traditional financial institutions (Randhawa & Gallardo, 2003). Due to their relationship with poor clients, understanding of their basic needs, and ability to provide end-user financing to overcome the affordability barriers associated with accessing modern energy services, microfinance institutions have been hailed as an effective and sustainable actor in addressing energy poverty (Morris *et al*., 2007).

Despite widespread access to microfinance among Tanzania's poor (Kasoga, 2020), the country's energy sector is still dominated by traditional biomass for home use, which is mostly harvested and processed in unsustainable ways (African Development Bank, 2015). Similarly, according to USAID (2018), the majority of Tanzanian families rely on charcoal, firewood, and cow dung as their primary energy sources. According to Bonjour *et al.* (2013), more than 85 percent of Tanzanians use traditional fuels as domestic energy sources, significantly limiting the country's economic and social growth potential. Similarly, the Tanzania Bureau of Statistics (2017) found that just 32.8 percent of Tanzanian households had access to electricity, with urban areas (65.3 percent) having better access than rural areas (16.9 percent).

The survey also shows that of the total electrified households, 74.9 percent use national grid power and 24.7 percent utilize solar power. Individual electricity generated from other sources, such as small generators, is used to electrify the remaining 0.3 percent. Although electricity access and consumption are still low, they are rapidly expanding, with 75 percent of Tanzanians expected to have access to electricity by 2035 (African Development Bank, 2015).

According to the statistics cited above, the majority of Tanzanians now rely on traditional energy sources. Traditional energy sources have an impact on health and contribute to climate change concerns, which are particularly concerning in developing nations (Bishoge *et al.,* 2018). According to the World Bank (2016) report, Tanzania's poverty reduction rate is slowing, with around 12 million residents out of a total population of 51.8 million living in extreme poverty, while a large share of the non-poor population lives just over the poverty line. The report maintains that increased productivity is required to generate jobs, improve the living conditions of Tanzanian households, and promote the achievement of the country's socioeconomic goals. This chapter is set to examine the role of microfinance in eradicating energy poverty, particularly focusing on the willingness to use and affordability of modern energy sources among micro-borrowers in Tanzania.

Sources of Energy in Tanzania

Biomass, hydropower, and solar power are Tanzania's principal energy sources (URT, 2017). Other sources include natural gas, petroleum, wind, and thermal energy (Bishoge *et al.,* 2018; African Development Bank, 2015). In Tanzania, hydropower accounts for almost one-third of the total installed power capacity of 2612 MW (International Hydropower Association, 2017; Otsuki, 2017).

Tanzania's prospective solar energy resources are found in the country's central regions, where 24.7 percent of households use solar energy as a source of power (Sarakikya, Ibrahim & Kiplagat, 2015). Solar energy is primarily used in rural areas (64.8 percent vs. only 3.4 percent in urban areas), with the Lindi, Njombe, Mtwara, Katavi, and Ruvuma regions leading the way in Tanzania's use of solar power (Bishoge *et al.,* 2018). In Tanzania, there are about 1,000,000 solar-powered homes, with solar photovoltaic panels ranging from 10 to 100 kW per home (Hansen *et al.,* 2014). Tanzania is naturally adapted to creating solar energy as a viable alternative source of contemporary energy supply and rural electrification (Bishoge *et al.,* 2018).

Biomass is the most frequent energy source in Tanzania's residential sector (Martin *et al.,* 2009), and it is mostly derived from forests, agricultural residue, animal dung, and solid industrial waste. Much of Tanzania's biomass is harvested in an unsustainable manner (Muhumuza & Balkwill, 2013; Gain & Watanabe, 2017), due to issues such as limited law enforcement, low knowledge, and high poverty levels.

Tanzania has 33 million hectares of forest, but it loses about 400,000 hectares each year, with around 75% of wood harvested not accounted for in government budget systems, resulting in tax collection losses (Smith, 2015). Tanzanian households consume an average of 46.4 kg of charcoal per month, with urban inhabitants consuming an average of 93.6 to 180 kg of charcoal per year (Msuya *et al.,* 2011). Biomass generates roughly 18 MW of grid power in Tanzania (Terrapon-Pfaff *et al.,* 2012). The raw materials available, such as municipal solid waste, forest residue, sugar bagasse, rice husk, sisal, and coffee, might be used to generate more power, according to these writers.

Other renewable energy sources in Tanzania include wind and geothermal energy. Tanzania has high wind potential areas that cover more than 10% of its land area in terms of wind energy (Tanzania Invest, 2015). There are places with annual average wind speeds of 5-8 m/s running from southeast to northeast over an 800 km shoreline (Kasasi & Kainkwa, 2002). Tanzania's wind energy resources, according to Bishoge *et al.* (2018), are concentrated in the Rift Valley's Great Lakes, lowlands, and highland plateau regions. Wind energy evaluation in Tanzania, according to URT (2015), suggests that sites like Makambako (Njombe area) and Kititimo (Singida region) have sufficient wind speed for grid-scale electricity generation, with average wind speeds of 8.9 m/s and 9.9 m/s at 30 meters, respectively. In Tanzania, the government and commercial firms (both domestic and foreign) are working on a number of wind energy generation projects (The Economist, 2017).

Tanzania has large geothermal energy resources, which are still unquantified (Bishoge *et al.,* 2018). Tanzania has a total capacity of 5000 MW of geothermal energy, according to URT (2018), with the majority of prospects located in the East African Rift System. Tanzania's geothermal blessings and prospects are grouped into three zones, according to ESI Africa (2016): northeast (Mara, Kilimanjaro, and Arusha areas); southwest (Rukwa and Mbeya regions); and the eastern coastal belt zone (Rufiji basin). Technology is another important factor (Rafay, 2019). According to Bishoge *et al.* (2018), every developing country is advised to increase infrastructure and update technology in order to supply clean energy as a basic goal that can boost socioeconomic and political growth while also improving the environment. As a result, in order to meet the Sustainable Development Goal number 7, the Tanzanian government is currently investing in increasing power generation, primarily by combining natural gas with coal and renewable energy sources such as hydro, solar, biomass, wind, and thermal energy, in collaboration with local and international private companies (Bishoge *et al.,* 2018).

HYPOTHESES DEVELOPMENT

Financial services such as loans help households increase their income and alleviate poverty by allowing them to make productive investments, maintain consumption levels over time, and endure economic shocks (Demirgüç-Kunt *et al.,* 2017). Inclusion of financial services such as credit has been linked to poverty reduction in numerous studies (Bruhn & Love, 2014; Burgess & Pande, 2005; Chibba, 2009; Churchill *et al.,* 2020b; Churchill & Marisetty, 2019; Koomson *et al.,* 2020a; Koomson & Ibrahim, 2018). Burgess and Pande (2005), for example, found a decrease in rural poverty in India as a result of an increase in bank branches in rural areas. In Ghana, Koomson *et al.* (2020) discovered that an increase in financial services is associated with a decrease in household poverty and reduces the likelihood of future poverty.

Churchill *et al.* (2020b) discovered that an increase in multi-dimensional financial services, such as bank accounts, credit, and insurance, is associated with a reduction in poverty. Other studies have argued that access to financial services promotes social inclusion by allowing low-income and vulnerable people in a society to obtain affordable financial services (Aslan *et al.,* 2017; Kim, 2016; Koomson *et al.,* 2020a). Equal access to financial services encourages the economic integration of socially disadvantaged households and improves society's overall welfare (Ibrahim *et al.,* 2018; Nanziri, 2016).

The studies described above were all about poverty reduction in general. Few studies have looked specifically at the effect of microfinance on eradicating energy poverty. Boutabba *et al.* (2020) discovered that microfinance decreases energy vulnerability, with microfinance customers in Togo's peripheral districts having greater energy poverty indices and energy expenditures than non-client households. As a result, financial services provide opportunities for poor parts of the community to thrive while also reducing income disparity (Omar and Inaba, 2020; Park and Mercado Jr, 2018). Financial inclusion, according to Koomson and Danquah (2021), has the potential to eliminate energy poverty in Ghana. Microfinance plays an important role in tackling energy poverty, according to Groh and Taylor (2015) and Mohiuddin (2006). Microfinance, according to Allet (2016) and Morris *et al.* (2017), improves access to contemporary energy sources.

According to Adusah-Poku and Takeuchi (2019), households must be willing and able to spend on contemporary fuels as they become more widely available in order to eliminate energy poverty. This means that the willingness and ability of micro-borrowers may impact the adoption of modern energy sources for cooking and other purposes, such as lighting and domestic appliances. Furthermore, past research has discovered a positive and significant association between contemporary energy use and demographic variables such as age, education, marital status, and household size (Boutabba *et al.,* 2020; Groh & Taylor, 2015; Koomson *et al.,* 2020a). Increased educational attainment, for example, improves energy poverty, according to Acharya and Sadath (2019), Crentsil *et al.* (2019), and Sharma (2016). As a result, the following hypotheses are presented based on the foregoing:

H1: There is a strong positive association between willingness to spend on contemporary energy sources and their use for (a) cooking and (b) other purposes.

H2: A considerable positive association exists between the affordability of contemporary energy sources and their use for a) cooking and (b) other purposes.

H3: There is a substantial positive link between (a) age, (b) marital status, (c) degree of education, and (d) family size and the use of contemporary energy sources for cooking.

H4: There is a substantial positive link between (a) age, (b) marital status, (c) degree of education, and (d) family size and the use of contemporary energy sources for other purposes.

METHODOLOGY

The study population was composed of micro-borrowers from three major microfinance institutions (NMB, FINCA (T) and BRAC (T) in three major commercial cities in Tanzania: Dar es Salaam, Arusha, and Mwanza. Many microfinance institutions and borrowers are found in major commercial cities in Tanzania (Kasoga, 2020). Questionnaires were distributed to a systematic sample of 600 joint liability borrowers using a step of 3 (200 borrowers from each of the three major commercial cities in Tanzania) as they exited microfinance institutions. Systematic sampling was used as a proxy for simple random sampling (Hair *et al.,* 2019). Participation was voluntary with respondents requested to answer questions concerning their willingness and ability to use modern energy sources.

The questionnaire items were validated in a pretest with 5 microfinance experts. The revised questionnaire was piloted among 20 individual group borrowers in Dodoma city before being accepted as the final version. A total of 490 useable responses were obtained with an average response rate of 82 percent across exits. The willingness to spend on contemporary energy sources for cooking, affordability of contemporary energy sources for cooking, use of contemporary energy sources for cooking, willingness to spend on contemporary energy sources for other purposes, such as lighting and running domestic appliances like refrigerators, televisions, radios, etc., affordability of contemporary energy sources for other purposes, and the usage of contemporary energy sources for other purposes were captured using a 5-point Likert scale ranging from (1) strongly disagrees to (5) strongly agrees. Previous studies have indicated that attitudes of customers can significantly predict their behavior.

The usage of contemporary energy sources among Tanzanian micro-borrowers was measured by asking respondents to indicate the extent of use of a combination of contemporary sources of energy such as biogas, electricity, natural gas, etc. for cooking and other purposes, such as lighting and running domestic appliances like refrigerators, televisions, radios, etc. The researchers decided to employ the extent of use because most poor people in Tanzania do not use contemporary sources of energy consistently as they tend to switch from one source of energy to another depending on the prevailing situation, particularly purchasing power (Teske *et al.,* 2017; URT, 2017). Correlation and multiple regression analyses were employed to predict the constructs' relationships.

Table 1. The demographics of the respondents (N = 490)

Variables		**Frequency**	**Percent**
Gender	Male	30	6.1
	Female	460	93.9
Age	18-25	30	6.1
	26-35	177	36.1
	36-45	197	40.2
	>45	86	17.6
Marital Status	Single	46	9.4
	Married	361	73.7
	Divorced	34	6.9
	Widowed	49	10
Level of Education	None	68	13.9
	Primary School	272	55.5
	Secondary	111	22.7
	Tertiary	39	8
Household Size	2-3	7	1.4
	4-5	87	17.8
	6-7	231	47.1
	> seven	165	33.7

Source: (Field Data, 2021)

RESULTS

Respondents' Demographic Characteristics

The demographic characteristics of respondents are shown in Table 1.

Table 1 shows that women made up the majority of the responders (93.9 percent). This means that the majority of micro-lenders in Tanzania are women. The bulk of respondents (76.3 percent) were between the ages of 26 and 45, indicating that youthful micro-borrowers are productive and have families and other community responsibilities. The fact that the majority of the respondents (73.7 percent) were married backs this up. Furthermore, the findings show that the majority of respondents (55.5%) had only an elementary education, implying that the majority of micro-borrowers are uneducated. Furthermore, the majority of respondents (80.8 percent) have a large household size (living with six or more family members), implying increased family responsibilities.

Descriptive Statistics

Table 2 shows the descriptive data for willingness, affordability, and usage of contemporary energy sources for cooking, as well as other purposes such as lighting and powering household equipment such as refrigerators, televisions, and radios.

Table 2. Descriptive statistics (N = 490)

Variables	Mean	SD	Min.	Max.	Skew	Kurtosis	Reliability Estimates
Willingness for Cooking	1.463	0.511	1.00	4.00	0.378	0.220	0.82
Willingness for Other Purposes	4.879	0.326	4.00	5.00	-0.340	1.490	0.89
Affordability for Cooking	1.155	0.362	1.00	2.00	0.911	1.660	0.81
Affordability for Other Purposes	4.063	0.243	4.00	5.00	0.599	1.990	0.87
Use of Contemporary Energy for Cooking	1.341	0.561	1.00	3.00	0.417	1.039	0.76
Use of Contemporary Energy for Other Purposes	4.798	0.402	4.00	500	-0.489	0.217	0.78

Source: (Field Data, 2021)

Table 2 shows that the willingness to use contemporary energy sources for cooking has a mean value of 1.463, indicating that micro-borrowers are unwilling to spend on modern energy sources for cooking. The average willingness to spend on contemporary energy sources for other purposes was also 4.879, according to the findings. This study suggests that micro-lenders are prepared to spend money on modern energy sources for other purposes, such as lighting and powering household equipment such as refrigerators, televisions, and radios. In addition, the data shows that the average affordability of contemporary energy for cooking is 1.155, implying that micro-borrowers cannot afford modern energy sources for cooking.

Furthermore, the mean value for contemporary energy affordability for other uses was 4.063, indicating that micro-borrowers can afford modern energy sources for other uses, such as lighting and running household appliances such as refrigerators, televisions, and radios. The average score for using contemporary energy sources for cooking was 1.341, indicating that micro-borrowers do not use contemporary energy sources for cooking. The mean score for using contemporary energy sources for other uses was 4.798, indicating that micro-borrowers utilize contemporary energy sources for things like lighting and powering household equipment like refrigerators, televisions, and radios.

Cronbach's alpha coefficients higher than the suggested limit of 0.6 were used to validate the measures' reliability, as indicated in Table 2. (Hair *et al.,* 2019). In addition, the skewness and kurtosis readings were within the required ranges (Hair *et al.,* 2019). Specifically, skewness values are not less than-1 nor more than +1, and kurtosis values are not less than-2 nor more than +2, implying a normal distribution within the sample (Table 2).

Correlation Results

The relationships between the research variables are shown in Table 3. The results suggest that there is no difficulty with multicollinearity among independent variables because the variables were unrelated to one another, with a correlation of less than 0.7. The findings of the correlation analysis between the independent and dependent variables demonstrate that the study hypotheses are tentatively supported or not supported. The positive correlation between willingness to spend on contemporary energy sources for cooking and the use of contemporary energy sources for cooking ($r = 0.090$, $p < 0.05$) suggests that willingness to spend on contemporary energy sources for cooking is related to the use of contemporary energy sources for cooking, implying that H1a is supported. Similarly, the willingness to spend on contemporary energy sources for other purposes was found to have a larger positive correlation than the use of contemporary energy sources for other purposes ($r = 0.635$, $p < 0.01$). This means that the readiness to spend on contemporary energy sources for other purposes is very important when it comes to employing contemporary energy sources for other purposes, which supports H1b. The findings support Adusah-Poku and Takeuchi's (2019) hypothesis that willingness to use contemporary energy sources is linked to willingness to use them.

In a similar vein, the study discovered that the affordability of contemporary energy sources for cooking had a favorable link with their use ($r = 0.102$, $p<0.05$). This means that the affordability of modern energy sources for cooking is linked to their use, implying that H2a is supported. Furthermore, a positive connection was discovered between the affordability of contemporary energy sources for other purposes and their use for other purposes ($r = 0.131$, $p<0.01$), showing that the affordability of modern energy sources for other purposes is related to their use for other purposes. As a result, H2b was accepted. The findings support those of Boutabba *et al.* (2020), who discovered that the affordability of contemporary energy sources is connected to their use.

Table 3 shows that use of modern energy sources for cooking has no statistically significant relationship with age ($r = -0.042$, $p>0.05$); married status ($r = 0.018$, $p>0.05$); degree of education ($r = -0.056$, $p>0.05$); and household size ($r = 0.040$, $p>0.05$), rejecting H3a, H3b, H3c, and H3d. In addition, all demographic characteristics, except household size, show no significant link with the use of contemporary energy sources for other purposes: age ($r = -0.058$, $p>0.05$); married status ($r = 0.051$, $p>0.05$); level of education ($r = -0.203$, $p>0.05$), rejecting H4a, H4b, and H4c. These findings suggest that demographic factors are unrelated to the use of modern energy sources for cooking and other functions such as lighting and operating household equipment such as refrigerators, televisions, and radios. Other research, such as Boutabba *et al.* (2020), Groh and Taylor (2015), and Koomson *et al.* (2020a), have revealed that demographic variables (age, education, and marital status) are positively connected to the use of contemporary energy sources. In terms of household size, there is a positive and substantial association ($r = 0.300$, $p<0.01$) between household size and the usage of contemporary energy sources for other purposes, which supports H4d. This finding supports Koomson *et al.* (2020a)'s hypothesis that household size is related to the utilization of contemporary energy sources for other purposes.

Table 3. Correlation matrix

Variables	WILL COOK	WILL OTHER	AFFORD COOK	AFFORD OTHER	USE COOK	USE OTHER	AGE	MST	LE	HS
WILLCOOK	1									
WILLOTHER	-.094*	1								
AFFORDCOOK	.031	-.067	1							
AFFORDOTHER	-.022	.096*	.028	1						
USECOOK	.090*	.046	.102*	-.023	1					
USEOTHER	-.011	.635**	-.065	.131**	.025	1				
AGE	.005	-.032	.003	-.055	-.042	-.058	1			
MST	.012	.003	-.003	.075	.018	.051	.309**	1		
LE	-.086	-.186	-.048	-.049	-.056	-.203	-.208	-.221	1	
HS	-.073	.191	-.007	.090	.040	.300**	.090*	.104	.022	1

Source: (Field Data, 2021)

**, * imply significance < 0.01 levels, and 0.05 levels (2-tailed) respectively. Willingness to spend on contemporary energy sources for cooking (WILLCOOK), affordability to contemporary energy sources for cooking (AFFORDCOOK), use of contemporary energy sources for cooking (USECOOK), willingness to spend on contemporary energy sources for other purposes (WILLOTHER), affordability of contemporary energy sources for other purposes (AFFORDOTHER), and the use of contemporary energy sources for other purposes (USEOTHER). Marital Status (MST); Level of Education (LE); Household size (HS)

Multiple Regression Results

Tables 4 and 5 provide the results of the multiple regression analyses, while Table 6 shows the results of the hypothesis testing. The effect of willingness to spend on contemporary energy sources for cooking on their use is positive and significant ($\beta=0.086$, $p<0.05$), indicating that H1a is correct (Table 4). On the other hand, the effect of willingness to spend on contemporary energy sources for other purposes on their use is positive and significant ($\beta=0.684$, $p<0.01$), indicating that H1b is correct (Table 5). The influence of the affordability of contemporary energy sources for cooking on their use is positive and significant ($\beta=0.097$, $p<0.05$), indicating that H2a is correct (Table 4). The influence of contemporary energy source affordability on the use of contemporary energy sources for other purposes, on the other hand, is positive and insignificant ($\beta=0.042$, $p>0.05$), rejecting H2b (Table 5).

In terms of demographic characteristics, Table 4 shows that age, marital status, level of education, and household size have no effect ($p>0.05$) on the use of contemporary energy sources for cooking ($\beta=$ -0.056, 0.019, -.053, 0.041, respectively). As a result, H3a, H3b, H3c, and H3d are ruled out. Similarly, all demographic characteristics, with the exception of household size, have no effect ($p>0.05$) on the usage of contemporary energy sources for other purposes: age ($\beta= -0.045$), married status ($\beta= 0.025$), and educational level ($\beta= -0.081$). As a result, H4a, H4b, and H4c are ruled out. Household size, on the other hand, had a positive and substantial effect on the use of contemporary energy sources for other purposes ($\beta= 0.160$, $p<0.01$), supporting H4d.

Table 4. Multiple regression results

Variables	Beta Coefficients (β)	t-Values	Sig.	Collinearity Statistics	
				Tolerance	VIF
Constant	1.087	5.064	.000		
Willingness for Cooking	.086	1.890	.052	.986	1.014
Affordability for Cooking	.097	2.152	.032	.997	1.003
Age	-.056	-1.155	.249	.870	1.149
Marital Status	.019	.319	.696	.861	1.161
Level of Education	-.053	-1.125	.261	.920	1.087
Household Size	.041	.899	.369	.967	1.035

$R = .158$, $R^2 = .025$, $Adj.R^2 = .013$, Durbin-Watson = 0.489, $F = 2.050$, Sig. 0.051
Dependent variable: Use of contemporary energy for cooking
Source: (Field Data, 2021)

Table 5. Multiple regression results

Variables	Beta Coefficients (β)	t-Values	Sig.	Collinearity Statistics	
				Tolerance	VIF
Constant	.246	.893	.372		
Willingness for Other Purposes	.684	22.130	.000	.917	1.091
Affordability for Other Purposes	.042	1.410	.159	.975	1.026
Age	-.045	-1.398	.163	.864	1.158
Marital Status	.025	.789	.431	.854	1.171
Level of Education	-.081	-2.577	.110	.888	1.126
Household Size	.160	5.227	.000	.930	1.075

$R = .760$, $R^2 = .577$, $Adj.R^2 = .572$, Durbin-Watson = 0.172, $F = 109.965$, Sig. 0.000
Dependent variable: Use of contemporary energy for other purposes
Source: (Field Data, 2021)

DISCUSSION OF RESULTS

The role of microfinance in reducing energy poverty among Tanzanian micro-borrowers is examined in this chapter. The findings confirm H1a by demonstrating that willingness to spend on contemporary energy sources for cooking has a positive and significant effect on the use of contemporary energy sources for cooking. This study implies that as people's desire to spend more on contemporary energy sources for cooking grows, so does their inclination to use them. The results in Table 2 support the lower regression coefficient for willingness to spend on contemporary energy sources for cooking on the use of contemporary energy sources for cooking, indicating that micro-borrowers are unwilling to spend on contemporary energy sources for cooking. This outcome could be explained by Tanzanian micro-borrowers' inability to buy contemporary energy sources for cooking (Table 2). According to Kasoga and Tegambwage (2021), Tanzanian micro-borrowers have greater degrees of over-indebtedness, resulting in reduced purchasing power.

Table 6. Results of hypotheses testing in summary

S/N	Hypothesis	Result
H1a	There is a strong positive association between willingness to spend on contemporary energy sources for cooking and the use of contemporary energy sources for cooking.	Accept
H1b	There is a strong positive association between willingness to spend on contemporary energy sources for other purposes and the use of contemporary energy sources for other purposes.	Accept
H2a	There is a considerable positive association between affordability of contemporary energy sources for cooking and the use of contemporary energy sources for cooking.	Accept
H2b	There is a considerable positive association between affordability of contemporary energy sources for other purposes and the use of contemporary energy sources for other purposes.	Reject
H3a	There is a substantial positive link between use of contemporary energy sources for cooking and age.	Reject
H3b	There is a substantial positive link between use of contemporary energy sources for cooking and marital status.	Reject
H3c	There is a substantial positive link between use of contemporary energy sources for cooking and level of education.	Reject
H3d	There is a substantial positive link between use of contemporary energy sources for cooking and household size.	Reject
H4a	There is a substantial positive link between use of contemporary energy sources for other purposes and age.	Reject
H4b	There is a substantial positive link between use of contemporary energy sources for other purposes and marital status.	Reject
H4c	There is a substantial positive link between use of contemporary energy sources for other purposes and level of education.	Reject
H4d	There is a substantial positive link between use of contemporary energy sources for other purposes and household size.	Accept

The influence of willingness to spend on contemporary energy sources for other purposes on the use of contemporary energy sources for other purposes, on the other hand, is positive and significant, indicating that H1b is correct. This conclusion implies that as people's willingness to spend money on modern energy sources for other purposes grows, so does their readiness to use modern energy sources for other purposes. The results in Table 2 support the higher regression coefficient for readiness to spend on contemporary energy sources for other purposes, implying that micro-borrowers are eager to spend on modern energy sources for other uses than cooking. This could be because, as shown in Table 2, modern energy sources for various applications are inexpensive for Tanzanian micro-borrowers.

The affordability of contemporary energy sources for cooking has a positive and considerable impact on the use of contemporary energy sources for cooking, which supports H2a. This conclusion suggests that as the cost of contemporary energy sources for cooking becomes more affordable, so does the use of contemporary energy sources for cooking. The results in Table 2, which show that micro-borrowers in Tanzania cannot afford contemporary energy sources for cooking, support the lower regression coefficient for affordability of contemporary energy sources for cooking and the use of contemporary energy sources for cooking. The fact that the majority of Tanzanian micro-borrowers live in poverty backs this argument (Kasoga & Tegambwage, 2021). This suggests that Tanzanian micro-borrowers have not been able to reduce their energy poverty, notably for cooking purposes. This finding agrees with Kumar (2020), who claims that even in industrialized countries with reliable access to contemporary energy, the affordability of modern energy sources for cooking remains a problem.

In order to address the affordability of contemporary energy sources among the poor and bring them out of energy poverty, it is critical to provide customized micro-credits to pay for contemporary energy services (Allet, 2016; Ekouevi & Tuntivate, 2012; Morris *et al.,* 2007; PAMIGA, 2020; Rao *et al.,* 2009). Ekouevi & Tuntivate (2012) discovered that programs that incorporate microfinance options to assist families in obtaining contemporary energy are more successful. Rao *et al.* (2009) recommended energy-microfinance initiatives that provide poor people with novel energy solutions such as clean lighting and upgraded cook stoves, as well as much-needed financing. In this regard, governments, with the help of the business sector, may push these micro-credit programmes. Two case studies, one from India and the other from Bangladesh, might be mentioned in this regard.

The Government of India implemented the [1]*Ujjwala* scheme in 2016 (GoI, 2021). The scheme proposed to offer Rs. 1600 per family to cover the security deposit and regulator for a 14.2-kilogram cylinder. A deposit-free liquefied petroleum gas (LPG) connection is offered to a woman from a below-poverty-line (BPL) family under the scheme. The beneficiary is responsible for the cost of the hot plate and the first refill. Beneficiaries have the option of borrowing a hot plate, a first refill, or both from public sector oil marketing companies (OMCs) at no interest. The loan is repaid using a subsidy that the beneficiary receives when he or she buys refills (s). As of July 30, 2021, there were 79, 995, 022 LPG cylinder hookups available under the plan (GoI, 2021). The *Ujjwala* plan is a good example of effective micro-credits that could inspire other countries to create tailored micro-credits to boost poor people's access to and affordability of contemporary energy sources.

Bangladesh's Solar Home System (SHS) program, which combines microfinance with rural electrification, has attracted international attention. The Government of Bangladesh (GoB) formed the Infrastructure Development Company Limited (IDCOL) in 1997 to help in SHS distribution by selling them to families and small businesses primarily through "cash sales" and "micro credit schemes" (GoB, 2008). In 1998, Bangladesh Bank granted IDCOL a non-bank financial institution (NBFI) license. IDCOL has been instrumental in bridging the finance gap for medium and large-scale infrastructure and renewable energy projects in Bangladesh since its start (GoB, 2008). In Bangladesh, the firm is the market leader in private sector energy and infrastructure financing (Khan *et al.,* 2009). By October 2013, the IDCOL program had sold over 2.3 million SHSs, making it one of the world's fastest growing renewable energy initiatives (Khan *et al.,* 2009). The lessons learnt from Bangladesh's microcredit programmes will aid other developing countries, notably African countries, in their efforts to make contemporary energy sources financially accessible to the poor.

The influence of contemporary energy source affordability on the use of contemporary energy sources for other purposes, on the other hand, is positive and minor, rejecting H2b. This study shows that affordability, rather than the desire of micro-borrowers, is a significant predictor of the use of contemporary energy sources for other purposes. This is because, as shown in Table 2, the use of contemporary energy sources for various uses other than cooking is inexpensive among Tanzanian micro-borrowers. This means that Tanzanian borrowers have been able to use microcredits to alleviate energy poverty for other uses such as lighting, radio, and television. This finding is consistent with the findings of Boutabba *et al.* (2020), who discovered that microfinance organizations helped Togolese borrowers lower their energy poverty.

In terms of demographic characteristics, studies show that age, marital status, education level, and household size have no effect on the use of contemporary energy sources for cooking, rejecting H3a, H3b, H3c, and H3d. This means that micro-borrowers' use of modern energy sources for cooking is unrelated to their age, marital status, degree of education, or family size. Similarly, with the exception of household size, all demographic variables had no effect on the utilization of contemporary energy sources for other purposes, rejecting H4a, H4b, and H4c. This means that age, marital status, and level of education have no impact on Tanzanian micro-borrowers' use of contemporary energy sources for other purposes. Other recent research, such as Acharya and Sadath (2019) and Crentsil *et al.* (2019), has revealed that demographic variables (age, education, and marital status) have a beneficial impact on the use of contemporary energy sources.

Household size, on the other hand, had a favorable and considerable impact on the use of contemporary energy sources for other purposes, indicating that H4d is correct. This suggests that the size of a household has a considerable impact on the use of contemporary energy sources for other purposes, suggesting that the larger the household, the more modern energy sources are used for other purposes. This could be owing to the fact that contemporary energy sources for other uses, such as lighting, radio, and television, are not prohibitively expensive for Tanzanian micro-borrowers. As a result, microcredits in Tanzania have enabled impoverished individuals to minimize their energy poverty, particularly for non-cooking uses. This finding is in line with that of Koomson and Danquah (2021), who discovered that increasing household size results in more use of contemporary energy sources for other purposes but not for cooking.

CONCLUSION AND RECOMMENDATIONS

Micro-borrowers are willing to spend on contemporary energy sources for cooking and other purposes, such as lighting and powering domestic appliances such as refrigerators, televisions, and radios, according to the findings of this study. Tanzanian micro-borrowers can afford contemporary energy sources for other purposes, but not for cooking. This suggests that microcredits have helped to alleviate energy poverty by allowing people to use contemporary energy sources for purposes other than cooking. Affordability and desire to spend on contemporary energy sources for cooking have a positive and major impact on their use, but willingness to utilize modern energy sources for other purposes has a positive and large impact on their use. The utilization of contemporary energy sources for cooking is unrelated to age, marital status, education, or household size in terms of demographic characteristics. In addition, age, marital status, and educational level have little bearing on the use of contemporary energy sources for other purposes. The size of a household, on the other hand, has a positive and considerable impact on the use of contemporary energy sources for other uses, but not for cooking.

This chapter adds to the body of knowledge by examining the influence of microfinance organizations on the decrease in energy poverty, with a focus on Tanzania. This was important because, while energy poverty is a context-specific problem, there is no general consensus on the influence of microfinance on the decrease of energy poverty around the world (Kumar, 2020). Furthermore, the research adds to the body of knowledge by exposing the positive and significant effects of micro-borrowers' affordability and willingness to utilize contemporary energy sources for cooking and other purposes on the use of contemporary energy sources for cooking and other purposes.

In terms of the chapter's practical implications, microfinance institutions in Tanzania should develop tailored micro-credits to make contemporary energy sources financially feasible to the poor. In other countries, such as Mali (Levaï *et al.,* 2011) and China, microfinance institutions have launched customized micro-credits to pay for contemporary energy sources with the goal of pulling the poor out of energy poverty.

Furthermore, policymakers are urged to develop strategies and policies aimed at reducing energy poverty by making contemporary energy sources more accessible and inexpensive for the poor. This will not only enhance the poor's use of modern energy sources, but it will also improve their health and preserve the environment. Other developing nations, notably in Africa, are likely to benefit from the lessons learned from India's *Ujjwala* system and Bangladesh's SHS program.

There are some limitations to this study. First, it made use of cross-sectional data. Longitudinal data could be employed in future studies to obtain additional insight into this problem. Second, it took place in Tanzania. This has an impact on the findings' generalizability to other contexts. As a result, comparable investigations should be carried out in various contexts.

DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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ENDNOTE

[1] *Ujjwala* scheme is a tailored micro-credit established by the Government of India in 2016 to boost poor people's access to and affordability of contemporary energy sources.

Chapter 3
Financial Assessment Model for Energy Streams:
Evidence From the Middle East

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ABSTRACT

The energy assessment in any industrial/engineering project is an important aspect of project identification in the environmental impact assessment (EIA) plan. It figures out the efficiency of projects through data envelopment analysis (DEA) in comparison with revenue, prior to the establishment of full-scale industries. This study assessed eight groups of Iranian small and medium-sized industries (ISMSI) for the energy stream/revenue. The DEA model is supported by weighing systems of Friedman test, criteria importance through intercriteria correlation (CRITIC), analytical hierarchy process (AHP), and entropy Shannon to assess the efficiency of industries. Four weighing systems of the multi-criteria decision-making (MCDM) model revealed no significant differences among findings of industrial groups, keeping in view the sensitivity analysis conducted and good reliability of Cronbach's Alpha ($\alpha = 0.858$). Therefore, the application of the DEA model is highly recommended for managing energy streams in the EIA plan.

INTRODUCTION

The ISMSI holds a prominent role in the economic cycle of any nation. In Iran, the dependence of the economic cycle of the country to ISMSI is 98% in comparison with large industries that its proportion is around 2% in this regard (Singh *et al.*, 2016). The project identification step is the first step of any industrial project before it goes to the next levels of assessment like screening. According to enacted rules of EIA, the whole inventory of availability of industrial projects must be listed as materials &

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energy streams, land area required for industrial projects individually, plus an inventory of facilities and equipment implemented (Lohani *et al.*, 1997). In this case, the Iranian evaluator team of the in-charge organizations took the assessment and tabulated the initial data for Iranian industrial projects. This research only used the collected data of the evaluator team for the first year of running industries before complete constructing them and data were processed to find the efficiency score.

There is no difference between guidelines for handling industrial projects in lots of nations in the EIA plan. The concept and procedure are the same depending on an inventory of the availability of projects. The importance of projects in itself and the environment depends on the properties of projects. The environmental impact pertains to pollutants dissipated from project ambient and mitigation of defined environmental impacts to impede culminating emissions. By the screening step of the project identification is sorted out the energy and materials streams and is listed whole facilities and equipment accommodated in the project ambient. On the other hand, experts can manage the time to make a list of whole properties of the project which underpin the content of financial, environmental, and economical assessments and pave the way towards modeling based on an inventory of properties and decision-making theory. Lots of criteria can be sorted out to assess financial, and environmental aspects. The variables or criteria proceed the projects towards decision-making science and configure the matrix of decision based on a variety of models developed. If the projects move ahead by a completed review in an uncertain situation decision theory brings MCDM models to solve the challenges raised. The prominent organizations that participated in the EIA plan of projects are industries organization, environment protection agency, World Bank, European Development Bank, Asian Development Bank, etc. (Lohani *et al.*, 1997).

DEA is an important decision-making instrument with a strong base in economic sciences consisting of a variety of introduced variables to assess the performance of projects. Concerning this fact that a wide range of DEA models was recently introduced and developed but all of them follow the same purpose to find the efficiency score of alternatives and discover the way to offer some improvement points for escalating the performance of assessed alternatives (Zurano-Cervello *et al.*, 2018).

DEA as a powerful management instrument for performance evaluation has gained considerable attention over the past decade. A decision tree is a data mining technique for classifying samples into nonlinear and nonparametric regression. Nowadays, the DEA model is recognized as a suitable method for evaluating the performance of units in which, based on the available information, the efficiency boundary is estimated empirically. As mentioned, DEA is an instrument to measure the relative efficiency of homogeneous decision-making units that have multiple inputs and outputs. In the conventional model of DEA analysis, decision-making units are viewed as a black box and therefore their internal structure is generally ignored and it is assumed that the performance of the decision-making unit is a function of selected inputs and outputs. But in many cases, decision-making units have hierarchical multilevel structures or an internal network of activities and decisions that the performance of each of these levels can affect the performance of the entire organization. DEA technique is not able to consider the necessary details, including the impact of decisions of different departments, existing levels, and mediating activities between these levels, each of which may affect the overall outcome of the performance appraisal, in calculating efficiency. Multilevel mathematical planning models are known as mathematical planning instruments that can solve decentralized planning problems with multiple implementers in a multilevel or hierarchical organization. Therefore, to eliminate the above shortcomings, by combining the concepts of DEA analysis and multilevel mathematical programming, an integrated model (called multilevel DEA analysis) can be presented. Mathematical techniques are methods that reduce mental effects and resort to objective methods and have the ability to combine different theoretical tendencies in measurement. DEA analysis is one of the mathematical techniques for performance evaluation that has been used in this article (Emrouznejad *et al.*, 2011).

By the present research, it is tried to compose the framework of inputs and outputs variables based on the initial assessment of in-charge organizations in the EIA plan. The inputs and outputs variables assumed for the DEA model arranged to be quantities of water, power, fuel consumed, and revenue of industries in currency reports individually. The eight groups of ISMSI have been taken into consideration by the present research. It was ignored to separate data of small industries from medium-sized industries because the medium-sized industries were in minority. The definition of the scale of industries refers to the number of employees in industries. This is a certain classification for industries groups that has been assumed up to 10 and 50 staff for micro and small industries respectively (Ghanatabadi, 2005).

The use of MCDM models has been encouraged in a variety of science these days. The DEA as an effective decision-making model has been applied in lots of studies to find the efficiency scores (ESs) of organizations regarding a certain time interval. But by the current study, it was employed for the industrial projects before complete construction. It means the DEA model assigned to figure out the efficiency of industrial projects for a time interval of one year or the first year of operation. The weighing systems of Friedman test, CRITIC, AHP, and entropy Shannon were used to release the weights for inputs and outputs variables. Generally, the base of both the weighing systems of Friedman test and CRITIC models gets back to statistical equations while mathematical equations interfere in releasing the weights via both models of AHP and entropy Shannon. So, the four weighing systems were joined to the conventional DEA model to rank the industries in an analysis of costs for energy stream/revenue.

The motivation in conducting this research derived from some initial objectives such as

1. Classification of industries based on ESs relied on costs of energy stream/revenue
2. Figuring out the values of the weights for criteria based on 4 weighing systems
3. Comparing the results of ESs in different weighing systems
4. Conducting statistical analysis (correlation test, t-test, null hypothesis) for the reported values in currency
5. Comparing the results of ESs in different weighing systems based on statistical analysis
6. Conducting a sensitivity analysis among results of ESs in 4 weighing systems.

MAIN FOCUS OF THE CHAPTER

The application of decision-making theory strongly emphasized to take into attention by scientists who are working in the EIA plan. The EIA reports enacted to give a relevant decision for the alternatives raised from projects. The important points refer to the allocation of decision-making theory consisting of a variety of models to prioritize, classify, select, and highlight the alternatives in the decision-making science. The main steps of EIA comprised project identification, screening, public involvement, scoping, impact analysis, mitigation and impact analysis, EIA report, review, decision-making process, and implementation of the project. It needs to point out that this is the first research for ISMSI based on Nominal Capacity (NC) of industrial projects that investigated the efficiency and performance of units across Iran.

Issues, Controversies, Problems

The energy and gas consumption in Pacific Northwest food processing industries have been scrutinized and classified as follows, animal slaughtering > grain and oilseed milling > dairy > fruit and vegetable preserving > sugar for electrical consumption. The natural gas consumption in food industries reported as animal slaughtering > grain and oilseed milling > fruit and vegetable preserving > dairy > sugar (Compton *et al.*, 2018).

A study conducted via the DEA-CCR model to determine the performance of around 744 Turkish industries picked up from 10 various groups. Inputs and outputs variables defined based on 14 items (12 inputs and 2 outputs variables) that accomplished by finding 94 full efficient plants and inefficient plants also distinguished to get some advice for improving performance (Bulak and Turkyilmaz, 2014). The research of Rezaee and Ghanbarpour (2016) made the framework of the traditional DEA model towards a linear multi-group extension to find the efficient units among 59 Iranian industries in different classes based on cost/revenue reports. The inputs and outputs variables of the DEA model encompassed the fuel, water, the power consumed plus the number of employees and revenue respectively. Hassanpour (2020) used the DEA-Additive Ratio Assessment (ARAS) model to classify 405 Iranian industries (in 9 groups) based on materials and energy streams with input and output variables in a variety of scales and dimensions (not in currency). The classification produced different values of the weights for the variables using the Friedman test as a weighing system. The iterative two-stage optimization model – a statistic-based applied model to figure out the strongest indicators of over 800 existing firms in the stock market of the US. The statistical analysis practices also assigned to further analysis of the model. The findings of the study promoted the dominance of the DEA model as a decision-making instrument (EdiriSinghe and Zhang, 2010). The dynamic slacks-based (DSB) DEA model exploited to sort out ESs between 0-1 for Chinese life insurance companies from 2006 to 2010. The findings manifested an efficiency score of around 0.905-0.973. Also, results were emerged different from the findings of the conventional DEA model (Lu *et al.*, 2014). Rahmani (2017) used the DEA-AHP model in the productivity assessment of 21 Iranian industries in a time interval of 1980 to 2000. The research reported the presence of 38% efficient units (8 industries) with an efficiency borders range of 0.0091-1 for the minimum and maximum values of weights in the model. The inputs and outputs criteria of research were manpower, remuneration, capital, inputs values, and outputs values, and added value respectively. A study assessed the eco-efficiency of Chinese industries in 30 regions via additive DEA model under variable return to scale from 2005 to 2013. The minimum and maximum ESs reported around 0.3298 to 1 respectively. The full efficiency reported for 48 cases among 240 alternatives. The financial assessment of 14 shipping industries carried out using the DEA-CCR model based on inputs and outputs variables of assets, stockholder's equity, and operating revenue, and net income respectively. The efficiency score reported to be around 0.07-1 for cases examined. The regression line has depicted based on input versus output variables and compared with efficiency borders of 14 shipping industries (Lin *et al.*, 2005). The thirty-two Chinese banks have passed through the efficiency assessment step via using DEA- Multiplier weights based on 3 inputs and two desirable outputs and one undesirable output variable from 2014 to 2018. The results appeared with a wide range of values between 0-1 (Li *et al.* 2020a). The integrated cooperative game DEA has applied to assess the performance of 31 manufacturing industries for carbon emission and mitigation plans. The assessment resulted in distinguishing 5 industries and 2 provinces for exceeding the allowable rules for the emissions and further mitigation plans recommended for them. The efficiency score ranged between 0-1 (Li *et al.*, 2020b). The importance of lean and sustainable direction novelty investigated in 35 small and medium-sized industries. The inputs and outputs variables of research comprised the lean practice, innovation, and economic performance, operational performance, environmental performance, and social performance respectively. The minimum and maximum DEA scores fell into a range of 0.772-1 (De *et al.*, 2020).

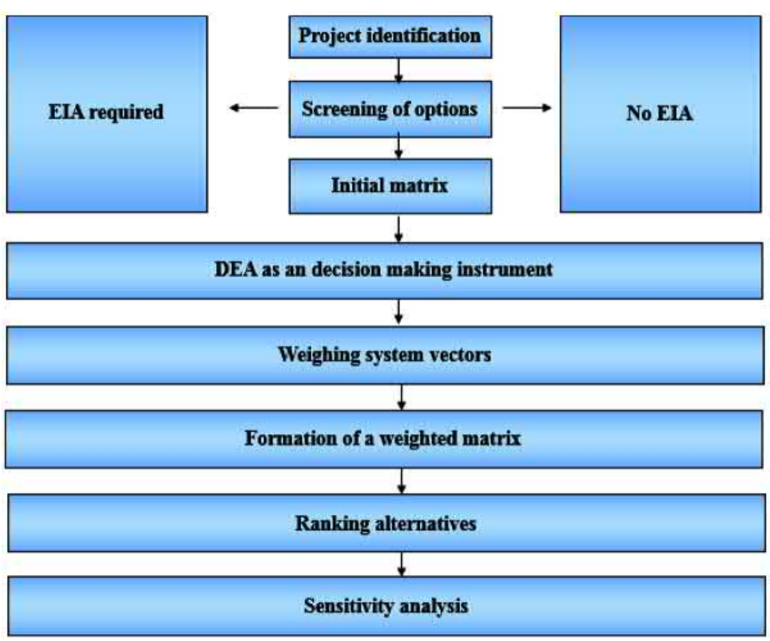
The DEA-CCR model has applied to estimate the ESs of 71 offshore wind farms across 5 European countries with regard to 4 inputs and 3 outputs variables. The ESs ranged between 0.52-1 for the alternatives (Akbari *et al.*, 2020). To evaluate the slack-based technical efficiency of 32 banks used DEA model consists of 3 inputs and 2 outputs variables from 2000 to 2017 in Ghana. The medium efficiency score obtained around 79% and some precautions emphasized to take into consideration for the inefficient cases (Duho 2020). To find the financial performance of 15 life insurance companies the DSB-DEA model requested. A time interval from 2005 to 2012 considered. By the way, the study revealed the prominent variations in ESs and paved the way towards offering some improvement points (Sinha, 2015). To assess the efficiency of 17 suppliers used the conventional DEA united with fuzzy-nearest weighted interval approximation. The ranking of suppliers accomplished regarding inputs and outputs variables (2*6) of economic, environmental, and social aspects (Izadikhah *et al.*, 2017). To assess and improve the performance of forty cloth retail shops utilized DEA-input oriented model from 2010 to 2013 in Portuguese. The findings declared a fall in technical efficiency during the time interval mentioned except 2013. Six variables used in distinguishing the values of DEA rank (Xavier *et al.*, 2015). The DEA enhanced Russell in fuzzy ambient requested to assess the sustainability of 26 suppliers with various variables as inputs and outputs. The ranking of alternatives completed with a sensitivity analysis based on rank reversal (Azadi *et al.*, 2015). To rank 12 garment suppliers assigned the DEA-principal component analysis-VIKOR models containing 6 inputs and 4 outputs variables. The weights of criteria determined by experts. It found 5 efficient suppliers among the 12 alternatives investigated (Karami *et al.*, 2021). The railways of 9 European countries have passed through the DEA-Fuzzy-AHP models to assess the ESs based on financial statements. Both models of CCR, and BCC of DEA model examined via considering 5 inputs and outputs variables. The maximum and minimum values of ESs estimated to be around 0.266 to 1. The use of information for right action planning and programming has recommended raising the ESs in future plans (Blagojevic *et al.*, 2020a). The financial variables (as inputs and outputs) have considered to figure out the performance of 5 car industries via DEA-CCR and DEA-BCC models in the Czech Republic and Germany respectively. The full ESs reported in most cases for the alternatives (Papouskova *et al.*, 2020). To find the performance of 42 main public roads of India consist of 23 criteria the DEA-AHP-VIKOR model used as the ranking and weighing systems. The variables encompassed accident, traffic revenue, expenses, vehicle operation, manpower, maintenance, utility score, and regret score respectively. The ranking system of VIKOR classified alternatives in a certain class. Then the alternatives classified in intervals of efficiency based on the DEA model (Kumar *et al.*, 2020). The DEA-Gray relational analysis model developed for assessing the performance of poultry houses in egg generation during 15 months of the year. The hens stayed in the best maintenance and service conditions to lay enough eggs. The combination of the DEA model with the gray system also examined other types of MCDM models as a sensitivity analysis. The similarity has proved the obtained results with partial compliance. The 5 variables assumed as the main criteria in this assessment (Küçükönder *et al.*, 2019). The Tobit analysis and DEA models integrated to assess 32 airports in Italy. It has reported the existence of some efficient units but small airports containing low-outlays could not be allocated in this list. The size of alternatives has an independent effect on their efficiencies. The variables of the study included percentages of movement, numbers of passengers, cargo, and transit. The sensitivity analysis put together the outputs of other DEA models to compare each other (Sergi *et al.*, 2020). Research conducted to determine the performance of 12 transport and cargo controls during 2008 to 2012 in Brazil. The inputs and outputs variables listed as a percentage of fuel, costs, acquis-transp, and revenue respectively. The level of total efficiency reached 91.5% and full efficiency reported for all years of study except 2010. To improve the ESs of alternatives has given some recommendations and advice (Lepchak and Voese, 2020). To estimate the ecological efficiency of 116 capital cities the DEA models supported by entropy Shannon integrated together regarding non-discretionary uncontrollable inputs, desirable and undesirable outputs in 2011 in Italy. The minimum and maximum ESs tabulated from 0-1 (Storto, 2016). China's transport sector in thirty locations has evaluated for sustainability via a three-stage DEA model by 2017. The maximum and minimum ESs estimated to be around 0.52-1 respectively. By the way, 3 inputs and 3 outputs variables have considered plus 5 environmental variables (Song *et al.*, 2020). The road transport operation has assessed in thirty locations regarding 11 variables for the inputs and outputs criteria from 2010 to 2017 in China. The methodology of research comprised basic DEA-directional distance function. The authors calculated the DEA score for each year individually. Then, they took the mean of years for releasing the total rank from 2010 to 2017. The minimum and maximum values of ESs reported being around 0.6028 to 1 respectively (Xu *et al.*, 2020). The circumstances of 9 railways traffic safety investigated by Blagojevic *et al.* (2020b) via Entropy-Fuzzy PIPRECIA-DEA model in Bosnia and Herzegovina. The variables of research included 6 inputs and 5 outputs totally. The results examined via sensitivity analysis to verify the accuracy and precision of findings. The low-performance alternatives removed from the following estimations. The minimum and maximum values of ESs estimated around 0.387 to 1.125 respectively. Badiezadeh *et al.* (2018) used the network-DEA model to discover the ESs of 9 alternatives in supply chain management for any kind of inputs and outputs variables. The efficiency of alternatives manifested to be around a range of 0.6-0.76 for minimum and maximum scores. The main achievement of this model gets back to the possibility of allocating desirable, undesirable, optimistic, pessimistic, and even intermediate variables for assessing ESs. The efficiency of 82 banks of the Mena region in 28 nations underwent an assessment by dynamic network DEA model regarding the financial statements from 2006 to 2014. The variables of the study were net loans, total earning assets, non-earning assets, loan loss, and costs respectively (Wanke *et al.*, 2019). The slack-based DEA model assigned to rank 13 life insurance companies with the presence of 3 inputs and 2 outputs variables in both China and Taiwan from 2005 to 2011. After comparing findings, it was found that the efficiency of alternatives in Taiwan was higher than the efficiency of alternatives in China before 2008. The total ranking of alternatives has shown very close results to the full efficiency border (Shieh *et al.*, 2020). The shipping services in 5 Malaysian ports in transport operation investigated for performance analysis using DEA-Window software for 5 years. This research consists of 4 inputs and 2 outputs variables. The highest efficiency reported for alternatives (Alwadood *et al.*, 2019).

A study reviewed the performance of insurance companies via dynamic network DEA and similar models of DEA in a matrix of 4*4 for inputs and outputs variables from 1993 to 2018. The application, methodologies, new changes, and developments have reviewed on efficiency promotions and have discussed improvement circumstances (Kaffash *et al.*, 2020). To evaluate the efficiency level of twenty-five Indian container ports exploited the DEA-Malmquist index model for a period of 2015 to 2018. The importance of terminal size highlighted in the efficiency score (Iyer and Nanyam, 2021). The 42 cement industries investigated by the non-radial DEA model from 2015-2017. By the way, 8 variables assumed as inputs, and outputs introduced into the model. The efficiency score had appeared in a range of 0.767-1 for all assayed years (Motevalli Darvish, 2020). The DEA models employed to assess the container ports, risk control in healthcare cardiovascular patients, the sustainability of supply chains, and sustainability of semiconductor industries by Mustafa *et al.*, (2021), Rafiei and Asadzadeh, (2020), Kahi *et al.*, (2017), and Lin *et al.*, (2018) respectively.

METHODOLOGY

Project identification is a compulsory step in project management and in the EIA plan. According to enacted rules of the Islamic republic Iran all industrial projects must go through the initial assessment of EIA to prepare an inventory of availability in the screening step. By this study, this step has carried out by the Iranian evaluator team and the initial data has exploited to further process. So, this study arranged a time to make the framework of the initial matrix for the decision-making process via DEA. Also, it was employed four weighing systems of Friedman test, CRITIC, AHP, and Entropy Shannon to estimate the values of the weights of criteria. The selected criteria in the current research encompass the main variables of energy stream outlays, the salary of employees, and annual revenue. To estimate the costs of the energy stream, the salary of employees and annual revenue (NC of industries or annual products generated) was exploited the daily prices in the market of Tehran, Iran. After that, all outlays were tabulated and the initial matrix of data was configured. To calculate the DEA scores the vectors of the values of weights were introduced into the initial matrix of costs based on variables. Then a division of values of weighted outputs to values of weighted inputs in the conventional DEA model has released the productivity of industries. Finally, the ESs were executed based on the maximum value of the productivity index. The sensitivity analysis was accomplished via a comparison based on values in 4 weighing systems integrated with the DEA model along with reliability test and statistical analysis. The steps underwent to finalize the assessment were presented in Figure 1.

Figure 1. The evaluation steps of EIA and followed work for current research



1. Weighing System of Friedman Test

In the review of studies, many equations have been introduced and developed in the estimation of the values of weights by the Friedman test. But the present study preferred to rely on the devised and designed formula in the framework of SPSS software for this test. The input of software is the initial matrix of variables and the output of the software is the weights of variables.

2. Entropy Shannon

In this method, each element of the matrix is divided by the sum of the elements of each column according to equation (1). The entropy of each criterion is calculated by equation (2). The applied factor of *K* causes the entropy value of the indices to remain between 0-1. The symbol of *m* indicates the number of alternatives. Using Equation 4, the distance of each index from the entropy value is determined. Finally, the weight of each criterion is calculated using equation 5 (Cavallaro *et al.*, 2016).

$$Pij = \frac{Xij}{\sum_{i=1}^{m} Xij}; j = 1,\ldots,n \tag{1}$$

$$Ej = -k\sum_{i=1}^{m} Pij \times LnPij; i = 1,2,\ldots,m \tag{2}$$

$$k = \frac{1}{Lnm} \tag{3}$$

$$dj = 1 - Ej \tag{4}$$

$$W j = \frac{dj}{\sum dj} \tag{5}$$

3. Weighing System of CRITIC

The decision matrix is used for weighting criteria in the CRITIC method. The decision matrix is made up of criteria for scoring them. The decision matrix is denoted by *X* and each element is distinguished by X_{ij}. The next step is to form a correlation matrix. Each element of this matrix is represented by a r_{ij}. The standard deviation (∂j) of the values of the correlation matrix is then calculated. The final weights are calculated using equation (8) (Mitrović Simić *et al.*, 2020).

$$rij = \frac{X_{ij} - \min\left(X_{ij}\right)}{\max\left(X_{ij}\right) - \min\left(X_{ij}\right)} \tag{6}$$

$$Cj = \sigma_j \sum_{j=1}^{m} \left(1 - r_{ij}\right) \tag{7}$$

$$Wj = \frac{C_j}{\sum_{j=1}^{m} C_j} \tag{8}$$

4. Weighing System of AHP

AHP is a simple computational method based on the main operation on the matrix, which calculates its specific values by creating a suitable hierarchy and processing step by step and constructing adaptive matrices at different levels of the hierarchy. Then, in the final weight coefficients vector, the relative importance of each option is determined. This method has many applications due to its simplicity, flexibility, application of quantitative and qualitative criteria simultaneously, as well as compatibility. The AHP method is based on multiplying the elements of the matrix by each other and dividing it by the inverse of the number of alternatives. Finally, the weight of the criterion is calculated from the arithmetic mean according to equation (10) (Stankovic *et al.*, 2019).

$$Xij = \left(\prod_{I=1}^{k} \alpha ijI\right)^{1/K}, I = 1, 2, \ldots, K\,i, j = 1, 2, \ldots, n, i \neq j \tag{9}$$

$$Pij = \frac{Xij}{\sum_{i=1}^{m} Xij}; j = 1, \ldots., n \tag{10}$$

5. Conventional DEA

To find the ESs of industries (alternatives) was sorted out the matrix of data for the inputs and outputs variables initially. Then the vectors of weights values were assigned to collect the weighted values of outputs and weighted values of inputs variables. The productivity was tabulated from the division of weighted values of outputs to weighted values of inputs. The DEA score was released based on maximum value among values of productivity. The outputs and inputs variables were allocated as revenue of products of industries and the salary of employees, the outlays of power, water, and fuel consumed respectively.

$$Ekk = \frac{\sum_{r=1}^{s} UrkYrk}{\sum_{i=1}^{m} VikXik} \tag{11}$$

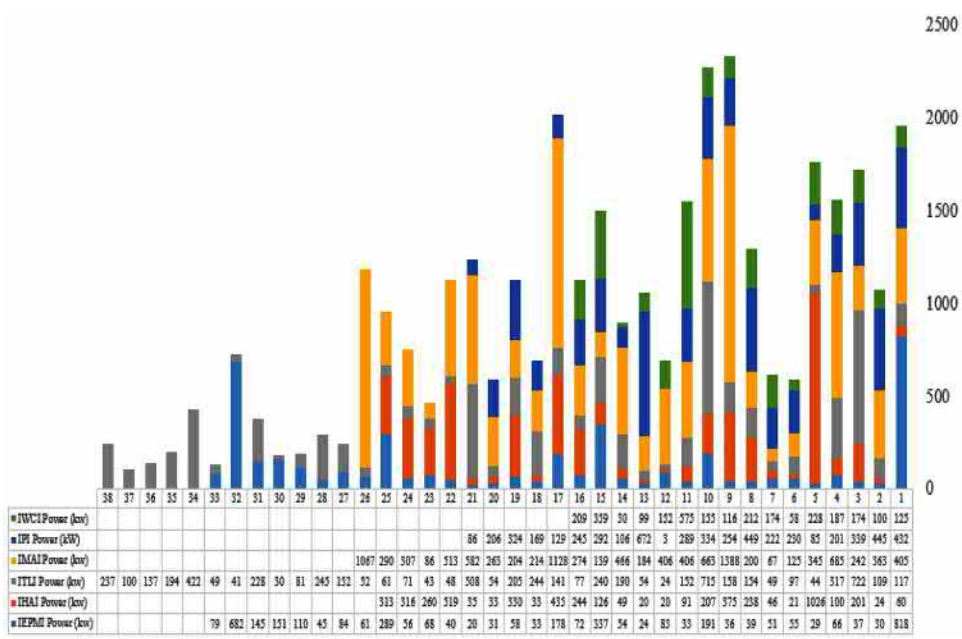
The presence of n DMUs (alternatives) and individual DMU j (j=1,….n) consist of outputs and m various inputs which are recognized by Yrd (r = 1,….,s) and Xij (I = 1,….,m) were evaluated the efficiency (E) of industrial projects (DMU K). The symbols of Vk = ($V1k$,…, Vmk) and Uk = ($U1k$,…, *Usk*) introduce the input and output weighing vectors to assess DMU *k*, as *Urk* and *Vik* were multipliers of the inputs and outputs respectively (Vujičić *et al.*, 2017).

RESULTS AND DISCUSSION

Iranian Industries

By the present study, the Iranian industries encompassed 8 groups according to appendices such as Iranian Wood and Cellulose Industries (IWCI), Iranian Textile and Leather Industries (ITLI), Iranian Mining and Aggregate Industries (IMAI), Iranian Food Manufacturing and Processing Industries (IFMPI), Iranian Plastic Industries (IPI), Iranian Electronic Products Manufacturing Industries (IEPMI), Iranian Chemical Industries (ICI), and Iranian Household Appliance Industries (IHAI). The existing information below, figures & Tables indicate the data of power, water, and fuel consumed and the number of employees as main industry-specific factors (energy stream) that estimated by the team of evaluators of Iranian organizations. The values have estimated for 8 industrial groups in the EIA plan initially.

Figure 2. The power demand of industrial units



The Values of Weighing Systems of MCDM Models

The values of weights for criteria were estimated in four weighing systems of MCDM and were tabulated according to Table 2.

Figure 3. The water demand of industrial units

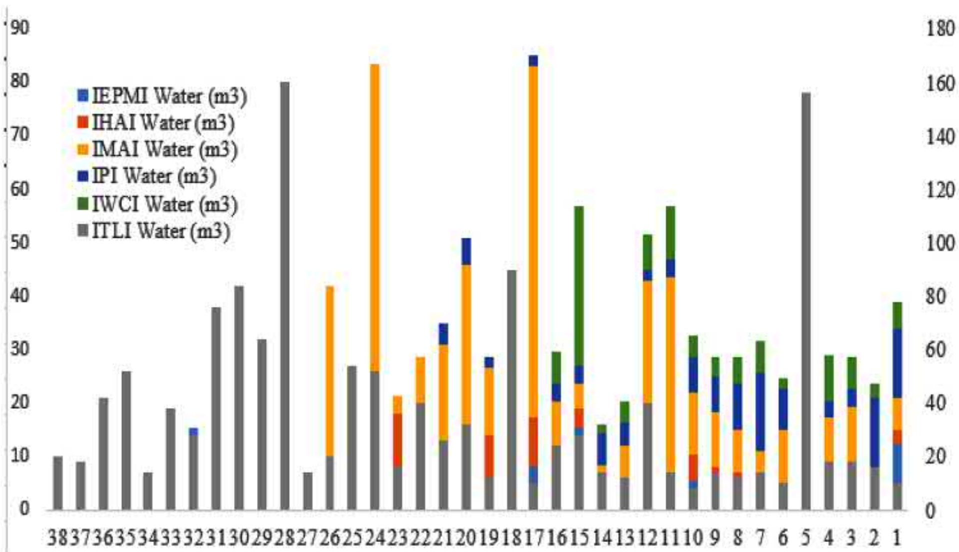


Figure 4. The fuel demand of industrial units

	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20
IEPMI Fuel (Gj)						17	10	5	20	5	2	3	12	10	4	3	2	3	3
IHAI Fuel (Gj)														8	5	168	179	4	4
ITLI Fuel (Gj)	5	10	960	4	131	4	5	10	4	6	4	55	5	3	52	21	3	211	3
IPI Fuel (GJ)																		3	101
IWCI Fuel (Gj)																			
IMAI Fuel (Gj)													67	6	2	10	7	163	168

	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
IEPMI Fuel (Gj)	3	3	5	4	7	4	4	2	3	8	3	2	3	2	4	4	5	3	5
IHAI Fuel (Gj)	7	4	7	15	10	3	3	3	4	13	16	9	4	3	116	5	5	4	2
ITLI Fuel (Gj)	12	10	22	4	140	8	5	11	68	23	45	5	6	12	4	7	109	7	9
IPI Fuel (GJ)	5	5	3	4	3	12	6	82	5	6	4	61	31	5	4	4	9	8	8
IWCI Fuel (Gj)				31	74	3	3	5	25	7	7	23	29	3	10	35	29	3	3
IMAI Fuel (Gj)	37	4	394	94	2	1	91	9	9	104	351	8	20	98	14	26	11	924	12

The t-test has revealed significant differences among the values of weights of 8 industries groups (p-value ≤ 0.012, 0.013, 0.03, 0.012, 0.061, 0.01, 0.012, 0.011, 0.012, 0.002, 0.01, 0.058, and 0.012) for the values of the weights of ITLI (F), IHAI (F and E), ICI (F and E), IMAI (F), IWCI (F and E), IFMPI (F and E), IPI (F and E), and IEMPI (F) respectively. The F and E indicate the values of the weights of the Friedman test and Entropy Shannon respectively. The same results were also reported using paired samples test. The depiction of the diagram of the sequence number for the same values in weighing systems has not followed a regular linear development trend among the values of 8 groups of industries. In the second analysis was conducted a t-test analysis among 4 columns of weighing systems and it resulted in coming into view significant differences (p-value ≤ 0.006) among the values of obtained weights via Friedman test, CRITIC, AHP, and Entropy Shannon weighing systems. Further analysis has performed by paired samples test but no significant difference was reported for the same data in 4 columns.

The Values of DEA Ranking for 8 Groups of Industries

The values of weights for alternatives were estimated in four weighing systems of MCDM models integrated with the DEA model and were tabulated according to Tables 3-10.

The output of SPSS software had shown a significant difference (p-value ≤0.001) for all variables of Table 3. It means there is no significant difference among results of DEA supported by 4 weighing systems.

The output of SPSS software had proved a significant difference (p-value ≤0.001) for all variables of Table 4. It means there is no significant difference among results of DEA supported by 4 weighing systems.

The t-test analysis had appeared with significant differences (p-value ≤0.002) and (p-value ≤0.001) between obtained results by both weighing systems of Friedman test - CRITIC and separately with Entropy Shannon respectively (Table 5). It needs to explain that the huge currency calculated for costs of products does not let us estimate the weights of criteria via AHP procedure for both groups of industries of ICI and IFMPI.

Conducting a t-test among findings of the DEA model supported with 4 weighing systems had presented no significant differences among them (Table 6).

The findings of the DEA model integrated with 4 weighing systems in Table 7 had represented the same significant difference among the 3 weighing systems of Friedman, CRITIC, and AHP (p-value ≤ 0.001) and (p-value ≤0.002) with the weighing system of Entropy Shannon respectively (Table 7).

The t-test had displayed no significant difference for the findings estimated via the DEA model integrated with 3 weighing systems of MCDM (Table 8).

It was found significant differences (p-value ≤0.005, 0.004, 0.004, and 0.006) among the findings of the DEA model united with four weighing systems of Friedman test, CRITIC, Entropy Shannon, and AHP respectively (Table 9).

The output of the t-test had revealed no significant difference among tabulated values of IEMPI in the DEA model joined to 4 weighing systems of MCDM (Table 10).

It needs to explain that the Iranian industrial projects had revealed a minimum ESs by the current research. One reason for this low level of ESs refers to raising prices in the market of Tehran because of sanctions enacted against the Iranian government. The awareness of the performance of industrial projects encourages the stakeholders to find the right way for investing their budget. Obviously, the efficient industries attract more interest of stakeholders, especially in the EIA plan. The first year of efficiency assessment procures enough knowledge for understanding the weakness points to offer some improvement pathways. Figure 7 displays the sequence number of the values of weights vs industrial units.

Table 1. IFMPI and energy demand

Industries	IFMPI; Power (kw)	IFMPI; Water (m³)	IFMPI; Fuel (Gj)
1	161	95	83
2	118	11	23
3	136	37	31
4	193	145	102
5	82	24	38
6	307	35	68
7	133	81	46
8	71	7	5
9	138	15	48
10	95	5	5
11	1749	5	19
12	199	26	67
13	67	7	3
14	320	23	217
15	306	130	26
16	174	23	37
17	216	39	37
18	196	15	10
19	229	27	82
20	175	11	19
21	217	27	4
22	92	4	12
23	132	50	241
24	91	7	9
25	132	50	241
26	77	8	4
27	91	5	2
28	64	4	6
29	122	51	41
30	87	15	20
31	301	31	123
32	87	15	20
33	292	16	99
34	133	21	47
35	164	33	63
36	75	33	21
37	120	8	20
38	173	19	37
39	258	29	4
40	60	5	19
41	509	30	10
42	807	87	145
43	524	40	103
44	67	15	4
45	224	9	11
46	49	10	7
47	269	55	62
48	128	10	60360
49	213	15	89
50	138	27	69
51	828	13	17
52	344	11	50
53	213	17	35
54	107	15	8
55	193	4	3
56	177	22	36
57	252	54	3

Source: Authors' Calculations

The application of the diagram of the sequence number is about presenting linear progress of the values of weights in various scenarios. But the linear development trend does not achieve by this study. It means that the compliance among values of weights is very low despite the existence of regular expansion of curves among them. The good reliability of findings in the DEA model united with weighing systems ($\alpha = 0.858$) has proved the existing precision and accuracy among findings of 8 industrial groups in 30 columns displayed by Tables 3-10 or sequence chart. With regard to the knowledge that the Cronbach's

Alpha rule of thumb is expressed as α ≥ 0.9 (excellent), 0.8 ≤ α <0.9 (good), 0.7 ≤ α < 0.8 (acceptable), 0.6 ≤ α < 0.7 (questionable), 0.5 ≤ α < 0.6 (poor), and α < 0.5 (unacceptable) (Hassanpour, 2018).

Figure 5. ICI and its energy demand

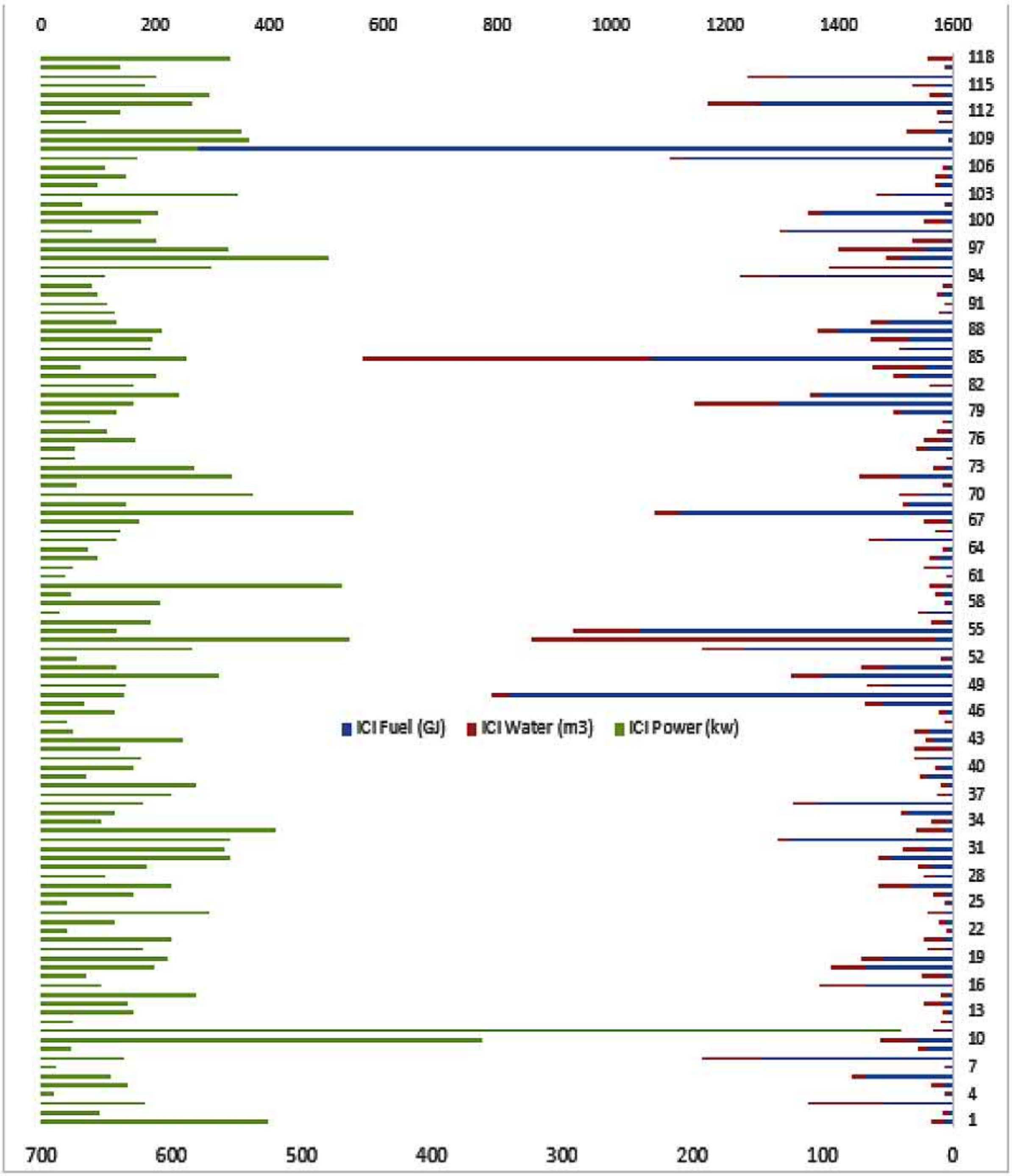
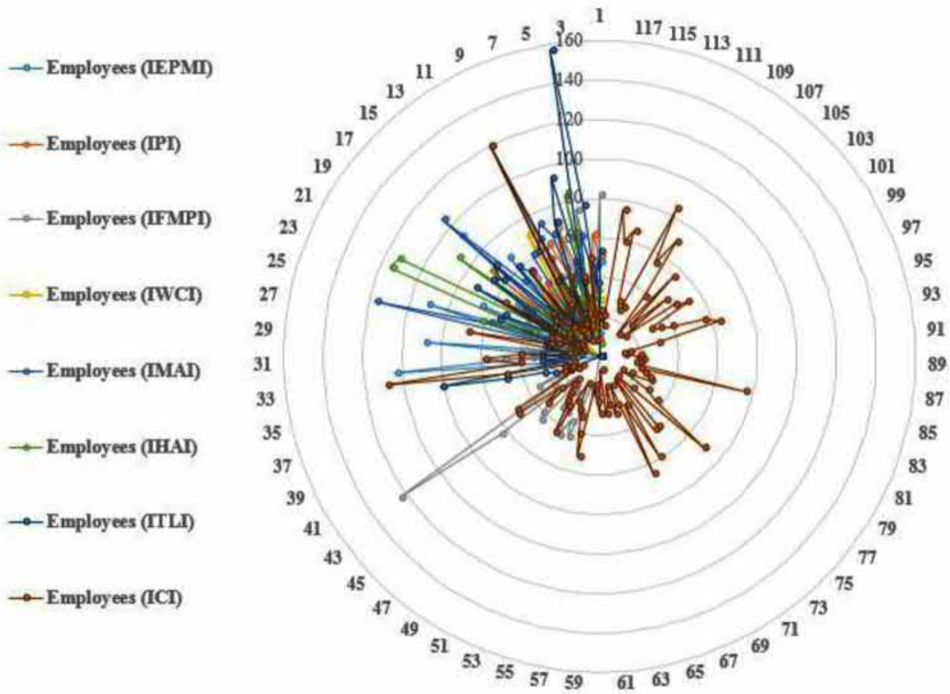


Figure 6. The number of employees in industrial units



Statistical Analysis for Eight Groups of Iranian Industries

To run a statistical analysis among criteria of 8 groups of industries, it was used IBM 20 statistic software after shifting the initial values of criteria in currency. Conducting the one-sample test among criteria of products, employees, power, water, and fuel of ITLI had shown no significant difference. The null hypothesis summary had proved that the distribution of all criteria was normal via the one-sample Kolmogorov-Smirnov test. The highest correlation had appeared between criteria of power and employees around 0.577 via Pearson correlation sig (2-tailed).

The distribution of 5 criteria of IHAI was obtained normally via one-sample Kolmogorov Simonov test in null hypothesis test summary. The null hypothesis was rejected for the 3 criteria of products, water, and fuel. The distribution of all criteria was also obtained normally via related samples Friedman's two-way analysis of variance by ranks. Therefore, it has resulted in the rejection of the null hypothesis in this regard. Conducting the t-test among 5 criteria of products, employees, power, water, and fuel in financial reports has proved significant differences around (p-value ≤ 0.047 and 0.025) for both criteria of products and fuel in comparison with other criteria respectively.

It was found a significant difference (p-value ≤ 0.014) among the 5 criteria of ICI. The highest correlation appeared with the value of about 0.433 between both variables of power and employees via Pearson correlation sig (2-tailed). The distribution of all variables of ICI emerged normally in the null hypothesis test summary via a one-sample Kolmogorov Smirnov test. It has resulted in the rejection of the null hypothesis. The findings of the null hypothesis summary via related samples Friedman's two-way analysis of variance by ranks were the same as findings of the one-sample Kolmogorov Simonov test.

Table 2. The values of weights in 4 weighing systems for 8 groups of industries

Weighing System/Criteria	Friedman Test	CRITIC	AHP	Entropy Shannon
ITLI				
Employees	4.03	0.173028396	0.070282574	0.037532146
water	3.05	0.215809	0.01860188	0.076878633
Fuel	1.05	0.174830387	4.03383E-05	0.645133645
Power	1.97	0.212189846	0.000307111	0.077145441
Product	4.89	0.224142386	0.910768097	0.163310135
IHAI				
Employees	4.08	0.186321655	0.041405978	0.06825935
Water	3.04	0.208767143	0.009348985	0.098809661
Fuel	1	0.24381589	1.72602E-05	0.343836217
Power	2	0.17990752	0.000218193	0.140487994
Product	4.88	0.181187791	0.949009583	0.348606778
ICI				
Employees	3.98	0.248805966	-	0.044045056
Water	3.08	0.191497173	-	0.172200434
Fuel	1.08	0.214381096	-	0.242914468
Power	1.94	0.182420263	-	0.066632059
Product	4.92	0.162895503	-	0.474207983
IMAI				
Employees	4	0.187729564	0.057963007	0.037931
Water	3.35	0.226250108	0.028588888	0.088777922
Fuel	1.04	0.198371648	6.3319E-05	0.228771382
Power	2	0.191024572	0.000723972	0.0539771
Product	4.62	0.196624108	0.912660814	0.590542596
IWCI				
Employees	4.13	0.180183559	0.074783351	0.009380528
Water	3.13	0.204923298	0.024533706	0.026326953
Fuel	1	0.225048447	5.26918E-05	0.036893858
Power	2	0.180101072	0.000669056	0.015763689
Product	4.75	0.209743624	0.899961196	0.036874146
IFMPI				
Employees	3.89	0.202413523	-	0.147052076
Water	3.16	0.24089177	-	0.156855733
Fuel	1.09	0.182542949	-	0.274369565
Power	1.95	0.190631167	-	0.153203567
Product	4.91	0.183520591	-	0.268519059
IPI				
Employees	2.88	0.172980489	0.051377287	0.082748739

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Table 2. Continued

Weighing System/Criteria	Friedman Test	CRITIC	AHP	Entropy Shannon
Water	1.74	0.212093396	0.012551738	0.108277691
Fuel	1.52	0.245805192	2.14789E-05	0.476580099
Power	3.86	0.172980489	7.47306E-05	0.082748739
Product	5	0.196140435	0.935974765	0.249644732
IEPMI				
Employees	4.15	0.211806934	0.10715445	0.042930425
Water	3.06	0.206686682	0.023237542	0.047706614
Fuel	1	0.201434716	2.46481E-05	0.052577033
Power	2	0.203587675	0.000376344	0.13443607
Product	4.79	0.176483994	0.869207015	0.722349857

Source; (This study)

Table 3. DEA rank based on 4 weighing systems for ITLI

Industry	Friedman Test	CRITIC	AHP	Entropy Shannon
(1)	0.088118644	0.089205537	0.086836597	0.09071905
(2)	0.096683792	0.096291019	0.09709802	0.095794277
(3)	0.070833802	0.069557059	0.072137908	0.066761066
(4)	0.006176884	0.006298937	0.006037227	0.006485743
(5)	0.014263778	0.014494222	0.014001585	0.014828765
(6)	0.016859333	0.017016994	0.016678515	0.017241176
(7)	0.007238812	0.007325668	0.007140605	0.007453779
(8)	0.06074182	0.049448233	0.083195555	0.039663211
(9)	0.011241912	0.009518423	0.014294268	0.00784019
(10)	0.122443642	0.120884141	0.124143546	0.11902301
(11)	0.024171766	0.019462134	0.03386089	0.015334293
(12)	0.074347441	0.074017355	0.07474343	0.073284367
(13)	0.10829634	0.101527926	0.117538114	0.093670797
(14)	0.006431531	0.006049304	0.006948132	0.005611422
(15)	0.058497471	0.055647382	0.062132587	0.050796758
(16)	0.379300651	0.37454026	0.384942109	0.368742618
(17)	0.090551156	0.089309417	0.092039942	0.087523062
(18)	0.321652621	0.323476908	0.319231145	0.326307411
(19)	0.074283932	0.074067234	0.074497286	0.073813108
(20)	0.057016434	0.057303927	0.056670317	0.057765067
(21)	0.308317975	0.2811149	0.346974098	0.244044719
(22)	0.08095208	0.082240738	0.079468323	0.084125071
(23)	0.040918347	0.041008235	0.040813048	0.040953597

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Table 3. Continued

Industry	Friedman Test	CRITIC	AHP	Entropy Shannon
(24)	0.032707928	0.032493866	0.032946841	0.031791202
(25)	0.111192296	0.110882312	0.111538656	0.110624938
(26)	0.043289492	0.043507322	0.043025949	0.043799611
(27)	0.007623064	0.006734639	0.009010318	0.005715019
(28)	0.348706549	0.344117741	0.353354395	0.339269855
(29)	0.034209494	0.032632389	0.036195014	0.030622573
(30)	0.018671148	0.018677341	0.018666709	0.018693827
(31)	0.000728024	0.000691072	0.000773366	0.000645614
(32)	1	1	1	1
(33)	0.055897957	0.055383882	0.056494371	0.054699129
(34)	0.008975363	0.00781362	0.010874652	0.006583413
(35)	0.002415814	0.002445828	0.002379092	0.002493478
(36)	0.011522591	0.008973124	0.013148625	0.001773549
(37)	0.403241072	0.393190462	0.415398499	0.379531838
(38)	0.001978288	0.001927311	0.002033193	0.001867938

Source: Authors' Calculations

Table 4. DEA rank based on 4 weighing systems for IHAI

Industry	Friedman Test	CRITIC	AHP	Entropy Shannon
(1)	0.638885629	0.581730764	0.759799141	0.542768443
(2)	0.031385352	0.031718625	0.030870604	0.03203558
(3)	0.01865783	0.01872714	0.018530403	0.018735167
(4)	0.05767559	0.05822894	0.056787012	0.058649973
(5)	0.009144908	0.008694983	0.009946107	0.008307244
(6)	0.109716208	0.111908018	0.106328041	0.113743257
(7)	0.128547063	0.129374663	0.127273937	0.13021555
(8)	0.000169203	0.000168731	0.000169835	0.00016799
(9)	0.165092262	0.162881056	0.168469307	0.160318644
(10)	0.085004924	0.085458516	0.084222098	0.085684999
(11)	0.048853758	0.049059825	0.048516484	0.049213745
(12)	0.009315694	0.009356901	0.009253109	0.009403776
(13)	0.142701088	0.143755856	0.141075634	0.14481871
(14)	0.186414317	0.187069863	0.185356441	0.187630468
(15)	0.016601703	0.016783231	0.016307257	0.016912825
(16)	0.183229224	0.178862078	0.189949444	0.173673956
(17)	0.029698651	0.028197357	0.032464359	0.027016603
(18)	0.355449852	0.359329936	0.349464499	0.363002706

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Table 4. Continued

Industry	Friedman Test	CRITIC	AHP	Entropy Shannon
(19)	1	1	1	1
(20)	0.29239686	0.294823291	0.288623281	0.29712764
(21)	0.328915395	0.328257814	0.330064817	0.328080014
(22)	0.065583614	0.064851367	0.066612118	0.063943441
(23)	0.00072672	0.000732511	0.000715787	0.000734128
(24)	0.054259909	0.048316076	0.06784477	0.044505327
(25)	0.455304514	0.457749016	0.451188592	0.459110072

Source: Authors' Calculations

Table 5. DEA rank based on 3 weighing systems for ICI

Industry	Friedman Test	CRITIC	Entropy Shannon
(1)	0.007333558	0.007311278	0.008623168
(2)	0.012158088	0.012156224	0.017306667
(3)	0.013000649	0.013023587	0.010606646
(4)	0.010682517	0.010690783	0.016261327
(5)	0.005647385	0.005649284	0.007871468
(6)	0.001849264	0.001845383	0.002014583
(7)	0.002846652	0.002848218	0.003544146
(8)	0.006709091	0.006710805	0.005659751
(9)	0.004235479	0.00423714	0.004952911
(10)	0.000151472	0.00015136	0.000222202
(11)	0.00640595	0.00633106	0.007756668
(12)	0.000852604	0.000853159	0.000857535
(13)	0.001747112	0.001744086	0.002478511
(14)	0.112056439	0.112127309	0.15546306
(15)	0.000784532	0.000782555	0.001049492
(16)	0.000528926	0.000529553	0.000397153
(17)	0.002713729	0.002717868	0.002890018
(18)	0.01782027	0.017816407	0.01594707
(19)	0.006497762	0.006488931	0.005799707
(20)	0.00524563	0.005244756	0.004272628
(21)	0.000675022	0.000675275	0.000904142
(22)	0.000238514	0.000238543	0.000320499
(23)	0.001535369	0.001532336	0.001650192
(24)	0.010255614	0.01024734	0.011044469
(25)	0.001472543	0.001473399	0.00232669
(26)	0.000892503	0.000892447	0.001101171
(27)	0.003780875	0.0037829	0.004675502
(28)	0.008965639	0.00896285	0.009125297
(29)	0.02094375	0.020916019	0.021521421
(30)	0.005995057	0.00598286	0.008808389
(31)	0.002581545	0.002580788	0.003510794
(32)	0.002508508	0.002499772	0.003543546
(33)	0.003543483	0.003543964	0.005444306
(34)	0.000248678	0.000248877	0.000356972
(35)	0.271634405	0.270879272	0.340501365
(36)	0.00069014	0.000688506	0.000589441
(37)	0.008610283	0.00859602	0.009221371
(38)	0.000392266	0.000391278	0.000524746
(39)	0.02052258	0.020493081	0.022880445
(40)	0.008002595	0.007984775	0.009830395
(41)	0.003005178	0.003005315	0.00444285
(42)	0.002681307	0.002684907	0.002990042
(43)	0.018111566	0.018076531	0.026280299
(44)	0.004658011	0.004662189	0.006044635
(45)	0.008598416	0.008605088	0.011413623
(46)	0.021851811	0.021837948	0.031066737
(47)	0.02097441	0.02096873	0.02271308
(48)	0.024830202	0.024622979	0.027559156
(49)	0.023147414	0.023147453	0.023669106

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Table 5. Continued

Industry	Friedman Test	CRITIC	Entropy Shannon
(50)	0.032195788	0.03215496	0.035033398
(51)	8.68466E-05	8.68331E-05	8.57612E-05
(52)	0.02074761	0.020759732	0.025265558
(53)	0.028233265	0.028175905	0.02326883
(54)	0.000508414	0.000510742	0.00025183
(55)	4.72008E-05	4.71686E-05	3.75357E-05
(56)	0.001260455	0.001260776	0.001839909
(57)	0.001925005	0.00192598	0.002210293
(58)	0.000434103	0.000433181	0.000647327
(59)	0.000568098	0.000568432	0.000798761
(60)	0.027591476	0.027514186	0.030461516
(61)	0.710286374	0.710356027	0.842940002
(62)	0.007841267	0.007849108	0.009732621
(63)	0.004121944	0.004122795	0.005418852
(64)	0.012148876	0.012145679	0.017284693
(65)	0.010215514	0.010211131	0.011704343
(66)	0.004436399	0.004437558	0.005477263
(67)	0.001274245	0.00127509	0.001052196
(68)	0.007005422	0.006981034	0.009354117
(69)	0.002166084	0.002163102	0.00337146
(70)	0.096757084	0.096700125	0.131497007
(71)	0.002109939	0.002111261	0.002506602
(72)	1	1	1
(73)	0.019589224	0.019578381	0.029917941
(74)	0.066063055	0.066059751	0.096355749
(75)	0.005356213	0.00535811	0.006837248
(76)	0.006394845	0.006399841	0.009042514
(77)	0.001052146	0.001052532	0.001553289
(78)	0.002695894	0.002696735	0.004266775
(79)	0.013145445	0.013115543	0.013523914
(80)	0.001313534	0.001315396	0.00076056
(81)	0.242813069	0.241812656	0.339473272
(82)	0.17993982	0.180036756	0.19407501
(83)	0.005583148	0.005575529	0.006435589
(84)	0.004114293	0.004125455	0.00286022
(85)	0.000869552	0.000872076	0.000528357
(86)	0.050994289	0.050830387	0.069471858
(87)	0.010447043	0.010454743	0.007870485
(88)	0.115609361	0.115299774	0.114144668
(89)	0.002753283	0.002750345	0.002725751
(90)	4.37036E-05	4.36759E-05	6.21335E-05
(91)	0.039999645	0.039964857	0.047908808
(92)	0.045797855	0.04574145	0.059201033
(93)	0.01036391	0.010365393	0.012615084
(94)	0.008628143	0.008622653	0.007479055
(95)	0.02021437	0.020260448	0.015713225
(96)	0.015689239	0.01566015	0.022722531
(97)	0.090141244	0.090307874	0.064916732
(98)	0.085167018	0.085263685	0.07926287
(99)	8.57735E-05	8.54936E-05	0.000126546
(100)	0.014458468	0.014467904	0.018900165
(101)	0.000860154	0.000858606	0.001263968
(102)	0.001266117	0.001266141	0.00180269
(103)	0.008080308	0.008069735	0.010355175
(104)	0.172279398	0.172233787	0.252103508
(105)	0.003836602	0.003838042	0.006154665
(106)	0.006536701	0.006530085	0.008904148
(107)	0.014896378	0.014835341	0.019808432
(108)	0.003650628	0.003624541	0.005320166
(109)	0.005109601	0.005101287	0.011226349
(110)	0.001083576	0.001083706	0.00154319
(111)	0.014992046	0.015004565	0.01947539
(112)	0.021951349	0.021942997	0.031614386
(113)	0.039898919	0.039853651	0.030695384
(114)	0.005776953	0.00577646	0.008817561
(115)	0.04847436	0.048499193	0.066040652
(116)	0.02501224	0.025009167	0.029961579
(117)	0.00505175	0.005045471	0.007174803
(118)	0.021764393	0.021746555	0.019479738

Source: Authors' Calculations

Table 6. DEA rank based on 4 weighing systems for IMAI

Industry	Friedman Test	CRITIC	AHP	Entropy Shannon
(1)	1	1	1	1
(2)	0.083788271	0.089115004	0.076888047	0.095733297
(3)	2.81241E-05	2.88347E-05	2.72989E-05	2.99876E-05
(4)	5.90824E-05	6.19849E-05	5.58562E-05	6.82259E-05
(5)	9.45104E-05	9.24337E-05	9.72167E-05	8.78941E-05
(6)	0.00880194	0.009133305	0.008415999	0.009689254
(7)	3.73104E-05	3.76022E-05	3.69327E-05	3.76569E-05
(8)	2.94594E-05	3.16265E-05	2.71675E-05	3.64858E-05
(9)	0.00029271	0.000307647	0.000275323	0.000339206
(10)	0.00013956	0.000146228	0.000132023	0.000159844
(11)	1.89839E-07	1.80179E-07	2.03356E-07	1.61974E-07
(12)	0.000189839	0.000180179	0.000203356	0.000161975
(13)	0.000903202	0.000856365	0.00096502	0.000765028
(14)	8.52306E-08	9.0611E-08	7.94368E-08	1.04374E-07
(15)	5.22338E-05	5.4288E-05	4.9916E-05	5.8256E-05
(16)	0.00015615	0.000159876	0.000151659	0.000165298
(17)	7.77128E-05	7.35663E-05	8.3393E-05	6.5697E-05
(18)	7.95922E-05	8.11285E-05	7.77864E-05	8.42663E-05
(19)	2.0212E-06	2.116E-06	1.91514E-06	2.29805E-06
(20)	1.38021E-05	1.25833E-05	1.56552E-05	1.05617E-05
(21)	1.4176E-06	1.34627E-06	1.51439E-06	1.21044E-06
(22)	2.92361E-05	2.76973E-05	3.13962E-05	2.51209E-05
(23)	0.000304556	0.000319951	0.000287469	0.000350732
(24)	8.6642E-05	7.22484E-05	0.000114959	5.38674E-05
(25)	1.13978E-05	1.23145E-05	1.04409E-05	1.447E-05
(26)	4.45739E-07	4.46907E-07	4.44304E-07	4.45096E-07

Source: Authors' Calculations

The t-test analysis had shown a significant difference (p-value ≤ 0.015) among the 5 criteria of IMAI such as products, employees, power, water, and fuel. The Pearson correlation sig. (2-tailed) appeared with the highest correlation between both variables of power and employees around 0.665. The null hypothesis test summary had presented with a normal distribution for all variables via a one-sample Kolmogorov-Smirnov test. It was retained the null hypothesis only for both variables of employees and power. Conducting the same hypothesis for the same variables led to reject the null hypothesis via related samples Friedman's two-way analysis of variance by ranks.

In the analysis of data of IWCI, the t-test analysis had shown significant differences (p-value ≤0.001 and 0.002) among three criteria of product, water, and fuel in comparison with the values of the employees, and power in currency. The output of Pearson correlation sig. (2-tiled) had proved the highest correlation between both criteria of water and fuel around 0.886. The distribution of all criteria had appeared normally via one-sample Kolmogorov Smirnov test so it resulted in retaining the Null hypothesis.

Analysis of one-sample test had manifested there is no significant difference among 5 variables of IFMPI. Using Pearson correlation sig. (2-tailed) led to the appearance of the highest correlation between both variables of water and employees around 0.579. The null hypothesis test summary had proved the normal distribution of all variables via a one-sample Kolmogorov-Smirnov test. The results of the test led to reject the null hypothesis except for the variable of employees. But the results of related samples Friedman's two-way analysis of variance by ranks came into view with the rejection of null hypothesis for all variables.

The t-test analysis confirmed a significant difference (p-value $\leq$0.009) between the criterion of fuel with the remaining criteria of IPI such as products, employees, power, and water. The highest correlation was obtained for the criteria of employees and water around 0.808 via Pearson correlation sig (2-tails) test. The distribution of all criteria had appeared with equal probabilities the via one-sample chi-square test except the normal distribution of products criterion via one-sample Kolmogorov Smirnov test.

Conducting one-sample statistics among the 5 criteria of IEMPI has presented a significant difference (p-value $\leq$ 0.307). The Pearson correlation sig. (2-tailed) test has proved the highest correlation between both criteria of water and the power of IEMPI. The distribution of criteria emerged normally via the one-sample Kolmogorov Smirnov test. So, it resulted in the rejection of the null hypothesis. The results were the same with the null hypothesis test summary in related samples Friedman's two-way analysis of variance by ranks.

Table 7. DEA rank based on 4 weighing systems for IWCI

Industry	Friedman Test	CRITIC	AHP	Entropy Shannon
(1)	0.289958269	0.298694258	0.278432766	0.323328128
(2)	0.054592697	0.057305553	0.051101389	0.065837956
(3)	1	1	1	1
(4)	0.184167166	0.181846839	0.18774274	0.175726515
(5)	0.431401161	0.457081036	0.398670959	0.543961023
(6)	0.789210812	0.829031973	0.738143532	0.952865479
(7)	0.194207093	0.197680131	0.189373319	0.207271789
(8)	0.107228042	0.100253492	0.119209554	0.086181093
(9)	0.094943903	0.098521167	0.090230599	0.109180486
(10)	0.25254635	0.266408002	0.234873889	0.310819609
(11)	0.001034095	0.001077094	0.000977311	0.00121271
(12)	0.005571509	0.005645341	0.005474695	0.005831164
(13)	0.005056294	0.00497441	0.00518907	0.004762119
(14)	0.584460001	0.621424618	0.538243095	0.741636734
(15)	0.26482382	0.240114385	0.312320607	0.192006467
(16)	0.305556495	0.300509087	0.31309236	0.288684701

Source: Authors' Calculations

Table 8. DEA rank based on 3 weighing systems for IFMPI

Industry	Friedman Test	CRITIC	Entropy Shannon
(1)	0.000625707	0.000626972	0.000627933
(2)	0.000362126	0.000401858	0.000390142
(3)	0.000199923	0.000206791	0.000205188
(4)	3.51972E-05	3.36154E-05	3.41266E-05
(6)	0.000958686	0.000987564	0.00098042
(5)	0.00029084	0.000297886	0.000295832
(7)	0.001789126	0.001788301	0.001792915
(8)	0.000259558	0.000294703	0.000284385
(9)	0.000691036	0.000742583	0.000727091
(10)	0.245892253	0.27136189	0.263812629
(11)	3.00057E-05	3.21816E-05	3.07701E-05
(12)	7.06514E-05	7.23691E-05	7.18392E-05
(13)	0.000543691	0.000592367	0.000578736
(14)	0.001325668	0.001436085	0.001397071
(15)	0.000783197	0.000695071	0.000719907
(16)	0.000790507	0.000805023	0.000801149
(17)	0.000315427	0.000313246	0.000314234
(18)	0.00632356	0.006949808	0.006769406
(19)	0.000513547	0.000514556	0.000513477
(20)	0.000619151	0.000703344	0.000678129
(21)	0.000660746	0.000683251	0.000677943
(22)	0.000763455	0.00087251	0.000839125
(23)	0.000873238	0.000868753	0.000867839
(24)	0.000633033	0.000708301	0.000686151
(25)	0.000942154	0.000937316	0.00093633
(26)	0.001918565	0.00215506	0.00208653
(27)	0.000619108	0.00069203	0.000670566
(28)	0.000913629	0.001018449	0.000987324
(29)	0.001186007	0.001174562	0.00118014

Industry	Friedman Test	CRITIC	Entropy Shannon
(30)	0.001341588	0.001391863	0.00137881
(31)	0.000538982	0.000569266	0.000559651
(32)	0.00038757	0.000402094	0.000398323
(33)	0.004011444	0.004236159	0.004153324
(34)	3.34228E-05	3.45853E-05	3.42554E-05
(35)	0.000935869	0.00087658	0.000892168
(36)	0.001647305	0.001588463	0.001608167
(37)	0.000143368	0.000154351	0.00015102
(38)	7.86657E-05	8.11901E-05	8.04577E-05
(39)	5.02195E-05	5.18594E-05	5.14695E-05
(40)	1.15476E-05	1.26825E-05	1.23361E-05
(41)	0.000966169	0.000971759	0.000969932
(42)	8.63566E-05	9.04689E-05	8.93044E-05
(43)	0.002315117	0.002447313	0.002406852
(44)	5.81794E-06	6.04054E-06	5.98953E-06
(45)	0.000179043	0.000203235	0.000195917
(46)	2.68621E-06	3.0507E-06	2.94469E-06
(47)	0.000199929	0.000184171	0.00018848
(48)	0.00035961	0.000221483	0.000122441
(49)	0.133022108	0.139333404	0.136983016
(50)	0.000169684	0.000175404	0.000173765
(51)	7.71806E-05	8.58407E-05	8.29751E-05
(52)	0.004132042	0.004595388	0.004446349
(53)	0.000385679	0.000423615	0.000412402
(54)	0.001096763	0.001186296	0.001161709
(55)	0.000359218	0.000403868	0.000389825
(56)	1	1	1
(57)	0.000399649	0.00036739	0.000376841

Source: Authors' Calculations

Table 9. DEA rank based on 4 weighing systems for IPI

Industry	Friedman Test	CRITIC	AHP	Entropy Shannon
(1)	0.104455476	0.108670903	0.101117053	0.109485087
(2)	0.053460833	0.057058095	0.050738654	0.057650574
(3)	1	1	1	1
(4)	0.009158892	0.01033219	0.008351899	0.010502459
(5)	0.044156815	0.049995523	0.040165582	0.050842691
(6)	0.017208122	0.019076298	0.01588445	0.019358763
(7)	0.097256218	0.104287217	0.091979646	0.105271117
(8)	0.118140866	0.128501285	0.110558144	0.129369606
(9)	0.112348625	0.128829869	0.101319609	0.131278573
(10)	0.089020018	0.101088672	0.080810894	0.102866804
(11)	0.159779391	0.180812728	0.145388856	0.183853044
(12)	0.129676123	0.146324613	0.118239834	0.145057155
(13)	3.38921E-05	3.90213E-05	3.04828E-05	3.97669E-05
(14)	0.305420411	0.326425154	0.289565613	0.329416749
(15)	0.012571866	0.013447567	0.011911778	0.013587401
(16)	0.089901595	0.103333168	0.080948757	0.105285003
(17)	0.85772266	0.940180355	0.798158286	0.952160041
(18)	0.184249158	0.210639309	0.166499654	0.214556439
(19)	0.102031855	0.111822119	0.094957975	0.113149168
(20)	0.373396792	0.425360767	0.338250327	0.428026152
(21)	0.01415359	0.015821455	0.012988516	0.016070743

Source: Authors' Calculations

Table 10. DEA rank based on 4 weighing systems for IEPMI

Industry	Friedman Test	CRITIC	AHP	Entropy Shannon
(1)	0.001741264	0.001712496	0.001815429	0.001671247
(2)	4.0068E-06	4.09758E-06	3.79818E-06	4.18456E-06
(3)	0.000137692	0.000142086	0.000127813	0.000146265
(4)	0.000159064	0.000160557	0.000155941	0.000162776
(6)	3.46029E-05	3.57958E-05	3.1937E-05	3.69214E-05
(5)	0.000137355	0.000140145	0.000131048	0.000143074
(7)	0.000274731	0.000280327	0.000262095	0.00028629
(8)	0.000397206	0.000405291	0.000378746	0.000413328
(9)	0.000288622	0.000295304	0.00027347	0.000302115
(10)	1.16195E-05	1.16606E-05	1.15338E-05	1.17003E-05
(11)	0.001482047	0.001527504	0.001379066	0.001569165
(12)	0.000409392	0.000421018	0.000382524	0.000430209

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Table 10. Continued

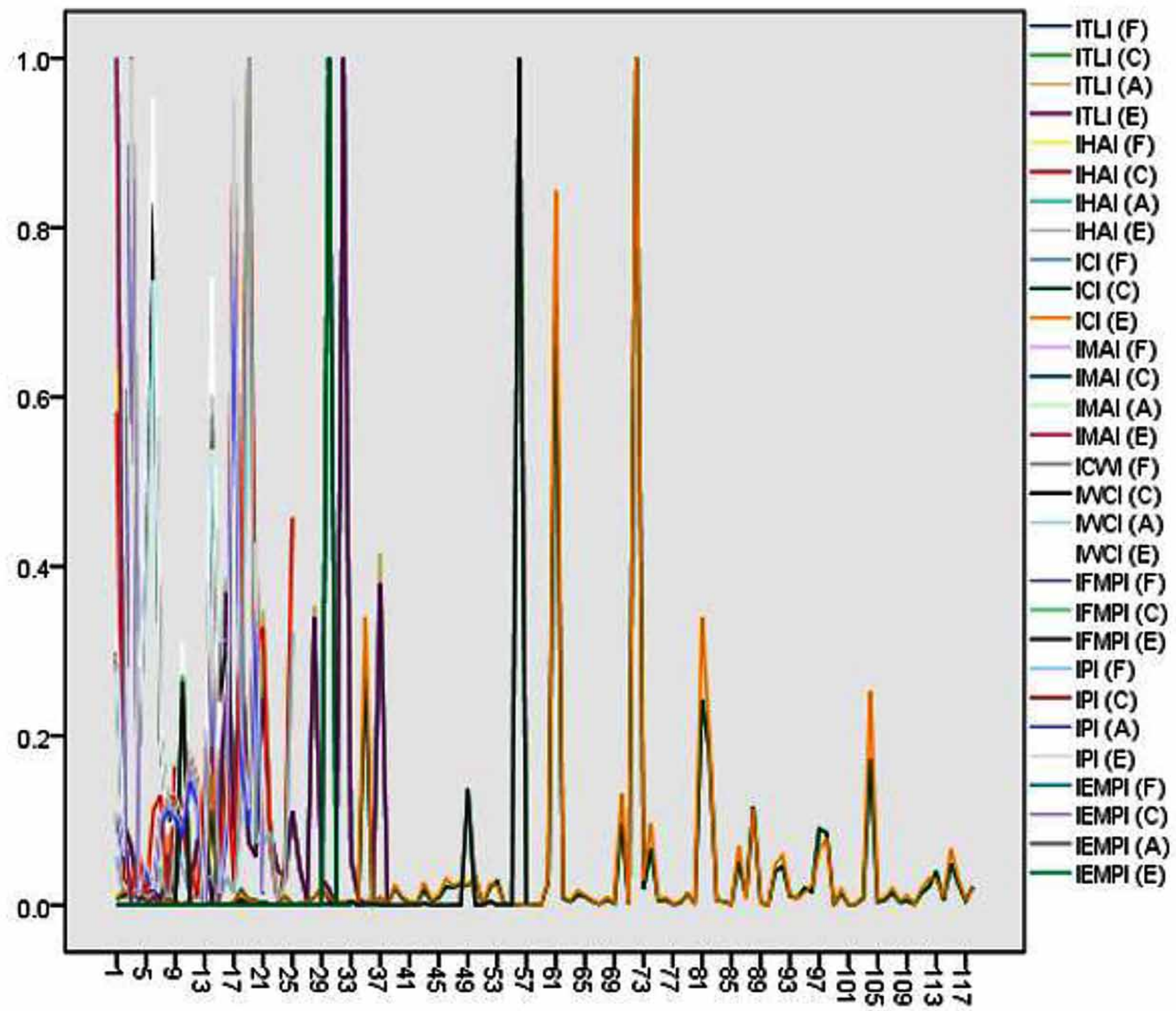
Industry	Friedman Test	CRITIC	AHP	Entropy Shannon
(13)	2.90289E-05	2.97567E-05	2.73937E-05	3.05301E-05
(14)	0.003480584	0.003514174	0.003411213	0.00356709
(15)	0.000111557	0.000111076	0.000113331	0.000111419
(16)	0.001340661	0.001353615	0.001313523	0.001372793
(17)	4.31388E-07	4.46485E-07	3.97334E-07	4.59365E-07
(18)	0.000276548	0.00028122	0.000266113	0.000286723
(19)	0.000396576	0.000400957	0.000386998	0.000406524
(20)	0.000640065	0.000654066	0.000608621	0.000669395
(21)	0.003434602	0.003553548	0.003168852	0.003665843
(22)	0.000897955	0.000920404	0.000846653	0.000941317
(23)	0.000230005	0.000237719	0.000212725	0.000244898
(24)	0.000500569	0.000514114	0.000469686	0.000526668
(25)	0.000543006	0.000559373	0.000505339	0.000572442
(26)	0.000869402	0.000883465	0.000837454	0.00089985
(27)	0.000265818	0.000274931	0.000245023	0.000282106
(28)	0.000769658	0.000784193	0.000736682	0.000799342
(29)	0.000141198	0.000146277	0.000129826	0.000150815
(30)	1	1	1	1
(31)	0.000369179	0.000376866	0.000351174	0.000383116
(32)	0.001835653	0.001861249	0.001773546	0.001876262
(33)	0.000144919	0.000143208	0.000150525	0.000143785

Source: Authors' Calculations

FUTURE RESEARCH DIRECTIONS

The DEA model integrated with weighing systems was employed to assess the industrial projects based on energy/revenue reports successfully. The future research orientation can take into consideration other types of DEA models to assess the ESs. Also, uniting the DEA model with other types of weighing and ranking systems of MCDM would be an alternative to figure out the ESs. The classification of industries based on NC in currency reports can be taken into progress in future studies for all existing industries. The sustainability assessment is the need of the hour (Rafay, 2022). It is recommended that Iranian industrial projects to be investigated by the right scientists of the field regarding a variety of environmental, social, financial, and theoretical criteria.

Figure 7. The sequence number of the values of weights (vertical axis) vs industrial units



CONCLUSION

In the current study, a financial assessment model was devised to demystify and classify industrial projects based on ESs. The model managed to manifest the findings in four weighing systems integrated with the DEA model. The productivity of projects came into view when the division of weighted outputs to weighted inputs variables was accomplished. The industrial projects were classified based on the ESs and weights of all criteria were tabulated. The first year is a very short time for industries to start making a profit or move towards a full efficiency border. It will take time to emerge the profit like a time interval of a few years. According to the number of employees assumed for each industry by the evaluator team of EIA, the main costs spent on employee's salaries and it induced a strong shock in the efficiency score obtained via the DEA model. However, it was assumed medium salary for staff by the current study individually. The decline in the number of staff to raise the efficiency score is a bit difficult but automation in industries can be a booster to improve efficiency score. Superseding renewable energy consumption in industrial units can be a prominent alternative to thrift the outlays.

The Nominal Capacity (NC) of industrial projects was taken into consideration as a distinguishing feature in this regard. Another option for escalating the ESs can be a layout of similar industries in certain groups based on NC and avoid putting a combination of small and medium-size industries together. However, the classification of industries as small and medium-sized industries based on employee numbers does not make anything to change. In this case, the highest productivity among a column of values plays a prominent role.

DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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KEY TERMS AND DEFINITIONS

DEA: It is a powerful instrument for assessing a variety of projects to find the efficiency score or performance of projects.

Decision Science: It seeks to make plain the scientific issues and value judgments underlying these decisions, and to identify tradeoffs that might accompany any particular action or inaction.

EIA: It is a plan for assessing many projects before the complete construction of projects.

Energy Demand in Industrial Projects: It includes the energy stream for running industries such as water demand, power demand, and fuel demand.

Nominal Capacity: It means materials streams produced (products of industries) by industries individually.

Screening: It is a step of EIA to assess the projects initially.

Sensitivity Analysis: It is a procedure to validate the findings.

APPENDIX 1

Iranian Textile and Leather Industries (ITLI)

ITLI comprised 38 various kinds of industries such as (1) Bag (NC=120000 No), (2) Carpet thread (NC=600t), (3) Cotton spinning (NC=1400t), (4) Jeans (NC=81000 No), (5) Leather artifacts (NC=90000 No), (6) Leather shoes (NC=135000 pairs), (7) Quilts, mattresses and pillows (NC=85000 No), (8) Raw leather (NC=618300 Ft^2), (9) Sewing and embroidery thread (NC=150t), (10) Spinning (NC=2500t), (11) Tannery (NC= 45500 skin covers+214.988t), (12) Underwear (embroidered series) (NC=350000 No), (13) Wicker oil burner (NC=620000 No), (14) Spinning the woolen yarn (NC= 306t), (15) Knitting cotton, synthetic fibers (NC=1000000 m^2), (16) Band and medical wound texture gas (NC= 1407659 No), (17) Rachel Curtain Fabrics (NC=330000 m), (18) Mink blankets (NC=500000 m^2), (19) Woolen blanket (NC=131500 No), (20) Spinning wool (NC=263.5t), (21) Palash and blanket (NC=2250000 m^2), (22) Winter clothing (NC=137500 No), (23) Clothing (shirt) (NC=135000 No), (24) Knitted Tricot (NC=130t), (25) Fishing net (NC=270t), (26) Stinger mosquito net (NC=300000 m^2), (27) Socks (NC=243000 jeans), (28) Crust leather (NC=2398000 Ft^2), (29) Cotton gloves (NC= 62400 pair), (30) Leather gloves (NC=70000 pair), (31) Wipes (Cleansing) (NC=4000 yard), (32) Ribbon Weaving (NC=3000000 m), (33) Carpet coverage (NC=54000 No), (34) Spinning silk (NC=102.8t), (35) Zipper (NC=3000000 m), (36) Animal skin pickle (NC= 200000 No), (37) Raw silk fabrics (NC= 330000 m), (38) Layer on diapers and sanitary pads (NC=8750 m^2).

Iranian Household Appliance Industries (IHAI)

Types of IHAI based on NC comprised 25 industries such as Earphone (20000 No) (1), Hairdryer Handheld (100000 No) (2), Household ventilator (100000 No) (3), Household crystal containers (500t) (4), Pyrex glass containers (100000 No) (5), Semi-Automatic Washing Machine (10000 No) (6), Tea flask (100000 No) (7), Teflon containers (211t) (8), Water Cooler (20000 No) (9), Gas oven (12000 No) (10), Steam iron (20000 No) (11), Juicer (48000 No) (12), Electrical miller and mixer (20000 No) (13), Steam cooked double glazed steel (50000 No) (14), Electrical stove (30000 No) (15), Gas stove (20000 No) (16), Semi-automatic electric cooker (20000 No) (17), Ceiling fan (assembly) (50000 No) (18), Desktop fan (100000 No) (19), Household vacuum cleaner (assembly) (30000 No) (20), Meat grinders (assembled) (40000 No) (21), Chinese dishes (800t) (22), Chinese decorative dishes (500t) (23), Samovar (electric and oil) (82500 No) (24), Household refrigerator (15000 No) (25).

Iranian Chemical Industries (ICI)

Types of ICI based on NC comprised 118 industries such as Animal Feed from Agricultural Waste (NC=10000t) (1), Animal drugs (NC= 500t+50000 No) (2), Ammonium Chloride (NC=1500t+2000t $NaSO_4$) (3), Antifreeze (NC=960 m^3) (4), Baby carriage (NC= 25000 No) (5), Blood Powder (NC=500t) (6), Buds of different seeds (NC=150t) (7), Barium carbonate (NC=3000t+1187t solfide sodium) (8), Braided wax plates (NC= 130t) (9), Calcium carbonate (light and active) (NC= 19200t) (10), Calcium carbide (NC=1350t) (11), Clothes hanger and pin (NC=504000 No) (12), Disinfectants (NC=900000 L) (13), Fiberglass boat (NC=5000 No) (14), Fiberglass pieces (NC=100t) (15), Fragrant aromas

(NC=130t) (16), Glass- strip away (NC=650t) (17), Glucose from starch (NC=2160t) (18), Healthy Soap (NC=1090t) (19), Helmet (NC=65000 No) (20), High pressure hoses (NC=240t) (21), Household Lighting Candles (NC=7560 No) (22), Insecticide coil (NC=50000 No) (23), Isolator (NC=2000000 m^2) (24), Kitchen lighter (NC=100000 No) (25), Knife with injectable handle (NC=800000 No) (26), Adhesive plaster (NC=1700t) (27), Lining materials and insulating gas pipes (NC=3500t) (28), Liquid fertilizer (NC=1250t) (29), Matches (NC= 7776000 No) (30), Mechanical disposable lighters (5000000 No) (31), Medicinal glycerin (NC=1500t) (32), Melamine dishes (NC=1000t) (33), Metal flexible hose pipes (NC=309t) (34), Nitrobenzene (NC=1620t) (35), Potassium chloride (NC=400t) (36), Printing ink (NC=500t) (37), Rubber parts (NC= 25t) (38), Shoe wax (NC=3750000 No) (39), Soft polyurethane foam (NC=6000t) (40), Starch from wheat (NC=1580t) (41), Throw-away crockery (NC=962.35t) (42), Tooth brush (NC=5000000 No) (43), Detergents (Shampoo, etc.) (NC=1080t) (44), Welding glasses (NC=50000 No) (45), Insecticide spray containing flavoring materials (NC=2700000 No) (46), Acetic acid ester (NC=1200t) (47), Phthalic anodic esters (NC=970t) (48), Calcium stearates (NC=2592t) (49), Boric acid (2700t + 3600t $NaSO_4$) (50), Hydrochloric acid (NC=3000t) (51), Chromic acid (270t) (52), Zinc oxide (500t+887.5t $NaSO_4$) (53), Oxygen; Ar and N_2 (NC=3643200 m^3) (54), Alcohol from beet molasses (NC=5000 No) (55), Types of gaskets (200t) (56), Acid and distilled water (NC=1725 m^3) (57), Rubber plugs (NC=25t) (58), Sprinkler (NC=81000 No) (59), Sodium hypochlorite (NC= 837900 gallon) (60), Recycling silver from film and its solution (NC=40.40t) (61), Industrial Paraffin (NC=3000t) (62), Raw silk fabrics (NC=330000 m) (63), Pacifier (NC=300000 No) (64), Unsaturated polyester (NC=1000t) (65), Bleach powder (NC=2700t) (66), Electrostatic coating (NC=81000 m^2) (67), Tri-calcium phosphate (NC=15000t) (68), Hub and rubber ball (NC=360000 No) (69), Synthetic leather of polyurethane (NC=12000000 m^2) (70), Gum stick (NC=200000 No) (71), Wood gum (polyvinyl acetate) (NC=7000t) (72), Shoe adhesive (NC=1800t) (73), Medical and sanitary adhesives (NC=45600000 No) (74), Toothpastes and health cosmetics (NC=800t) (75), Hexagon pen (NC=24000000 NO) (76), Pen (NC=2000000 No) (77), Plugs and screws head (NC=800000 No) (78), Diethyl ether (NC=100t) (79), CO_2 (NC=1800t) (80), Epoxy resin (NC=5475t) (81), Alkyd resin (NC=17500t) (82), Bakelite resin (NC=2000t) (83), Resin; urea formaldehyde gum (NC=1000t) (84), Dyeing and printing of fabrics (NC=2000000 m^2) (85), Transformer Oil (NC= 8100 m^3) (86), Used motor oil and grease recycling (NC=3000 m^3 + 750t, grease) (87), Drying oils (500t+1000t wastes) (88), Rubber profiles (200t) (89), Insecticide spray (NC=2700 No) (90), Rubber glass head (NC=3240000 No) (91), Canopy (NC=1540t) (92), Agricultural liquid pesticides, Butachlor (NC=750t) (93), Zinc sulfate (NC=3400t) (94), Sodium sulfate (NC=25000t) (95), Alkyl benzene sulphonation (NC=5000t) (96), Sodium sulfite (NC=5000t) (97), Sodium sulfide (NC=3000t) (98), Sodium silicate (NC=3000t) (99), Drip irrigation system (NC= 1000 No+383.9t) (100), Glasses frames (NC=80000 No) (101), Oil filter recycling (NC=2000t) (102), Thermos and ice box (NC= 150000 No) (103), Industrial and consumable taps (NC=3000000 No) (104), Teflon strips (NC=12393000 No) (105), Hair comb (NC=1000000 No) (106), Glass artifacts (NC=1787.5t) (107), Industrial crystals (NC=1000t) (108), Spectacle glass (NC=500000 pairs) (109), Chinese insulator (NC=730t) (110), Ceramic magnet (NC=869565 m) (111), Tape (for electronic equipment) (NC=3370000 No) (112), Fruit concentrate (NC= 19820t) (113), Shuttered windows (NC=330000 No) (114), Hygiene products made of artificial stone (NC=4500t) (115), Household, industrial and medical gloves (NC=12600000 pair) (116), Metal octet of Ca, Zn, Mn, Co (NC=1000t) (117), Refrigerator above zero for crops (NC=5000t) (118).

Iranian Mining and Aggregate Industries (IMAI)

IMAI encompassed 26 various types of industries as (1) Bitumen blown 90/15 (NC= 27000t), (2) Building plaster (NC=150000t), (3) Ceramic dishes (NC=250t), (4) Ceramic tiles (NC= 600000 m^2), (5) Floor Tiles (NC=600000 m^2), (6) Glazed tile and ceramic (NC=150000t), (7) Gypsum (NC= 500 packages), (8) Industrial ceramic parts (NC=300t), (9) Ceramic brick (NC=30000000 moulds), (10) Fire-brick (NC=10000t), (11) Façade brick (NC=30000 pieces), (12) Semi-automatic brick (NC=30000000 moulds), (13) Hot asphalt (NC=135000t), (14) Building lime (NC=75000t), (15) Orthopedic bandage (NC=1300000 rolls), (16) Rock wool (NC=1500t), (17) Glass wool (NC= 7000t), (18) Stone powder and mosaic (NC= 18000t), (19) Precast pressed beam and concrete pile (NC=15000 pieces), (20) Gypsum prefabricated walls (NC=356400 m^2), (21) Prefabricated wooden wall by wood powder (NC=15000 m^3), (22) Cutting granite stone (NC=30000 m^2), (23) Grindstone (NC= 500t), (24) Broken stone and debris washed (NC=200000t) (25) Mineral powders (NC=200000t), (26) Cement asbestos tube (NC=500t).

Iranian Wood and Cellulose Industries (IWCI)

IWCI included 16 types of industries based on confirmation information in IIO such as (1) Cooler bangs (NC=1400t), (2) Carton (NC=1500t), (3) Industrial drying wood (NC= 7500t), (4) Hydrophilic cotton (NC=400t), (5) Sheet rolls and packing (NC= 1000t), (6) Wax paper (NC= 1000t), (7) Booklet (NC=2600000 No), (8) Hasp (NC=120000 No), (9) Decal (NC=6250000 piece), (10) Multilayer paper bags (NC= 12000000 No), (11) Row board (NC=12000 Piece), (12) Wooden and paper disposable products (NC=7565000t), (13) Wooden pencil (NC=324000 No), (14) Carbon paper (NC= 450000 package), (15) Parquet (NC=150000 m+150000 m^2), (16) Sandpaper (NC= 2000000 m^2).

Iranian Food Manufacturing Industries (IFMPI)

IFI comprised many of confirmed industries in the industries organization in Iran such as (1) Barley water (NC=30000000 bottles), (2) Cake and muffins (NC=650 kg), (3) Canned Beans and Caviar Eggplant (NC=3700 No), (4) Canned fish (tuna) (NC=11000 No+1056t), (5) Canned meat (NC=6500000 bottles), (6) Canned mushrooms (NC=2800000 bottles), (7) Compote (NC=8000000 No), (8) Concentrated fructose syrup of corn sugar (NC=2400t), (9) Corn Flakes (NC= 600t), (10) Fantasy Bread (NC=1000000t), (11) Fish food (NC= 12000 kg), (12) Glucose from starch (NC=2160t), (13) Hamburger (NC=1000t), (14) Margarine (NC= 12000t), (15) Milk, yogurt and pasteurized cream (NC=8255t), (16) Date sap (NC=2000t), (17) Potatoe based foods (NC=800t), (18) Poultry slaughterhouse (NC=3780000 No), (19) Iodized salt (NC=10000t), (20) Starch from wheat (NC=1580t), (21) Treating fish (NC=1000t), (22) Wafer chocolate (NC=500t), (23) Alcohol from beet molasses (NC= 1500000 No), (24) Mineral water (NC= 12000t), (25) Wheat flour (NC=27000t), (26) Pistachio packaging (NC=1269.5t), (27) Packing grains; peeling off barley (NC= 2430t), (28) Spice Packing (NC=250t), (29) Fruit packaging (NC=10000t), (30) Wafer biscuits (NC=1000t), (31) Corn grits (NC= 5800t), (32) Biscuit (NC=1000t), (33) Soya protein (NC=1900t), (34) Mushroom cultivation (NC=600t), (35) Cheese from fresh milk (NC= 1500t), (36) Cheese Pizza (NC=1500t), (37) Meat and Olive Industrial Powder (NC= 545.5t), (38) Fish powder (NC= 500t), (39) Artificial sausage and sausage coating (NC=243t), (40) Preparation; packaging of honey (NC=24000 No), (41) Purification and packaging of salt (NC=21600t), (42) Cream dyed (NC= 1400t), (43) Dates and liquid sugar (NC=4680t), (44) Smoked fish (NC= 15t), (45) Tomato paste (NC=1500t), (46) Flour string (NC= 24192 No), (47) Olive oil (NC=280t), (48) Oil Seeds from Vegetable Seeds (except soya; olive) (NC=8000t), (49) Drying oils (NC= 1500t), (50) Dried vegetables (NC= 1412000 No), (51) Soya sauce (NC= 60000 barrels+72000 bottles), (52) Ketchup (NC= 16000t), (53) Food sauces (NC= 4451998 (bottles 300 g)+1250000 (bottles 120g)), (54) Raisin Packaging (NC= 1000t), (55) Dates packaging (NC= 400t), (56) Sausage (NC=1000000t), (57) Ice (NC= 12920t).

Iranian Plastic Industries (IPI)

Types of IPI based on NC comprised 21 industries such as congressional sheets of PP (Polypropylene) and PS (Polystyrene) (2000 T (Ton)), (1), Flat sheets of PP and PS (1200t), (2), Plastic waste recycling (630t), (3), Plastic buttons (100t), (4), PVC (Polyvinylchloride) hose (500t), (5), Plastic rope (1000t), (6), PVC flooring (1700t), (7), PP bags (900t), (8), Plastic bags (1052.67t), (9), PE (Polyethylene) pipes and fittings (1500t), (10), PVC pipes and joints (1400t), (11), Plastic welding artifacts (1000000 No = Number), (12), Plastic bottle (18000 No), (13), PVC shoe bed (2160000 No), (14), Plastic Box (Fruit, Chili) (246140 No), (15), Plastic flashlight (600000 No), (16), PVC gum (4854109 No), (17), Plastic shaver (75000000 No), (18), Cellular Plastic Sheets (385000 m^2), (19), PVC film for agricultural use (21600000 m^2), (20), Plastic products (175.26t+13580 rolls), (21).

Iranian Electronic Products Manufacturing Industries (IEPMI)

Types of IEPMI based on NC comprised 33 industries such as Flux wire (NC=2000t) (1), Thermostat samovar (NC= 200 kg) (2), Automatic starter (NC=100000 NO) (3), Automotive starter (NC=20000 NO) (4), Automatic selector (NC=5400 NO) (5), Adapter (NC=100000 NO) (6), Ampere meter, voltmeter (NC=200000 NO) (7), Alarm (NC=100000 NO) (8), Desktop phone device (NC=20000 NO) (9), Electrical connector (NC=5000 NO) (10), Electro-Motor (NC=120000 NO) (11), Electronic thermostat (assembly) (NC=20000 NO) (12), Electronic laboratory devices (NC=10000 NO) (13), Electronic encoder lock (NC=100000 NO) (14), Electric key and socket (NC=500000 NO) (15), Soldering iron (NC=110000 NO) (16), Sockets and rods (NC=2000 NO) (17), Flashing device (NC=20000 NO) (18), Home electric drill (NC=10000 NO) (19), Household Emergency Light (NC=20000 NO) (20), Gas torch relay (NC=50000 NO) (21), Limit Switch (NC=70000 NO) (22), Moonlight ballast (NC= 200000 NO) (23), Moonlight Starter (NC=2000000 NO) (24), Paper loudspeakers (NC=500000 NO) (25), Projector and spotlight (NC=100000 NO) (26), Plugs and screws head (NC= 800000 NO) (27), Pocket radio (NC=40000 NO) (28), Trans-amplification (NC=100000 NO) (29), Trans moonlight (NC=450000000 NO) (30), Thermal relay (NC=60000 NO) (31), Coaxial cables (NC=408000 crank) (32), Electronic boards and printed circuits (NC=20000 m^2) (33).

APPENDIX 2

List Price of Products of Industries

Table 11. The prices of products of industries for ITLI

Industry	$	Total $
(1) Bag (NC=120000 No)	19	2280000
(2) Carpet thread (NC=600t)	3	1800000
(3) Cotton spinning (NC=1400t)	2	2800000
(4) Jeans (NC=81000 No)	5.7	467307.7
(5) Leather artifacts (NC=90000 No)	3	270000
(6) Leather shoes (NC=135000 pairs)	5.7	778846.2
(7) Quilts, mattresses and pillows (NC=85000 No)	3	255000
(8) Raw leather (NC=618300 Ft^2)	2	1236600
(9) Sewing and embroidery thread (NC=150t)	2	300000
(10) Spinning (NC=2500t)	3	7500000
(11) Tannery (NC= 45500 skin covers+214.988t)	9+2.7	409500+578813.9
(12) Underwear (embroidered series) (NC=350000 No)	Avg 3	1050000
(13) Wicker oil burner (NC=620000 No)	Avg 2	1240000
(14) Spinning the woolen yarn (NC= 306t)	3+10	528+204000
(15) Knitting cotton, synthetic fibers (NC=1000000 m^2)	Avg 2	2000000
(16) Band and medical wound texture gas (NC= 1407659 No)	4	5630636
(17) Rachel Curtain Fabrics (NC=330000 m)	10	3300000
(18) Mink blankets (NC=500000 m^2)	Avg 20	10000000
(19) Woolen blanket (NC=131500 No)	Avg 19	2498500
(20) Spinning wool (NC=263.5t)	3	790272
(21) Palash and blanket (NC=2250000 m^2)	6	13500000
(22) Winter clothing (NC=137500 No)	8	1100000
(23) Clothing (shirt) (NC=135000 No)	8	1080000
(24) Knitted Tricot (NC=130t)	Avg 7	910000
(25) Fishing net (NC=270t)	6	1620000
(26) Stinger mosquito net (NC=300000 m^2)	2	600000
(27) Socks (NC=243000 jeans)	0.5	121500
(28) Crust leather (NC=2398000 Ft^2)	2	4796000
(29) Cotton gloves (NC= 62400 pair)	3	187200
(30) Leather gloves (NC=70000 pair)	8	280000
(31) Wipes (Cleansing) (NC=4000 yard)	1.5	6000
(32) Ribbon Weaving (NC=3000000 m)	0.2	15000000
(33) Carpet coverage (NC=54000 No)	10	540000

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Table 11. Continued

Industry	$	Total $
(34) Spinning silk (NC=102.8t)	8+4+1.5	388800+90800+32250
(35) Zipper (NC=3000000 m)	0.058	57692
(36) Animal skin pickle (NC= 200000 No)	1	200000
(37) Raw silk fabrics (NC= 330000 m)	16	5285328
(38) Layer on diapers and sanitary pads (NC=8750 m^2)	0.5	17500

Source: Authors' Calculations

Table 12. The prices of products of industries for IHAI

Industry	$	Total $
(1) Earphone (20000 No)	153.85	3076923
(2) Hairdryer Handheld (100000 No)	4.5	450000
(3) Household ventilator (100000 No)	3.5	350000
(4) Household crystal containers (500t)	2	1000000
(5) Pyrex glass containers (100000 No)	5.26	526923.07
(6) Semi-Automatic Washing Machine (10000 No)	76.92	769230.77
(7) Tea flask (100000 No)	24	2403846.15
(8) Teflon containers (211t)	19.23	4057.53
(9) Water Cooler (20000 No)	192.3	3846153.84
(10) Gas oven (12000 No)	192.3	2307692.3
(11) Steam iron (20000 No)	38.46	769230.77
(12) Juicer (48000 No)	2	96000
(13) Electrical miller and mixer (20000 No)	82.30	1546153.8
(14) Steam cooked double glazed steel (50000 No)	38.5	1923076.923
(15) Electrical stove (30000 No)	11.55	346153.85
(16) Gas stove (20000 No)	88.5	1769230.769
(17) Semi-automatic electric cooker (20000 No)	38.5	769230.76
(18) Ceiling fan (assembly) (50000 No)	123	6153846.154
(19) Desktop fan (100000 No)	38..85	53846153.84
(20) Household vacuum cleaner (assembly) (30000 No)	134.61	4038461.53
(21) Meat grinders (assembled) (40000 No)	96	3846153.846
(22) Chinese dishes (800t)	58	4640000
(23) Chinese decorative dishes (500t)	38	50000
(24) Samovar (electric and oil) (82500 No)	20.7	1707115.4
(25) Household refrigerator (15000 No)	1153.85	17307692.31

Source: Authors' Calculations

Table 13. The prices of products of industries for ICI

Industry	$	Total $
(1) Animal Feed from Agricultural Waste (NC=10000t)	0.115	1153846.154
(2) Animal drugs (NC= 500t+50000 No)	3	1501000
(3) Ammonium Chloride (NC=1500+2000t $NaSO_4$)	2+2	6000000
(4) Antifreeze (NC=960 m^3)	1	960000
(5) Baby carriage (NC= 25000 No)	58	1442308
(6) Blood Powder (NC=500t)	0.5	250000
(7) Buds of different seeds (NC=150t)	1	150000
(8) Barium carbonate (NC=3000t+1187t solfide sodium)	0.61+0.61	2554070
(9) Braided wax plates (NC= 130t)	4	520000
(10) Calcium carbonate (light and active) (NC= 19200t)	0.0057	110770
(11) Calcium carbide (NC=1350t)	1	1350000
(12) Clothes hanger and pin (NC=504000 No)	0.115	58153.85
(13) Disinfectants (NC=900000 L)	0.2	173076.93
(14) Fiberglass boat (NC=5000 No)	770	38461153.85
(15) Fiberglass pieces (NC=100t)	1	100000
(16) Fragrant aromas (NC=130t)	1	130000
(17) Glass- strip away (NC=650t)	1	650000
(18) Glucose from starch (NC=2160t)	2	4320000
(19) Healthy Soap (NC=1090t)	1	1090000
(20) Helmet (NC=65000 No)	9	585000
(21) High pressure hoses (NC=240t)	1	240000
(22) Household Lighting Candles (NC=7560 No)	2	15120
(23) Insecticide coil (NC=50000 No)	2	100000
(24) Isolator (NC=2000000 m^2)	1	2000000
(25) Kitchen lighter (NC=100000 No)	2	200000
(26) Knife with injectable handle (NC=800000 No)	0.19	153846.2
(27) Adhesive plaster (NC=1700t)	1	1700000
(28) Lining materials and insulating gas pipes (NC=3500t)	0.27	942307.7
(29) Liquid fertilizer (NC=1250t)	2	2500000
(30) Matches (NC= 7776000 No)	0.192	1495384.5
(31) Mechanical disposable lighters (5000000 No)	0.192	960000
(32) Medicinal glycerin (NC=1500t)	0.42	634615.4
(33) Melamine dishes (NC=1000t)	2.3	2307692.3
(34) Metal flexible hose pipes (NC=309t)	2.42	74870.8
(35) Nitrobenzene (NC=1620t)	15.4	24923076.9
(36) Potassium chloride (NC=400t)	0.286	114400
(37) Printing ink (NC=500t)	2	1000000
(38) Rubber parts (NC= 25t)	2	50000

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Table 13. Continued

Industry	$	Total $
(39) Shoe wax (NC=3750000 No)	0.38	1442307.7
(40) Soft polyurethane foam (NC=6000t)	0.115	692307.7
(41) Starch from wheat (NC=1580t)	0.57	911538.5
(42) Throw-away crockery (NC=962.35t)	1	962350
(43) Toothbrush (NC=5000000 No)	0.57	2884615.4
(44) Detergents (Shampoo, etc) (NC=1080t)	1	1080000
(45) Welding glasses (NC=50000 No)	17.5	876923
(46) Insecticide spray containing flavoring materials (NC=2700000 No)	1	2700000
(47) Acetic acid ester (NC=1200t)	3	3600000
(48) Phthalic anodic esters (NC=970t)	4.9	4812692.3
(49) Calcium stearates (NC=2592t)	2	5184000
(50) Boric acid (2700t+3600t $NaSO_4$)	3.65+0.135	10341000
(51) Hydrochloric acid (NC=3000t)	0.0068	17307.7
(52) Chromic acid (270t)	7.7	2076923
(53) Zinc oxide (500t+887.5 $NaSO_4$)	14.6 + 0.135	7427504.8
(54) Oxygen; Ar and N_2 (NC=3643200 m^3)	0.125+0.23+0.38	617616
(55) Alcohol from beet molasses (NC=5000 No)	3.65	18269.24
(56) Types of gaskets (200t)	2	400000
(57) Acid and distilled water (NC=1725 m^3)	0.115	199038.5
(58) Rubber plugs (NC=25t)	2	50000
(59) Sprinkler (NC=81000 No)	1	81000
(60) Sodium hypochlorite (NC= 837900 gallon)	Gallon:0.68	5697992
(61) Recycling silver from film and its solution (NC=40.40t)	Kg; 834	33693600
(62) Industrial Paraffin (NC=3000t)	0.5	1500000
(63) Raw silk fabrics (NC=330000 m)	2	660000
(64) Pacifier (NC=300000 No)	4	1200000
(65) Unsaturated polyester (NC=1000t)	2.11	2115384.62
(66) Bleach powder or hypochlorite calcium (NC=2700t)	0.28	764307.7
(67) Electrostatic coating (NC=81000 m^2)	2.3	186300
(68) Tri-calcium phosphate (NC=15000t)	0.192	2884615.385
(69) Hub and rubber ball (NC=360000 No)	1	360000
(70) Synthetic leather of polyurethane (NC=12000000 m^2)	3	36000000
(71) Gum stick (NC=200000 No)	1	200000
(72) Wood gum (polyvinyl acetate) (NC=7000t)	20 g = 1	350000000
(73) Shoe adhesive (NC=1800t)	3	5400000
(74) Medical and sanitary adhesives (NC=45600000 No)	Avg=0.115	5244000
(75) Toothpastes and health cosmetics (NC=800t)	1	800000
(76) Hexagon pen (NC=24000000 NO)	0.115	2769230.77

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Table 13. Continued

Industry	$	Total $
(77) Pen (NC=2000000 No)	0.115	230000
(78) Plugs and screws head (NC=800000 No)	0.57	461538.5
(79) Diethyl ether (NC=100t)	13	1269230.8
(80) CO_2 (NC=1800t)	0.23	414000
(81) Epoxy resin (NC=5475t)	7.7	42115385.6
(82) Alkyd resin (NC=17500t)	2	35000000
(83) Bakelite resin (NC=2000t)	0.46	923077
(84) Resin; urea formaldehyde gum (NC=1000t)	1	1000000
(85) Dyeing and printing of fabrics (NC=2000000 m^2)	0.5	1000000
(86) Transformer Oil (NC= 8100 m^3)	0.7	5774859
(87) Used motor oil and grease recycling (NC=3000 m^3 + 750t, grease)	0.57+0.57	2137500
(88) Drying oils (500t+1000t wastes)	38+0.46	19461538
(89) Rubber profiles (200t)	2	400000
(90) Insecticide spray (NC=2700 No)	2	5400
(91) Rubber glass head (NC=3240000 No)	1	3240000
(92) Canopy (NC=1540t)	2.3	3553846
(93) Butachlor 60% (NC=750t)	1.38	1038461.5
(94) Zinc sulfate (NC=3400t)	0.65	2223076.9
(95) Sodium sulfate (NC=25000t)	0.5	12500000
(96) Alkyl benzene sulphonation (NC=5000t)	1.07	5384615.5
(97) Sodium sulfite (NC=5000t)	7.7	38500000
(98) Sodium sulfide (NC=3000t)	7.5	22730770
(99) Sodium silicate (NC=3000t)	0.005	15000
(100) Drip irrigation system (NC= 1000 No+383.9t)	Avg; 12.5	4830572
(101) Glasses frames (NC=80000 No)	3	240000
(102) Oil filter recycling (NC=2000t)	Avg:0.25	125000
(103) Thermos and ice box (NC= 150000 No)	Avg; 15	2307692.3
(104) Industrial and consumable taps (NC=3000000 No)	7.7	23100000
(105) Teflon strips (NC=12393000 No)	0.1	1239300
(106) Hair comb (NC=1000000 No)	0.57	576923
(107) Glass artifacts (NC=1787.5t)	Avg; 2	3575000
(108) Industrial crystals (NC=1000t)	Avg; 1.53	1538461.5
(109) Spectacle glass (NC=500000 pairs)	Avg; 3	1500000
(110) Chinese insulator (NC=730t)	Avg; 0.76	561538.5
(111) Ceramic magnet (NC=869565 m)	3	2608695
(112) Tape (for electronic equipment) (NC=3370000 No)	1	3370000
(113) Fruit concentrate (NC= 19820t)	Avg; 0.57	11434615.4
(114) Shuttered windows (NC=330000 No)	6.92	2284615.4

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Table 13. Continued

Industry	$	Total $
(115) Hygiene products made of artificial stone (NC=4500t)	Avg; 4	18000000
(116) Household, industrial and medical gloves (NC=12600000 pair)	Avg; 1	12600000
(117) Metal octet of Ca, Zn, Mn, Co (NC=1000t)	Avg: 0.5	500000
(118) Refrigerator above zero for crops (NC=5000t)	0.77	3846153.9

Source: Authors' Calculations

Table 14. The prices of products of industries for IMAI

Industry	$	Total $
(1) Bitumen blown (NC= 27000t)	269.23	7269230770
(2) Building plaster (NC=150000t)	7.7	1153846154
(3) Ceramic dishes (NC=250t)	2	500000
(4) Ceramic tiles (NC= 600000 m^2)	2	1200000
(5) Floor Tiles (NC=600000 m^2)	2	1200000
(6) Glazed tile and ceramic (NC=150000t)	1	150000000
(7) Gypsum (NC= 500 packages)	0.36	182692.30
(8) Industrial ceramic parts (NC=300t)	2	600000
(9) Ceramic brick (NC=30000000 moulds)	0.23	6923076.9
(10) Firebrick (NC=10000t)	0.307	3070000
(11) Façade brick (NC=30000 pieces)	0.192	5769.23
(12) Semi-automatic brick (NC=30000000 moulds)	0.192	5769230.77
(13) Hot asphalt (NC=135000t)	38	5192307.7
(14) Building lime (NC=75000t)	0.223	557.5
(15) Orthopedic bandage (NC=1300000 rolls)	0.3	390000
(16) Rock wool (NC=1500t)	2	3000000
(17) Glass wool (NC= 7000t)	0.57	4038461.5
(18) Stone powder and mosaic (NC= 18000t)	19/t	342000
(19) Precast pressed beam and concrete pile (NC=15000 pieces)	3	45000
(20) Gypsum prefabricated walls (NC=356400 m^2)	1	356400
(21) Prefabricated wooden wall by wood powder (NC=15000 m^3)	2	30000
(22) Cutting granite stone (NC=30000 m^2)	8	240000
(23) Grindstone (NC= 500t)	4	2000000
(24) Broken stone and debris washed (NC=200000t)	11.5	2300000
(25) Mineral powders (NC=200000t)	1/kg	200000
(26) Cement asbestos tube (NC=500t)	40/t	20000

Source: Authors' Calculations

Table 15. The prices of products of industries for IWCI

Industry	$	Total &
(1) Cooler bangs (NC=1400t)	1	1400000
(2) Carton (NC=1500t)	0.115	173076.92
(3) Industrial drying wood (NC= 7500t)	576	4320000
(4) Hydrophilic cotton (NC=400t)	2.5	1000000
(5) Sheet rolls and packing (NC= 1000t)	2	2000000
(6) Wax paper (NC= 1000t)	2	2000000
(7) Booklet (NC=2600000 No)	0.384	998400
(8) Hasp (NC=120000 No)	2	240000
(9) Decal (NC=6250000 piece)	0.057	356250
(10) Multilayer paper bags (NC= 12000000 No)	0.115	1384615.4
(11) Row board (NC=12000 piece)	1	12000
(12) Wooden and paper disposable products (NC=7565000 No)	0.00385	29096.2
(13) Wooden pencil (NC=324000 No)	0.0385	12474
(14) Carbon paper (NC= 450000 Package)	3	1350000
(15) Parquet (NC=150000 m+150000 m^2)	9.6	2880000
(16) Sandpaper (NC= 2000000 m^2)	0.577	1153846.15

Source: Authors' Calculations

Table 16. The prices of products of industries for IFMPI

Industry	$	Total $
(1) Barley water (NC=30000000 bottles)	0.27	8076923
(2) Cake and muffins (NC=650000 kg)	2	1300000
(3) Canned Beans and Caviar Eggplant (NC=3700000 No)	0.335	1238076.92
(4) Canned fish (tuna) (NC=11000 No+1056t)	0.77+0.5	536470
(5) Canned meat (NC=6500000 bottles)	0.57	3750000
(6) Canned mushrooms (NC=6500000 No)	0.57	1615384.6
(7) Compote (NC=8000000 No)	2.42	19384615.5
(8) Concentrated fructose syrup of corn sugar (NC=2400t)	343.076	823384.61
(9) Corn Flakes (NC= 600t)	4	2400000
(10) Fantasy Bread (NC=1000000t)	Avg 0.38	380000000
(11) Fish food (NC= 12000 kg)	4.8	57600
(12) Glucose from starch (NC=2160t)	0.135	291600
(13) Hamburger (NC=1000t)	1	1000000
(14) Margarine (NC= 12000t)	0.65	7846153.85
(15) Milk, yogurt and pasteurized cream (NC=8255t)	0.9+0.9+2.5	7837500
(16) Date sap (NC=1200t+800t)	2+0.46	2769230.77
(17) Potato based foods (NC=800t)	2	1600000

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Table 16. Continued

Industry	$	Total $
(18) Poultry slaughterhouse (NC=3780000 No)	7.3	27594000
(19) Iodized salt (NC=10000t)	0.192	1923076.95
(20) Starch from wheat (NC=1580t)	2	3160000
(21) Treating fish (NC=1000t)	3	3000000
(22) Wafer chocolate (NC=500t)	3.2	1609615.4
(23) Alcohol from beet molasses (NC= 1500000 No)	3.85	5775000
(24) Mineral water (NC= 12000t)	0.134	1615384.6
(25) Wheat flour (NC=27000t)	0.23	6230769.24
(26) Pistachio packaging (NC=1269.5t)	4.6	5859230.77
(27) Packing grains; peeling off barley (NC= 2430t)	0.46	1121538.5
(28) Spice Packing (NC=250t)	5.1	1275000
(29) Fruit packaging (NC=10000t)	0.76	7692307.7
(30) Wafer biscuits (NC=1000t)	3.46	3461538.4
(31) Corn grits (NC= 5800t)	0.57	3346153.84
(32) Biscuit (NC=1000t)	1	1000000
(33) Soya protein (NC=1900t)	6.92	13148000
(34) Mushroom cultivation (NC=100t+500t)	1+38per t;	119000
(35) Cheese from fresh milk (NC= 1500t)	2	3000000
(36) Cheese Pizza (NC=1500t)	4	6000000
(37) Meat and Olive Industrial Powder (NC= 545.5t)	0.5	272750
(38) Fish powder (NC= 500t)	0.5	250000
(39) Artificial sausage and sausage coating (NC=243t)	1	243000
(40) Preparation; packaging of honey (NC=24000 No)	0.5	16800
(41) Purification and packaging of salt (NC=21600t)	0.192	4147200
(42) Cream dyed (NC= 1400t)	1	1400000
(43) Dates and liquid sugar (NC=4680t)	4	18720000
(44) Smoked fish (NC= 15t)	1	15000
(45) Tomato paste (NC=1500t)	0.5	750000
(46) Flour string (NC= 24192 No)	0.5	12096
(47) Olive oil (NC=280t)	3.5	990769.23
(48) Oil Seeds from Vegetable Seeds (except soya; olive) (NC=8000t)	0.27	2153846.15
(49) Drying oils (NC= 1500t)	380+0.27	380134618
(50) Dried vegetables (NC= 1412000 No)	0.385	770000
(51) Soya sauce (NC= 60000 barrels+72000 bottles)	1	372000
(52) Ketchup (NC= 16000t)	1	16000000
(53) Food sauces (NC= 4451998 (bottles 300 g) + 1250000 (bottles 120g))	1	1900666
(54) Raisin Packaging (NC= 1000t)	4	4000000
(55) Dates packaging (NC= 400t)	1.5	600000

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Table 16. Continued

Industry	$	Total $
(56) Sausage (NC=1000000t)	3	3000000000
(57) Ice (NC= 12920t)	1	1920000

Source: Authors' Calculations

Table 17. The prices of products of industries for IPI

Industry	$	Total $
(1) Congressional sheets of PP (Polypropylene) and PS (Polystyrene) (2000t)	1.35 kg	2700000
(2) Flat sheets of PP and PS (1200t)	1.35 kg	1620000
(3) Plastic waste recycling (630t)	7.69 kg	4846153.85
(4) Plastic buttons (100t)	Kg 1	100000
(5) PVC (Polyvinylchloride) hose (500t)	1	500000
(6) Plastic rope (1000t)	0.4 kg	400000
(7) PVC flooring (1700t)	Kg 2	3400000
(8) PP bags (900t)	3	2700000
(9) Plastic bags (1052.67t)	3	3158010
(10) PE (Polyethylene) pipes and fittings (1500t)	1.5	2250000
(11) PVC pipes and joints (1400t)	1.5	2100000
(12) Plastic welding artifacts (1000000 No = Number)	1	1000000
(13) Plastic bottle (18000 No)	0.038	692.307
(14) PVC shoe bed (2160000 No)	2	4320000
(15) Plastic Box (Fruit, Chili) (246140 No)	0.42	104136.16
(16) Plastic flashlight (600000 No)	2	1200000
(17) PVC gum (4854109 No)	1	4854109
(18) Plastic shaver (75000000 No)	0.077	5775000
(19) Cellular Plastic Sheets (385000 m^2)	1.5	577500
(20) PVC film for agricultural use (21600000 m^2)	0.358	7714285.714
(21) Plastic products (175.26t+13580 rolls)	1	188840

Source: Authors' Calculations

Table 18. The prices of products of industries for IEPMI

Industry	$	Total $
(1) Flux wire (NC=2000t)	2	4000000
(2) Thermostat samovar (NC= 200 kg)	10	2000
(3) Automatic starter (NC=100000 NO)	2	200000
(4) Automotive starter (NC=20000 NO)	8	160000
(5) Automatic selector (NC=5400 NO)	10	54000
(6) Adapter (NC=100000 NO)	1.5	150000
(7) Ampere meter, voltmeter (NC=200000 NO)	1.5	300000
(8) Alarm (NC=100000 NO)	2.5	250000
(9) Desktop phone device (NC=20000 NO)	12	240000
(10) Electrical connector (NC=5000 NO)	3	15000
(11) Electro-Motor (NC=120000 NO)	10	1200000
(12) Electronic thermostat (assembly) (NC=20000 NO)	20	400000
(13) Electronic laboratory devices (NC=10000 NO)	3	30000
(14) Electronic encoder lock (NC=100000 NO)	35	3500000
(15) Electric key and socket (NC=500000 NO)	0.7	350000
(16) Soldering iron (NC=110000 NO)	13.8	1523076.9
(17) Sockets and rods (NC=2000 NO)	0.8	1600
(18) Flashing device (NC=20000 NO)	10	200000
(19) Home electric drill (NC=10000 NO)	31	310000
(20) Household Emergency Light (NC=20000 NO)	30	615384.61
(21) Gas torch relay (NC=50000 NO)	76	3846153.84
(22) Limit Switch (NC=70000 NO)	9	630000
(23) Moonlight ballast (NC= 200000 NO)	3	600000
(24) Moonlight Starter (NC=2000000 NO)	0.28	553846.16
(25) Paper loudspeakers (NC=500000 NO)	4	2000000
(26) Projector and spotlight (NC=100000 NO)	10	1000000
(27) Plugs and screws head (NC= 800000 NO)	0.38	307692.30
(28) Pocket radio (NC=40000 NO)	14.6	584615.4
(29) Trans-amplification (NC=100000 NO)	5	500000
(30) Trans moonlight (NC=450000000 NO)	2	900000000
(31) Thermal relay (NC=60000 NO)	9	540000
(32) Coaxial cables (NC=408000 crank)	20	8160000
(33) Electronic boards and printed circuits (NC=20000 m^2)	10.38	207692.30

Source: Authors' Calculations

APPENDIX 3

The Values of Productivity in 8 Groups of Industries Based on Weighing Systems of Friedman (F) Test, CRITIC (C), AHP (A), and Entropy (E) Shannon

Table 19. The values of productivity

Industries	ITLI (F)	ITLI (C)	ITLI (A)	ITLI (E)	IWCI (F)	IWCI (C)	IWCI (A)	IWCI (E)
1	28.28474162	28.22112337	324.5917993	85.45192728	27.65261332	25.65872788	322.2540946	63.78821102
2	31.03402352	30.46269137	362.9485952	90.23248839	5.206372478	4.922717963	59.1440154	12.98892694
3	22.73657077	22.00511787	269.6486762	62.88493746	95.36756248	85.90298328	1157.385675	197.2863029
4	1.982685633	1.992735952	22.56691826	6.109183029	17.56357367	15.62118598	217.2907573	34.66843448
5	4.578455248	4.585401846	52.33737649	13.96781151	41.14167721	39.26462461	461.4160565	107.3160591
6	5.411588856	5.383507762	62.34363585	16.24015793	75.26511145	71.2163197	854.3167495	187.9873075
7	2.323548217	2.317553274	26.69130044	7.021014525	18.52105704	16.981313	219.1779661	40.89188494
8	19.49719859	15.64347628	310.9817264	37.36037652	10.22607703	8.612074024	137.9714304	17.0023493
9	3.608482378	3.01125469	53.43141248	7.38499056	9.054568599	8.463262128	104.431603	21.53981441
10	39.30254302	38.24298783	464.0437126	112.1125676	24.08472984	22.88524211	271.8396749	61.32045153
11	7.758768558	6.157053865	126.5706793	14.44398801	0.098619073	0.092525563	1.131125679	0.239251067
12	23.86439535	23.41618005	279.3880162	69.0294978	0.531341212	0.484951634	6.336333598	1.150408823
13	34.76147466	32.11944272	439.3528664	88.2322975	0.482206423	0.42731667	6.005755451	0.939500905
14	2.064423411	1.913761872	25.97184394	5.285624083	55.73852569	53.38222859	622.9548475	146.3147693
15	18.77679653	17.60464304	232.249176	47.84751248	25.2556022	20.62654199	361.4753965	37.88024602
16	121.7497278	118.4898079	1438.898528	347.3335263	29.14017815	25.81462704	362.368612	56.95353739
17	29.06554107	28.25398707	344.0416981	82.44149774				
18	103.2455891	102.3353716	1193.273517	307.3620951				
19	23.84401	23.43195986	278.4679375	69.52754036				
20	18.30140621	18.12870883	211.8314275	54.4112436				
21	98.9653709	88.93369833	1296.97559	229.8755524				
22	25.98438389	26.01773501	297.0494789	79.24079321				
23	13.13416584	12.97339272	152.5575763	38.57584305				
24	10.49874629	10.27978116	123.1539999	29.94541364				
25	35.69103244	35.07880251	416.9271266	104.2020851				
26	13.89526722	13.7640055	160.8293138	41.25661766				
27	2.446887215	2.13057493	33.68021503	5.383206367				
28	111.9294875	108.8653194	1320.824892	319.5719438				
29	10.98072622	10.32360436	135.2955436	28.84463486				
30	5.993153833	5.90877617	69.77542588	17.60846881				
31	0.23368462	0.21862799	2.890810204	0.608129445				
32	320.9847587	316.3606706	3737.96084	941.9402841				

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Table 19. Continued

Industries	ITLI (F)	ITLI (C)	ITLI (A)	ITLI (E)	IWCI (F)	IWCI (C)	IWCI (A)	IWCI (E)
33	17.94239208	17.52128215	211.1737468	51.52331341				
34	2.880954855	2.471922186	40.64902442	6.201181713				
35	0.775439545	0.773763658	8.892952877	2.348707271				
36	3.698576163	2.838743656	49.14904675	1.670577491				
37	129.4342381	124.3899984	1552.743322	357.4963273				
38	0.635000323	0.609725334	7.599997344	1.759485608				

Source: Authors' Calculations

Table 20. The values of productivity

Industries	IPI (F)	IPI (C)	IPI (A)	IPI (E)	IHAI (F)	IHAI (C)	IHAI (A)	IHAI (E)
1	44.41793319	24.04198114	530.4671459	62.50218206	245.3277691	169.9187075	6172.689377	785.9178477
2	22.73331964	12.62333888	266.1785347	32.91120964	12.05176331	9.264746111	250.796084	46.38687908
3	425.2331715	221.2365994	5246.070067	570.8739304	7.164480619	5.470041359	150.542977	27.12814651
4	3.894664833	2.285858611	43.81464984	5.995580185	22.14703727	17.00818802	461.3437549	84.92398839
5	18.77694266	11.0608396	210.7114567	29.02476659	3.511582778	2.539731942	80.80323394	12.02872367
6	7.317464387	4.220375198	83.33093562	11.05141308	42.13028328	32.68739945	863.8203629	164.6979613
7	41.35657024	23.07214918	482.5316699	60.0965361	49.36120444	37.78926064	1033.987055	188.5495122
8	50.23741533	28.42918732	579.995771	73.85373524	0.064972735	0.049284886	1.379754963	0.243246297
9	47.774362	28.50188213	531.5297702	74.94351472	63.39431441	47.57619886	1368.662642	232.1381902
10	37.85426443	22.36451406	423.9396117	58.72397648	32.64131723	24.9617202	684.2293237	124.0701639
11	67.9434971	40.00239318	762.7201262	104.9569099	18.75951336	14.3299659	394.1530968	71.26051883
12	55.14258903	32.3723598	620.2944535	82.80934808	3.577163513	2.733072765	75.17324992	13.61648026
13	0.014412027	0.008632932	0.159914649	0.022701885	54.79625453	41.98988736	1146.113517	209.6945959
14	129.8748901	72.21719093	1519.081496	188.0554342	71.58183954	54.64154781	1505.855528	271.685164
15	5.345974406	2.975094064	62.49002382	7.756693122	6.374941743	4.902241844	132.4818952	24.48943248
16	38.22914058	22.86107874	424.662853	60.10446333	70.35878529	52.24412221	1543.16957	251.476414
17	364.732127	208.0023046	4187.194294	543.5633452	11.40408136	8.236213066	263.7439182	39.11950073
18	78.34885387	46.60112435	873.4688496	122.4846776	136.4903438	104.9572794	2839.086916	525.6206578
19	43.38732926	24.73914524	498.1561903	64.59391033	383.9932503	292.091665	8124.106812	1447.979997
20	158.780702	94.1053697	1774.484917	244.3489716	112.2784208	86.11542585	2344.80636	430.2348792
21	6.018575816	3.500284963	68.13866629	9.174368153	126.3012915	95.88137149	2681.481825	475.0532974
22					25.18366518	18.94254387	541.16396	92.58882294
23					0.279055639	0.213960322	5.8151325	1.06300228
24					20.83543896	14.11272306	551.1781557	64.44282289
25					174.8338601	133.7046721	3665.504314	664.7822

Source: Authors' Calculations

Table 21. The values of productivity

Industries	IFMPI (F)	IFMPI (C)	IFMPI (E)	ICI (F)	ICI (C)	ICI (E)
1	42.52449118	25.38349732	54.03973156	29.18782943	15.39924409	134.6379765
2	24.61091874	16.2695762	33.57547553	48.38963956	25.60382195	270.2179378
3	13.58723203	8.372103806	17.65844445	51.7430607	27.43068768	165.6070506
4	2.392082427	1.360945925	2.936924597	42.51680932	22.51726368	253.8965112
5	65.15448253	39.98236695	84.37463216	22.4768005	11.89869926	122.9012978
6	19.76616824	12.06018033	25.45924169	7.360139224	3.886803186	31.4547342
7	121.5931333	72.40084961	154.2976678	11.329781	5.999005272	55.3365906
8	17.64017114	11.93131441	24.47410945	26.70243094	14.13450822	88.36862465
9	46.96437265	30.064109	62.57319911	16.85736228	8.924398153	77.33235921
10	16711.40312	10986.31379	22703.63231	0.602863965	0.318798894	3.46935247
11	2.03925801	1.30289975	2.648067362	25.4959163	13.33467768	121.1088767
12	4.801633891	2.92992211	6.182462695	3.39339539	1.79694969	13.38914106
13	36.95052398	23.9824836	49.80581905	6.953569791	3.673449111	38.6982686
14	90.09546265	58.14109742	120.2314591	445.9887495	236.1660627	2427.325185
15	53.22786063	28.14052355	61.95501226	3.122464663	1.648242394	16.3862676
16	53.72468437	32.59201755	68.94667214	2.105146	1.115361396	6.200948839
17	21.43711218	12.68203167	27.04289932	10.80074275	5.724459996	45.1233445
18	429.7637165	281.3687971	582.5729423	70.92532847	37.52547659	248.9898602
19	34.90183012	20.83222177	44.18967134	25.86133015	13.66719032	90.55382937
20	42.07895156	28.4754545	58.35955795	20.87780076	11.04667055	66.71075657
21	44.90582143	27.66200947	58.34357021	2.686613571	1.422285821	14.11683487
22	51.88613365	35.32428586	72.21482808	0.949292946	0.50242762	5.004124157
23	59.3472356	35.17220352	74.68597412	6.110825028	3.227453365	25.76530369
24	43.02239445	28.67617157	59.04991847	40.81772234	21.58326888	172.4430036
25	64.03098356	37.94803183	80.5802719	5.860773606	3.103319193	36.32781051
26	130.3900573	87.2494097	179.5661281	3.552193048	1.879699991	17.19315211
27	42.0760326	28.01741482	57.70869717	15.04802035	7.967662888	73.00103215
28	62.09230122	41.23277895	84.9688004	35.68357347	18.877837	142.4779781
29	80.60374215	47.55312295	101.5624462	83.3568969	44.05397648	336.0250823
30	91.17740284	56.3507469	118.6599514	23.86054922	12.60128843	137.5299339
31	36.63047194	23.0472137	48.16341429	10.27464282	5.435736373	54.81583882
32	26.34013907	16.27910495	34.27954214	9.983952452	5.265097385	55.32721963
33	272.6269669	171.5044479	357.4337874	14.1031926	7.464407356	85.00476858
34	2.271488885	1.400216711	2.948005488	0.989749012	0.524192108	5.573586839
35	63.60380205	35.48905876	76.77971418	1081.114927	570.5344395	5316.423975
36	111.9546332	64.31024069	138.3983451	2.746783287	1.450153229	9.20325263
37	9.743590247	6.24901015	12.99672669	34.26924308	18.10520783	143.9780366
38	5.346300204	3.287049033	6.924166698	1.561232332	0.824121197	8.1931338

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Table 21. Continued

Industries	IFMPI (F)	IFMPI (C)	IFMPI (E)	ICI (F)	ICI (C)	ICI (E)
39	3.413031552	2.099569933	4.429447602	81.6806244	43.1631714	357.2442187
40	0.784798631	0.513463585	1.061644955	31.85062276	16.81778426	153.4870377
41	65.66309228	39.34245907	83.47201809	11.96071821	6.329889092	69.36851379
42	5.868996076	3.662708358	7.685508878	10.67170102	5.655035318	46.68507806
43	157.3406941	99.08151297	207.1329194	72.08470065	38.07335732	410.3279042
44	0.395400508	0.244556143	0.515456999	18.53905389	9.819649585	94.37801795
45	12.16819597	8.228139813	16.86058845	34.22201077	18.12430737	178.2068054
46	0.182560692	0.123510218	0.253419176	86.97101178	45.99577301	485.0610445
47	13.58761439	7.456336863	16.22053446	83.47892186	44.16499807	354.6310692
48	24.43994488	8.966935254	10.53724206	98.82511645	51.86169306	430.2953602
49	9040.488437	5641.029741	11788.71546	92.12755912	48.75389279	369.5579973
50	11.53210034	7.101381262	14.95415812	128.1404197	67.72578778	546.9945702
51	5.245371408	3.475334285	7.140813698	0.345652551	0.182890549	1.339034733
52	280.8230962	186.0481198	382.6513986	82.57625013	43.72480101	394.4842285
52	26.21160254	17.15039234	35.49114921	112.3694347	59.34497805	363.3082821
54	74.53855435	48.02818736	99.97627384	2.023506787	1.075740772	3.931958147
55	24.41327164	16.35094464	33.54823371	0.187860728	0.09934802	0.586065068
56	67962.30033	40485.83894	86059.68703	5.016656063	2.655486701	28.72744587
57	27.16105526	14.87410334	32.43083872	7.661592035	4.056560073	34.51044108
58				1.727744106	0.912380253	10.10705682
59				2.261049424	1.197249133	12.47147508
60				109.8150917	57.95124307	475.6114141
61				2826.96591	1496.174199	13161.25835
52				31.20852976	16.53203903	151.9604405
63				16.40548838	8.683560658	84.60734723
64				48.35297198	25.58161054	269.8748482
65				40.65812103	21.50700544	182.7459703
66				17.65703268	9.346524523	85.51934356
67				5.071543266	2.685633664	16.42847789
68				27.88183935	14.70367428	146.0506613
69				8.621093479	4.555993779	52.64035465
70				385.0967556	203.6728439	2053.130796
71				8.39763498	4.446803474	39.13687281
72				3980.036801	2106.231442	15613.51735
73				77.96583406	41.2366006	467.1242959
74				262.9333918	139.1371252	1504.45216
75				21.31792342	11.28541876	106.7534949

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Table 21. Continued

Industries	IFMPI (F)	IFMPI (C)	IFMPI (E)	ICI (F)	ICI (C)	ICI (E)
76				25.45172015	13.47954617	141.1854518
77				4.187578656	2.216875792	24.25230711
78				10.72975863	5.679948475	66.6193676
79				52.31935495	27.62436897	211.1558669
80				5.227911887	2.770529211	11.87502041
81				966.4049502	509.3134185	5300.371825
82				716.1671056	379.1990754	3030.193536
83				22.22113359	11.74335529	100.4821832
84				16.37503724	8.689162118	44.65809945
85				3.46084785	1.836793045	8.249513515
86				202.9591476	107.0605585	1084.700062
87				41.57961694	22.02010833	122.8859564
88				460.129513	242.8480101	1782.19976
89				10.95816893	5.792863547	42.55856197
90				0.173942024	0.091991546	0.970122089
91				159.2000593	84.17523841	748.0250024
92				182.2771482	96.34208063	924.3363488
93				41.24874491	21.83191576	196.9658378
94				34.34032518	18.16130198	116.7743498
95				80.45393665	42.67319252	245.3387102
96				62.44374839	32.98390054	354.7786271
97				358.7654677	190.2092834	1013.578522
98				338.967865	179.5850534	1237.572202
99				0.341381594	0.180069225	1.975829631
100				57.54523484	30.47275463	295.0980489
101				3.423445683	1.808423339	19.73498641
102				5.039194114	2.666786653	28.14633417
103				32.15992409	16.99672855	161.6807081
104				685.6783434	362.7642172	3936.222503
105				15.26981625	8.083804782	96.09596482
106				26.01631139	13.75386972	139.0250654
107				59.28813386	31.24666156	309.2792926
108				14.5296336	7.634121656	83.06650898
109				20.33639909	10.74449206	175.2827995
110				4.312673413	2.28253473	24.09462044
111				59.6688954	31.6030866	304.0793335
112				87.36717559	46.21703048	493.611771

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Table 21. Continued

Industries	IFMPI (F)	IFMPI (C)	IFMPI (E)	ICI (F)	ICI (C)	ICI (E)
113				158.7991643	83.94101313	479.262904
114				22.99248547	12.16656103	137.6731424
115				192.9297369	102.1505255	1031.126864
116				99.54963521	52.67509357	467.8056309
117				20.10615067	10.62693002	112.0239112
118				86.62308452	45.80327767	304.1472322

Source: Authors' Calculations

Table 22. The values of productivity

Industries	IMAI (F)	IMAI (C)	IMAI (A)	IMAI (E)	IEMPI (F)	IEMPI (C)	IEMPI (A)	IEMPI (E)
1	184884.5149	146705.6804	2908541.33	1597485.52	43.95554984	29.22744572	374.9960683	547.7718681
2	15491.15375	13073.67729	223632.0628	152932.5561	0.101145435	0.069934142	0.784554572	1.371542358
3	5.19971652	4.230209573	79.39984716	47.90482593	3.475823975	2.425010314	26.40119777	47.94024718
4	10.92341671	9.093532352	162.4600781	108.9898232	4.015338341	2.740245038	32.21121928	53.35169928
5	17.47350778	13.56054906	282.7588251	140.4095274	0.873498706	0.610933131	6.596923687	12.10144581
6	1627.342419	1339.907786	24478.28155	15478.44303	3.467305983	2.39188591	27.06927096	46.89421836
7	6.898119302	5.516462643	107.42016	60.15629336	6.935164178	4.784381586	54.13858178	93.83508388
8	5.446588163	4.639781516	79.01779259	58.28547968	10.0268695	6.91717227	78.23389921	135.4733616
9	54.11760649	45.1336177	800.7884583	541.8762341	7.285822117	5.040008489	56.48812465	99.0218461
10	25.80245256	21.45252231	383.9930486	255.3489518	0.293316906	0.19901315	2.382437351	3.83490872
11	0.035098251	0.026433319	0.591470324	0.258751898	37.41201051	26.0701647	284.8606301	514.3131885
12	35.09825585	26.43332245	591.4704033	258.7519326	10.33447897	7.185587433	79.01442436	141.0062881
13	166.9880894	125.6336577	2806.801964	1222.120747	0.732791262	0.50786272	5.65844903	10.00662446
14	0.015757827	0.013293154	0.231045182	0.166735814	87.86204114	59.97698678	704.6221906	1169.158017
15	9.657226039	7.96436036	145.1826878	93.06312485	2.816097022	1.895752796	23.40978508	36.51898717
16	28.86978828	23.45464816	441.1077035	264.0608532	33.84295038	23.10236452	271.3220547	449.9498329
17	14.36789487	10.79259729	242.5518446	104.9499834	0.010889745	0.007620228	0.082073529	0.150562531
18	14.71537205	11.90200902	226.2450894	134.6142469	6.981031706	4.799624275	54.96847073	93.97696629
19	0.373688588	0.310428757	5.570253551	3.671103819	10.01095549	6.8432036	79.93860916	133.2434316
20	2.551803248	1.846038091	45.53391777	16.87220593	16.15745783	11.16305675	125.717116	219.402553
21	0.262092315	0.197505969	4.404667511	1.933652774	86.70127971	60.64898308	654.5598796	1201.525659
22	5.405298526	4.063354033	91.31726204	40.13032372	22.66750495	15.7086886	174.885088	308.5282704
23	56.30768567	46.93863059	836.1163062	560.2892071	5.806130983	4.057184894	43.94067869	80.26851107
24	16.0187723	10.59925778	334.3643314	86.05243192	12.63609009	8.774472674	97.01862428	172.6220908
25	2.10728523	1.806614266	30.36784752	23.11559643	13.7073582	9.546914279	104.3830787	187.6248375
26	0.082410251	0.065563754	1.29227739	0.711034352	21.94673495	15.07824236	172.9850536	294.9369769

continues on following page

Table 12. Continued

Industries	IMAI (F)	IMAI (C)	IMAI (A)	IMAI (E)	IEMPI (F)	IEMPI (C)	IEMPI (A)	IEMPI (E)
27					6.710164899	4.692286926	50.61215813	92.46375932
28					19.42885288	13.38395595	152.1694442	261.994108
29					3.564338164	2.49653979	26.81696313	49.43137494
30					25243.47569	17067.16263	206560.6002	327762.4162
31					9.319368332	6.43203979	72.53873017	125.5710225
32					46.33826421	31.76624622	366.3446255	614.9680462
33					3.658247414	2.444158621	31.0924872	47.1274424

Source: Authors' Calculations

Chapter 4
Distributional Effects of Reduction in Energy Subsidy: Evidence From Kuwait

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ABSTRACT

This study examined the distributional effects of energy subsidy reduction in Kuwait. A computable general equilibrium (CGE) model was calibrated on a Kuwaiti social accounting matrix (SAM). A simulation experiment was conducted by applying a 25% energy subsidy reduction. The SAM consisted of 10 household groups, categorized into nationals and expatriates, and subsequently classified into five income levels. The employed labor force was classified into two groups (nationals and expatriates), each disaggregated by four skill levels. Industries were disaggregated into 65 branches. The CGE model was specified in such a way that it would be possible to quantify welfare effects on each household group and then trace the changes to distributional effects, factor income, and employment by industrial origins. When accompanied by compensation, the energy subsidy led to an aggregate efficiency (increase in GDP) and welfare gains. The welfare gains among Kuwaiti nationals were progressive; the lower-income groups gained more than higher-income groups.

INTRODUCTION

Kuwait is one of the most energy-intensive countries in the world. In 1990, just before the Iraqi invasion, Kuwait's per-capita energy consumption was 4.3 tons of oil equivalent (toe). This increased to 9.1 toe in 2000 (a 110% rise), corresponding to more than a twofold increase in a decade. By 2015, the corresponding figure slightly fell to 8.8 toe, which was a 3.9% drop from the consumption level in 2000, but

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still represented a 102% increase over the 1990 level. Consequently, Kuwait is now the second highest country in the world in terms of per-capita energy consumption (after Qatar) (World Bank, 2020).

The per capita CO_2 emission of Kuwait was 21.1 tons in 2018, again placing Kuwait second in the world after Qatar. Kuwait's excessive energy consumption pattern is the result of an extremely generous energy subsidy. In 2018, Kuwait came first in world in energy subsidies, at US$1,308 per person.

For two decades (2000-2020), the size of Kuwait's economy nearly doubled in real terms, while that of population more than doubled, with an annual average population growth rate of rate of 4% (IMF, 2021). These rapid economic and demographic expansions have given rise to a growing awareness among researchers and decision makers that the existing energy policy is not compatible with the country's sustainable development goals (Kiranmai *et al.,* 2022).

Attempts to reform energy policy have encountered rigid opposition in parliament (Al-Saidi, 2020; Shehabi, 2020). The cause of disagreement has been the possible adverse effects of a subsidy reduction on welfare, and the political backlash that would result from it. However, the recent sharp decline in the price of oil in the world market has compelled the authorities to soften their position. Not only has a consensus been reached, but energy tariff reforms have already started in earnest.

Partial equilibrium modelling studies (BuShehri & Wohlgenant, 2012) have shown that it is possible to gain public support and avoid political backlash by paying a cash equivalent to compensation consumers for welfare losses. Gelan (2018a) applied a computable general equilibrium (CGE) modelling approach and extended the scope of the study to show that compensation of energy users not only leads to a reinstatement of household welfare, but it also causes marginal increases in both aggregate household welfare and the gross domestic product (GDP). Additionally, there could be gains in terms of environmental benefits measured in terms of reduction in CO_2 emissions.

The objective of this study was to examine the distributional effects of an energy subsidy reduction in Kuwait. The main source of prolonged delay in deploying an energy subsidy reduction has been concern about the potential adverse effects on social welfare. This study thoroughly investigated designs in energy reforms programs, in order to avoid or minimize deterioration in social equity or production efficiency. This study built on the results of Gelan (2018a), and disaggregated households by income classes and conducted extensive simulation experiments, focusing on the distributional outcomes of subsidy reduction (Husaini, Puah, & Lean, 2019; Rentschler, 2016).

STUDY CONTEXT

Kuwait spent US$5.5 billion on energy subsidies in 2019 (IEA, 2020). The bulk of this money went to electricity (57%), while the remaining proportion was shared equally between petroleum products and natural gas. These energy subsidies constitute 4% of Kuwait's GDP.

Kuwait's energy subsidy is approximately US$1,308 per person. This value puts Kuwait at the top in terms of world ranking, just above Iran (US$1,038) and Libya (US$838). This lavish energy subsidy rate did not happen by accident. The Kuwaiti government has a long-held policy to maintain a welfare state, using various subsidies as mechanisms to transfer wealth acquired from exploitation of the country's natural resources to citizens. For instance, "the government owns a vertically integrated monopoly and manages the entire supply chain from electricity generation to retail distributions" charging consumers a nominal tariff of 6 cents per kWh, one of the lowest in the world (Gelan, 2018a).

The dynamics of energy consumption in Kuwait are compared with selected countries along three broad categories of indicators (Table 1). The first indicator is the total primary energy supply (TPES) per capita, measured in toe. This converts and combines all energy types into a single composite indicator.

Table 1. Key energy statistics for Kuwait

Description	1990	2000	2015
Total primary energy supply (TPES) per capita (toe)			
Qatar	13.7	18.5	17.7
Kuwait	4.3	9.1	8.8
USA	7.7	8.1	6.8
OECD	4.2	4.6	4.1
EU	3.3	3.1	2.8
World	1.7	1.6	1.9
CO_2 emissions per capita (t CO_2/capita)			
Qatar	**26.1**	**35.9**	**31.3**
Kuwait	**13.2**	**22.6**	**23.3**
USA	19.2	20.3	15.3
OECD	10.3	10.8	9.1
EU	8.4	7.8	6.3
World	3.9	3.8	4.4
Sectoral share in total final consumption (TFC) (%)			
Kuwait			
Industry	43	39	36
Transport	25	25	26
Residential	**22**	**16**	**15**
Commercial & public services	0	7	7
Non-energy use	**10**	**13**	**16**
Qatar			
Industry	37	38	35
Transport	13	14	23
Residential	**6**	**6**	**8**
Commercial & public services	3	4	4
Non-energy use	**40**	**38**	**30**

Source: IEA. World Energy Balances 2019
https://www.iea.org/subscribe-to-data-services/world-energy-balances-and-statistics.

Kuwait's TPES in 2015 was 8.8 toe, about half of the corresponding figure for Qatar, and 1.3 times that of the USA. It was just over two times the OECD average, three times EU average, and nearly five times the world average. Kuwait's CO_2 emission per capital in 2015 was a quarter of Qatar's, 1.5 times that of the USA, and 5.3 times the world average.

The fact that Kuwait came second after Qatar in per-person TPES and CO_2 emissions obscures some essential differences. Kuwait's TPES and CO_2 emissions per capita in 2015 were 2 times and 1.8 times, respectively, the levels reached during the prewar 1990 period. The corresponding figures for Qatar were much lower—1.3 and 1.2, respectively.

By far the most significant difference between Qatar and Kuwait lies in the sectoral share in total final consumption (TFC) of energy, displayed in the lower part of Table 1. Focusing on the 2015 values, contrasting features are observed between sectoral shares for Qatar and Kuwait. For Kuwait, household residential consumption (15%) and transport (26%) exceeded the corresponding figures for Qatar by 8% and 23%, respectively.

The most persistent difference in the energy use patterns of the two countries is in the share of non-energy use. For Qatar, non-energy use had a share of 30% in 2015 (about twice that of Kuwait), 38% in 2000 (about three times that of Kuwait), and 40% in 1990 (about four times that of Kuwait). Non-energy use refers to energy products used as raw materials in production activities, rather than being consumed or transformed as fuel or transformed into another fuel. It means Qatar uses a lot of energy, but mostly as intermediate inputs; on the contrary, the bulk of energy used in Kuwait goes to household final consumption expenditures.

Energy subsidy reforms have been fiercely debated in the Kuwaiti parliament. Concerns that a subsidy reduction may adversely affect citizen welfare has led to rigid opposition by members of parliament. However, the sharp decline in the price of oil in the world market has made it impossible to maintain the existing subsidy regime (Kilinc-Ata, 2022; Bayramov & Islamli, 2022). Consequently, the dispute among parliamentarians has shifted to the extent of the subsidy reduction and its timing.

LITERATURE REVIEW

Distributional outcomes of subsidy reforms have been the focus of many recent studies. Energy subsidy reforms commonly remain essentially regressive and pro-rich due to poor design, often retaining features of a flat subsidy rate rather than explicitly targeting vulnerable households (Giuliano *et al*., 2020; Lin & Kuang, 2020; Schaffitzel *et al*., 2020).

Another strand of literature on energy subsidy reform has focused on mechanisms to overcome inequalities by switching to subsidizing energy-efficient buildings with low-carbon technologies (Stewart, 2021; Lekavičius *et al*. 2020). The potential distributional impacts of investment subsidies may improve energy efficiency in aggregate, but they tend to provide the greatest benefits to high-income households.

The literature on Kuwait's energy sector is extremely scarce, with analysts focusing exclusively on various aspects. The bulk of studies have applied descriptive statistics to examine, for instance, drivers of Kuwait's recent rise in energy consumption (Azar *et al*., 2021; Alotaibi, 2011). Other studies have focused on the impact of heavily subsidized energy prices on the residential building sector (Ameer & Krarti, 2016), cogeneration of power and water desalinated (Ghaffour *et al*., 2015; Darwish & Darwish, 2008), and the environmental impacts of Kuwait's refineries (Al-Salem, 2015).

Gelan (2018a) classified analytical models applied to Kuwait's energy sector into three broad groups. The first group was econometric models (Al-Mutairi & Burney, 2002; Burney & Al-Matrouk, 1996), which focused on economies of scale, energy conservation in power plants, and factor substitution possibilities in production processes.

The second category was a partial equilibrium modeling approach (BuShehri & Wohlgenant, 2012) that analyzed conflicts that might arise due to the inevitable adverse effects of electricity subsidy removal or reductions in household welfare. This was related to concerns that explain the reluctance of Kuwaiti parliamentarians to indulge in full-fledged energy subsidy reform. The findings of this study implied that compensation of consumers for losses in welfare was justified to avoid welfare losses (social concerns), gain popular support for subsidy reform, or preempt public protests (political concerns).

Bourgeois, Giraudet, & Quirion (2021) used 'subsidy recycling' as an alternative expression for cash payments or compensations. They found "*lump-sum recycling to be particularly effective in reducing inequalities between owner-occupiers and tenants…. In turn, subsidy recycling saves energy and increases comfort more cost effectively... In the discussion, we argue that subsidy recycling has advantages from both a political and administrative perspective*."

A series of recent studies have broadened the scope of analysis (Gelan, 2018a; Gelan, 2018b; Shehabi, 2020). These studies adopted a CGE modelling approach that allowed the authors to capture the economy-wide feedback effects of subsidy reductions. Importantly, the motivation for subsidy reform was extended beyond social and political concerns to incorporate economic and environmental dimensions. The first such study was Gelan (2018a), in which the author examined the economic, social, and environmental effects of electricity subsidy reductions. This was followed by Gelan (2018b), which extended the scope of energy subsidy reductions to all energy products, namely electricity, oil, and gas.

The findings of both studies indicated that energy subsidies with compensation would lead to an aggregate increase in GDP from baseline and reduced environmental costs in terms of CO_2 emissions. However, although these previous studies applied detailed sectoral breakdowns to measure CO_2 emission and economic gains, social welfare and income distribution effects were measured only at aggregate level; a representative household for the Kuwaiti economy and two labor categories, nationals and expatriates.

This study aimed to fill the gaps in the previous studies by disaggregating households by nationality, and income quintiles and labor. First, they were disaggregated into two nationality categories (Kuwaiti nationals and expatriates), and then by four skill levels. The modelling framework and the baseline data applied in this study are discussed in the subsequent sections.

THE MODEL

This study was conducted using a CGE modelling approach. The structure of the CGE model is described in this section. Figure 1 presents a diagrammatic exposition and highlights the processes of production, commodity supply, and demand. The model equations are presented in Appendix– II.

The Process of Production and Commodity Supply

The Kuwaiti CGE model was previously developed and applied in Gelan (2014, 2018a, 2018b). The basic structure of the model and the construction of a comprehensive baseline database, the social accounting matrix (SAM), followed the comparative static version of the standard International Food Policy Research Institute (IFPRI) CGE modelling tradition, specifically having a SAM with supply and use at its core (Lofgren, Harris, & Robinson, 2002). Due to the focus of the current and previous studies on energy policy, the model specification progressively departed from the structure of the IFPRI model and moved towards strands of models in energy-environment and society interactions (Lee, Oliveira-Martins, & Mensbrugghe, 1994; Pan, 2005).

The model structure, and the functional forms for commodity production (or supply) and commodity demand are presented in Figure 1 and Figure 2, respectively. In each case, model specification followed a nested, multilevel structure. The functional forms are denoted by letters, as follows: C (Constant Elasticity of Substitution, CES), CT (Constant Elasticity of Transformation, CET), L (Leontief), E (Linear Expenditure System), S (share parameters), and + (simple sum aggregations).

The structure of labor demand is displayed on the left-hand side, at the bottom of the production nest (Figure 1). In the Kuwaiti economy, employment is classified by nationality. In the diagram, Labor demand for nationals (LDNs) and average wage rates for nationals (WNs) denote the number of Kuwaiti nationals and their average wages, respectively. Similarly, labor demand for expatriates (LDEs) and average wage rate for expatriates (WEs) represent the number of expatriates in the labor force and their average wages, respectively. Nationals and expatriates were each classified into four skill levels, with level one representing the least-skilled workers and level four representing the most-skilled workers. The composite demand for labor (LDs) and average wages (WLs) were obtained by aggregating nationals and expatriates in each skill level.

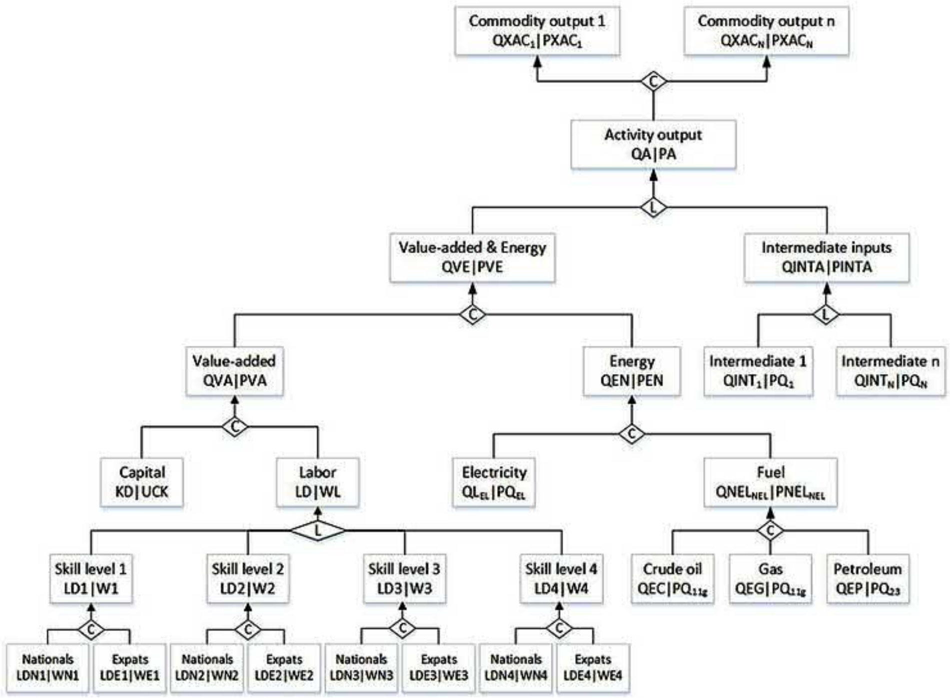
The substitution possibilities are complicated by the reality of labor market conditions in Kuwait. That is, even if they are unskilled, nationals are highly unlikely to be employed in low-skill jobs. This fact is accounted for by using low substitution elasticities for skill level 1, slightly higher elasticities for skill level 2, etc. At the next level, the Leontief aggregation combines skills to obtain composite labor demand and aggregate wage level (LD, WL). This means, for instance, that skill level 1 is not substitutable with skill level 4. Further, the value-added (QVA) and price of value-added (PVA) are obtained by aggregating labor and capital stock (KD) with user cost of capital (UCK) with aggregate labor demand (LD) with average national wage (WL).

The factor market equilibrium requires that two of these variables be fixed and the other two be flexible. Accordingly, from the factor price side, the economy-wide factor price was allowed to be flexible but the factor price differential was fixed at the baseline level. Similarly, factor quantities by industries were assumed to be flexible, but the economy-wide factor quantity was fixed at the baseline level. These specifications were chosen deliberately to isolate the effect of policy shock.

In line with CGE modeling in the tradition of energy-economy-environment interactions, value-added is aggregated with composite energy demand to obtain the value-added and energy composite (QVE) demand and composite price of value-added and energy (PVE). The innovation in such models has been that energy products, although intermediate, are treated as substitutes with factor inputs. The OECD (Organization for Economic Co-operation and Development) Green Model was among the pioneers of introducing the possibility of factor-energy substitutions in the production function (Lee *et al*., 1994), and was subsequently applied in other studies (AlShehabi, 2012; Koesler & Schymura, 2015; Truong, Kemfert, & Burniaunx, 2007). The rationale behind the value added-energy substitution possibility is in the need to invoke the notion of energy savings occurring in the production process (Burney & Al-Matrouk, 1996; Koesler & Schymura, 2015).

Kuwait's input-output table presents broad energy classifications, with only four energy commodities; namely, crude oil, gas, petroleum, and electricity. Accordingly, the energy aggregate (QEN) is obtained by first aggregating the three fuel products (crude oil, natural gas, and petroleum) to obtain the fuel aggregate (QNEL), and then generating a composite energy product as a combination of electricity (QL) and fuel (or non-electricity).

Figure 1. Nested structure in the production function



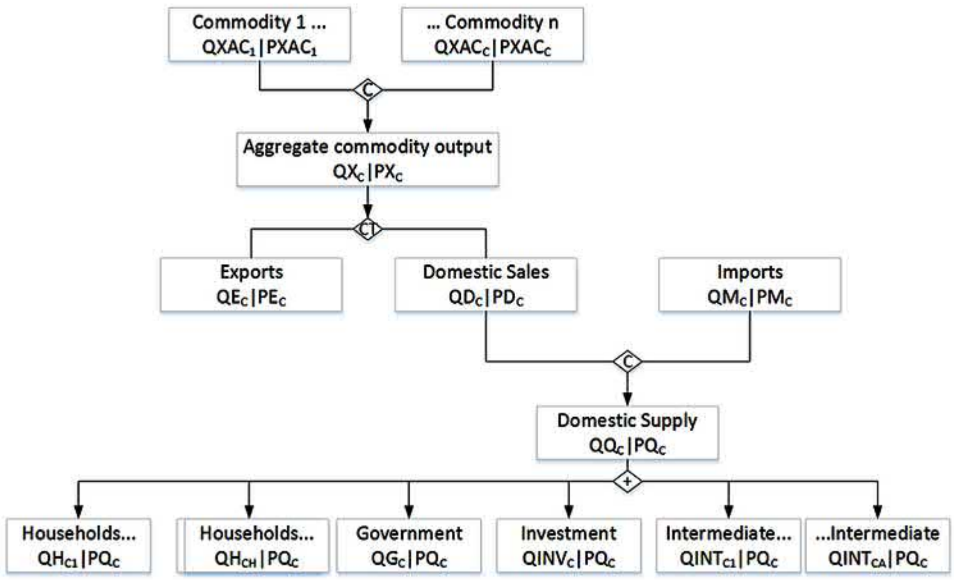
Composites of non-energy intermediate inputs (QINTA) were obtained by using a Leontief specification to combine non-energy intermediate material inputs (QINT). Finally, the gross input from each industry (QA) was acquired using the Leontief functional form by the aggregation of the value added-energy composite and the non-energy intermediate composites. The production nest ends with the commodity supply (QXAC), with each industry producing one or more products.

The Structure of Consumption and Commodity Demand

In Figure 2, the top nest shows the specifications and functional forms used in transforming the activity output to commodity outputs. This corresponds with the make matrix component of the SAM that links commodity supply and activity or industry outputs. The domestic commodity output (QX_C) totals were obtained by aggregating over the industry origins of commodities, $QXAC_{A,C}$ (commodity C produced by Industry A). The sum of commodities denoted by C and produced by activity A should equal the level of activity output (QA_A), as shown in Figure 1. Domestically produced commodity (QX_C) was allocated to domestic sales (QD_C) and export supply (QE_C) using a CET function.

The composite commodity demand in the domestic economy (QQ_C) was obtained using the Armington assumption (Armington, 1969). This assumption is employed by applying a CES aggregation of commodities by source of supply; that is, domestic output (QD_C) and imports from the rest of the world (QM_C). On the other hand, the total commodity supplied to the domestic economy is given as a summation of different demand categories, including non-energy intermediate demand by producing sectors ($QINT_{NE,A}$), household final consumption ($QH_{C,H}$), government final consumption (QG_C), and capital formation or investment demand ($QINV_C$).

Figure 2. Nested structure in commodity supply and demand



Below each final demand category lies the functional forms to specify commodity demand. For instance, demand for each commodity by households was specified using the linear expenditure system (LES), which allocates the total commodity demand into subsistence requirements, and then demand beyond the minimum requirement subject to additional income. For the other demand categories, demand for a specific commodity was derived using a fixed-share parameter obtained from the baseline SAM. The analytical model, presented diagrammatically and discussed in this section, was transformed into the structural algebraic equations presented in Appendix–II, which was then programmed using a General Algebraic Modelling System (GAMS) computer language to solve and obtain numerical values from the model.

SOCIAL ACCOUNTING MATRIX FOR KUWAIT

The CGE model developed through this study was calibrated to a Kuwaiti SAM developed with 2013 as its base year. The SAM was constructed by pooling data from a comprehensive set of socioeconomic databases in the Kuwaiti economy, and then establishing consistency between them. Further details on the methodological background for designing and constructing the Kuwaiti SAM are provided in Gelan *et al*. (2018). This section provides a brief highlight, anchoring the discussion on a condensed numerical SAM that shows a snapshot of the structure of the Kuwaiti economy by succinctly presenting the country's system of economic accounts.

The SAM is a comprehensive, efficient, and flexible method of presenting economic transactions rooted in the circular flow of income and expenditure. In a SAM, an account is listed in a column heading and then repeated in a row heading. This means that the number of rows and columns is equal in a SAM; that is, it is essentially a square matrix. A transaction is recorded only once in a cell, which, by definition, is an interaction between two institutional accounts. Therefore, the entry in a given cell represents both "payment" by the institutional unit in the column heading, and "receipt" by the institutional unit in the row heading.

The choice of base year was made primarily on the availability of data, particularly the Kuwaiti Supply and Use Table. The CGE model was developed by using a SAM with 145 by 145 accounts.

Table 2 presents a condensed version of the SAM with 34 by 34 dimensions. This was created mainly by aggregating products and industries each into five accounts, and the tax accounts into a single net taxes account. The dimensions of the remaining SAM accounts were left unaltered, as in the full SAM version.

Given that the focus of this chapter is energy subsidy, the energy products are listed separately, but all of the non-energy products are aggregated. Additionally, all energy products belong to the public sector. Hence, the five product and industry accounts are mostly public: three energy products/industries are listed separately, all other public sector products/industries are aggregated to "other public," and all private sector activities are aggregated to "private". Kuwait has a very simple energy mix, consisting of three products: the primary energy source (crude oil and gas), and two secondary energy sources (petroleum and electricity). Renewables have not yet entered the energy mix of Kuwait. Energy is exclusively produced in the public sector. The condensed matrix is presented over four pages, repeating the 34 row headings on each page, but showing the columns as four groups.

- Products accounts (1 to 5)
- Industry accounts (6 to 10)
- Labor accounts (nationals 11 to 14, expatriates 15 to 18)
- Capital account (19)
- Net taxes (20)
- Household accounts (nationals 21 to 25, expatriates 26 to 30)
- Government account (31)
- Gross fixed-capital formation account (32)
- Rest of the world (33)
- Totals (34)

It should be noted that there are 34 separate accounts, including the row and column totals (see Table 2). This means that there are 33 individual accounts. Each account has separate entries for totals, sum of receipts, or sum of payments. For instance, the total receipts by the government (government revenue), KD 24,032 million, is given at the intersection between row 31 and column 34. On the other hand, total payments made by the government (including surplus) is the corresponding total at the interaction between column 31 and row 34, which is given as KD 24,032 million.

As expected, total incomings and outgoings from the government account are equal. This holds true for all 34 accounts in the SAM; the total receipts and total payments for each individual account are equal. In other words, the numerical values under "Totals" in the column vector are equal to the corresponding values in cells in "Totals" in the row vector. The SAM is balanced when this condition is fulfilled.

A value in a particular cell in the SAM represents payment by an account in the column heading and receipt by an account in the row heading. For instance, the intersection between "Capital" (column 19) and the government account (row 31) is KD 24,339 million, which is the government capital income, which in turn reflects oil rent, one of the entries in the capital account row at the intersection between row 19 and column 6 (oil & gas industry).

Table 2. Kuwaiti social accounting matrix (million Kuwaiti Dinar; KD, 2013, balanced)

			PRODUCTS					INDUSTRIES				
			Oil & Gas	**Petroleum**	**Electricity**	**Other Pub**	**Private**	**Oil & Gas**	**Petroleum**	**Electricity**	**Other Pub**	**Private**
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
PRODUCTS	Oil & Gas	**1**						80	7953	388	30	
	Petroleum	**2**						4	1136	2613	98	204
	Electricity	**3**						3	1588		39	31
	Other Public	**4**		1			9	99	11	4	169	611
	Private	**5**	4	124		63	1686	1379	893	65	2020	9349
INDUSTRIES	Oil & Gas	**6**	33670			187	5					
	Petroleum	**7**		12883								
	Electricity	**8**			3586							
	Other Public	**9**				9158						
	Private	**10**					23786					
NATIONAL LABOR	Skill level 1	**11**						4	4	1	22	43
	Skill level 2	**12**						756	161	103	1659	515
	Skill level 3	**13**						216	48	105	518	199
	Skill level 4	**14**						364	131	131	2625	84
EXPAT. LABOR	Skill level 1	**15**						3	11		69	866
	Skill level 2	**16**						43	11	5	140	1807
	Skill level 3	**17**						21	1	8	322	176
	Skill level 4	**18**						71	6	12	729	704
CAPITAL		**19**						25115	1248	164	745	9163
NET TAXES		20	- 1503	- 746	- 1 684	- 6	139	5704	- 319	- 13	- 27	34
NATIONAL HOUSEHOLDS	Quintile 1	**21**										
	Quintile 2	**22**										
	Quintile 3	**23**										
	Quintile 4	**24**										
	Quintile 5	**25**										

continues on following page

Table 2. Continued

			PRODUCTS					INDUSTRIES				
			Oil & Gas	Petroleum	Electricity	Other Pub	Private	Oil & Gas	Petroleum	Electricity	Other Pub	Private
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
EXPATRIATE HOUSEHOLDS	Quintile 1	**26**										
	Quintile 2	**27**										
	Quintile 3	**28**										
	Quintile 4	**29**										
	Quintile 5	**30**										
GOVERNMENT		**31**										
SAVING-INVESTMENT		**32**										
REST OF THE WORLD		**33**	18	45		875	12012					
TOTALS		**34**	**32189**	**12307**	**1902**	**10277**	**37638**	**33862**	**12883**	**3586**	**9158**	**23786**

Table 3. Continuation of Table 2.

			NATIONAL LABOR				EXPATRIATE LABOR				CAPITAL	NET TAXES
			Skill level 1	Skill level 2	Skill level 3	Skill level 4	Skill level 1	Skill level 2	Skill level 3	Skill level 4		
			11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
PRODUCTS	Oil & Gas	**1**										
	Petroleum	**2**										
	Electricity	**3**										
	Other Public	**4**										
	Private	**5**										
INDUSTRIES	Oil & Gas	**6**										
	Petroleum	**7**										
	Electricity	**8**										
	Other Public	**9**										
	Private	**10**										

continues on following page

Table 3. Continued

			NATIONAL LABOR				EXPATRIATE LABOR				CAPITAL	NET TAXES
			Skill level 1	Skill level 2	Skill level 3	Skill level 4	Skill level 1	Skill level 2	Skill level 3	Skill level 4		
			11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
NATIONAL LABOR	Skill level 1	**11**										
	Skill level 2	**12**										
	Skill level 3	**13**										
	Skill level 4	**14**										
EXPAT. LABOR	Skill level 1	**15**										
	Skill level 2	**16**										
	Skill level 3	**17**										
	Skill level 4	**18**										
CAPITAL		**19**										
NET TAXES		**20**										
NATIONAL HOUSEHOLDS	Quintile 1	**21**		294	127	135					1049	
	Quintile 2	**22**		446	194	356					1566	
	Quintile 3	**23**	18	608	202	539					1883	
	Quintile 4	**24**	28	683	242	781					1449	
	Quintile 5	**25**	28	1163	321	1524					2781	
EXPAT. HOUSEHOLDS	Quintile 1	**26**					313		46	41		
	Quintile 2	**27**					303	159	62	77		
	Quintile 3	**28**					254	450	73	39		
	Quintile 4	**29**					66	561	228	253	831	
	Quintile 5	**30**					13	836	119	1112	2537	
GOVERNMENT		**31**									24339	1579
SAVING-INVESTMENT		**32**										
REST OF THE WORLD		**33**										
TOTALS		**34**	**74**	**3194**	**1086**	**3335**	**949**	**2006**	**528**	**1522**	**36435**	**1579**

Table 4. Continuation of Table 2.

			NATIONAL HOUSEHOLDS					EXPATRIATE HOUSEHOLDS				
			Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
			21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
PRODUCTS	Oil & Gas	**1**	1	1	2							
	Petroleum	**2**	25	31	31	31	31	6	9	7	11	28
	Electricity	**3**	25	30	37	39	45	9	11	11	12	22
	Other Public	**4**	55	79	127	85	149	42	56	61	68	105
	Private	**5**	820	1121	1432	1617	2006	317	432	494	528	828
INDUSTRIES	Oil & Gas	**6**										
	Petroleum	**7**										
	Electricity	**8**										
	Other Public	**9**										
	Private	**10**										
NATIONAL LABOR	Skill level 1	**11**										
	Skill level 2	**12**										
	Skill level 3	**13**										
	Skill level 4	**14**										
EXPAT. LABOR	Skill level 1	**15**										
	Skill level 2	**16**										
	Skill level 3	**17**										
	Skill level 4	**18**										
CAPITAL		**19**										
NET TAXES		**20**										
NATIONAL HHOLDS	Quintile 1	**21**		33	35	38	53	3	6	8	35	102
	Quintile 2	**22**	6		13	14	18	1	2	3	8	22
	Quintile 3	**23**	4	9		10	15	1	2	2	11	32
	Quintile 4	**24**	7	57	43		122	7	16	20	183	564
	Quintile 5	**25**	4	38	29	36		5	11	14	130	403

Table 4. Continued

			NATIONAL HOUSEHOLDS					EXPATRIATE HOUSEHOLDS				
			Quintile 1	**Quintile 2**	**Quintile 3**	**Quintile 4**	**Quintile 5**	**Quintile 1**	**Quintile 2**	**Quintile 3**	**Quintile 4**	**Quintile 5**
			21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
EXPATRIATE HHOLDS	Quintile 1	**26**	4	33	23	26	58		7	10	89	266
	Quintile 2	**27**	8	33	28	32	62	3		10	79	238
	Quintile 3	**28**	3	19	15	17	37	2	5		52	158
	Quintile 4	**29**										
	Quintile 5	**30**										
GOVERNMENT		**31**	618	693	710	1009	1236	512	516	542	336	806
SAVING-INVESTMENT		**32**	586	929	1251	1477	2818	3	4	5	2	20
REST OF THE WORLD		**33**										
TOTALS		**34**	**2166**	**3106**	**3776**	**4431**	**6650**	**911**	**1077**	**1187**	**1544**	**3594**

Table 5. Continuation of Table 2

			GOVERNMENT	SAVING-INVESTMENT	REST OF THE WORLD	TOTALS
			31	**32**	**33**	**34**
PRODUCTS	Oil & Gas	**1**		96	23638	**32189**
	Petroleum	**2**		111	7931	**12307**
	Electricity	**3**				**1902**
	Other Public	**4**	8073	53	420	**10277**
	Private	**5**		9530	2929	**37638**
INDUSTRIES	Oil & Gas	**6**				**33862**
	Petroleum	**7**				**12883**
	Electricity	**8**				**3586**
	Other Public	**9**				**9158**
	Private	**10**				**23786**

Table 5. Continued

			GOVERNMENT	SAVING-INVESTMENT	REST OF THE WORLD	TOTALS
			31	**32**	**33**	**34**
NATIONAL LABOR	Skill level 1	**11**				**74**
	Skill level 2	**12**				**3194**
	Skill level 3	**13**				**1086**
	Skill level 4	**14**				**3335**
EXPATRIATE LABOR	Skill level 1	**15**				**949**
	Skill level 2	**16**				**2006**
	Skill level 3	**17**				**528**
	Skill level 4	**18**				**1522**
CAPITAL		**19**				**36435**
NET TAXES		**20**				**1579**
NATIONAL HOUSEHOLDS	Quintile 1	**21**	248			**2166**
	Quintile 2	**22**	458		-1	**3106**
	Quintile 3	**23**	442		-2	**3776**
	Quintile 4	**24**	163		66	**4431**
	Quintile 5	**25**	160		3	**6650**
EXPATRIATE HOUSEHOLDS	Quintile 1	**26**	9		-14	**911**
	Quintile 2	**27**	19		-36	**1077**
	Quintile 3	**28**	23		40	**1187**
	Quintile 4	**29**			-395	**1544**
	Quintile 5	**30**			-1023	**3594**
GOVERNMENT		**31**			-8864	**24032**
SAVING-INVESTMENT		**32**	14437		-11742	**9790**
REST OF THE WORLD		**33**				**12951**
TOTALS		**34**	**24032**	**9790**	**12951**	

Source: Authors' Calculation using Gelan *et al.* (2018).

The SAM is a sparse matrix, such that many of the cells are zeros. The full sequence of economic accounts in Table 2 follows the United Nations system of national accounts (United Nations *et al*., 2008). The sequence of transactions in the SAM starts with the products account; continues along income generation, distribution, and use; and culminates with net-lending or net-borrowing in the capital and financial accounts, depicted in the cells where domestic institution accounts intersect with the rest of the world account (account 33).

Energy-related taxes and subsidy are accommodated in account 20, which is labelled as "net taxes." This incorporates net taxes (intersections of row 20 with columns 1 to 5). This vector represents an aggregation of product subsidies and import duties on goods and services. In the SAM, subsidies enter with negative values as negative taxes. The rates of product subsidies in the SAM are given by dividing the subsidy rows with the corresponding commodity value totals (in row 34). For instance, the rate of energy subsidy for the electricity sector is given as 88%, dividing the entry in cell (20, 5) with that in cell (34, 5). The total energy subsidy in the SAM is given as the sum of entries in cells (20, 1 to 4). This is given as KD -2.4 billion. Entry in the last cell of the product subsidy is a positive net tax because row 20 is an aggregation of the domestic product subsidy, plus import duties on products. For non-energy products (account 5) import duties (positive entries) exceed product subsidies (negative entries). Hence, net tax becomes a positive number (KD 139 million).

The second segment of energy finance is given in terms of net taxes on production. These are given at the intersection of row 20 with the industry columns (accounts 6 to 10). The first entry is a large positive number (KD 5.7 billion). This represents oil rent, government surplus from the oil and gas industry. It represents the bulk of government revenue from natural resource rent. Although the primary oil and gas sector generates huge rent, the secondary oil sector or petroleum processing industry (column 7) receives a net subsidy, amounting to KD -319 million. In Kuwait's economic accounting, the electricity subsidy is mainly considered as a product subsidy, leaving a relatively small sum as a production subsidy (KD -13 million).

Total net taxes are given as the sum of net taxes on products (KD -3.8 billion) and net taxes on production (KD 5.4 billion), resulting in a value of KD 1.6 billion. The positive net tax is attributable to the hefty sum of oil rent extracted from the primary energy industry (column 6).

The simulation experiments in the study involved exogenously reducing the energy subsidy rates, and then examining the economy-wide impacts of this change. Given that the SAM is a square matrix, the model is calibrated to replicate the baseline SAM; that is to say, the original SAM is fed into the model, which then generates the original SAM itself. It is only after calibrating the model and generating obtaining a balanced SAM that the model is suitable for conducting the simulation experiment. The impact of exogenous change is measured by comparing the simulation results with the baseline values from the original SAM.

SIMULATION RESULTS AND DISCUSSION

The CGE model was implemented by applying a 25% subsidy reduction to all energy products. This section starts by describing the simulation scenarios, and then presents key findings. The focus of the discussion is on the effects of the subsidy reduction on household welfare, which was the main objective of this study. The simulation results are systematically arranged to trace the channels through which the simulation shocks reverberate, and eventually affect household welfare. The discussion on the simulation experiments ends by highlighting the aggregate economic efficiencies and environmental effects of the subsidy reduction.

Scenarios

BuShehri & Wohlgenant (2012) stated that subsidy reductions would inevitably lead to adverse welfare effects. The implication was that subsidy reductions must be accompanied by cash payments to households to avoid political backlash. Gelan (2018a; 2018b) further established justification for compensating energy users, not just in social and political concerns, but also in economic rationale. For this reason, it was necessary to conduct separate simulation runs to examine the effects of the subsidy reductions "with compensation" or "without compensation" to all energy users (i.e., not just to households, but also to industries).

In this study, the simulation experiments were run in three scenarios.

- *Base*. In this scenario, the model was run to replicate the baseline SAM. The model was solved with no subsidy reduction; hence, this scenario served as a yardstick against which to compare the remaining scenarios that involved subsidy reduction shocks.
- *Without compensation*. This was a shorthand for subsidy reduction without compensating energy users. In this scenario, subsidies for all energy products were reduced by 25%.
- *With compensation*. This involved two shocks concurrently being applied. First, subsidies to all energy products were reduced by 25%, as in the *without compensation* scenario. Second, the budget savings from the subsidy reductions were allocated to the energy users (both intermediate and final demand) according to the share of each user category in total demand for the corresponding energy product.

In the subsequent sections, the results from the three rounds of simulation experiments are reported. The simulation results are organized and presented with a focus on distributional outcomes. Finally, the aggregate effects are presented and discussed to confirm the existence of equity and efficiency trade-offs.

Energy Price and Output Effects

This section discusses the effects of an energy subsidy reduction on energy outputs and energy price (Table 6). The results showed that outputs of all energy products fell from the baseline scenario. Without compensation, the largest impacts were on power plants, whose output fell by 15%. The corresponding contraction in oil refinery outputs was 12%. With compensation, outputs of most of the energy products fell by negligible percentage points. Oil refinery output increased by about 3%.

Without compensation, primary domestic prices for energy products fell, but those for each of the secondary energy prices rose from the baseline scenario. This result reflected interactions between own price and cross price effects with secondary energy products. When all energy products simultaneously received subsidy reduction shocks, the highest energy price increase occurred in electricity (by 14%). With compensation, the increase in electricity output was less pronounced (11%). The effect on petroleum products was relatively small, with an increase of 1.1%.

Table 6. Energy sector output and price effects

Descriptions/Scenarios	Without Compensation	With Compensation
Energy output		
Crude oil & gas	-6.01	-0.26
Petroleum products	-12.15	2.78
Electricity	-15.22	-0.92
Energy prices		
Crude oil & gas	-3.99	5.65
Petroleum products	1.72	1.07
Electricity	14.12	10.73

Distributional Effect

The distributional effects of the policy shocks are discussed in two stages. The impact of the subsidy reduction on household welfare is first discussed and is then followed by a discussion of the effects on household income and industry value-added, by way of providing explanations for the patterns of change in household welfare effects. The two effects are interconnected in that the welfare effects were linked to the income-generation effects of the policy shock.

Household Welfare

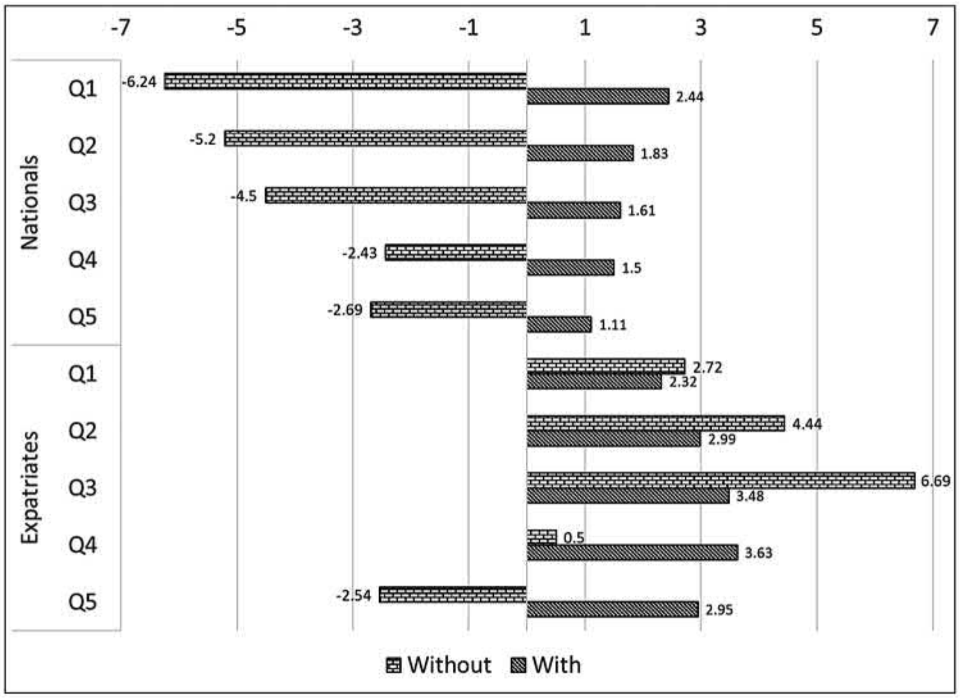
The ultimate test of the effects of subsidy reform is in the way it affects household welfare. The household welfare effects should be understood in the context of Kuwait's unique socioeconomic reality. The implicit understanding in Kuwait has always been that Kuwaiti nationals represent a permanent resident population, while expatriates are considered as transitory population. From the point of view of the authorities, the target beneficiaries of any policy initiative are the nationals—not only because of their permanent residence status, but also because they are citizens with a stake in national wealth.

The expatriates constitute about two-thirds of the population, and the bulk of the expats are permanent residents in terms of the duration of stay. However, this sector of the population are not citizens. Hence, they are not supposed to be the beneficiaries of a variety of public transfers, including energy subsidies. The authorities designed and began to implement energy subsidy policies with this rationale in mind and are expected to continue with this approach in the future. Bearing this unique case of Kuwait in mind, the effects of subsidy reduction effects on household welfare are discussed.

Figure 3 presents the household welfare effects of a uniform 25% subsidy reduction for all energy products. The effects of the policy shock are separately presented for nationals and expatriates, and then by income quintiles for each category.

Focusing on Kuwaiti national households, the subsidy reduction without compensation had mostly regressive impacts. The rate of decline in household welfare was the highest (-6.24%) for the lowest quintile (Q1), and declined consistently thereafter, reaching the lowest rate (-2.43%) for the fourth quintile (Q4). Welfare loss for the highest quintile (Q5) was slightly higher that of the next highest quintile. However, a subsidy reduction with compensation gives fully consistent progressive effects on household welfare along all quintiles. If accompanied by compensation, the 25% subsidy reduction led to a rise in the welfare of Kuwaiti national households of a minimum of 1.11% (Q5) to a maximum of 2.44% (Q1). The rate of welfare improvement for the remaining quintiles was 1.6% (Q2), 1.61% (Q3) and 1.83% (Q4).

Figure 3. Household welfare effects
**Qn = Quintile n*



Next, the patterns of change in the welfare of expatriate households in response to the subsidy reduction are considered. The impacts of the subsidy reduction on expatriate households were more mixed compared with the impacts on Kuwaiti national households. Expatriate households mostly experienced welfare gains, regardless of compensation—except for those households in the highest income bracket (Q5). Welfare changes for this sector of the population were similar to those for national households. Expats in the fourth quintile (Q4) experienced positive changes in welfare under both scenarios, but the welfare gain without compensation was negligible (0.5%). A much larger welfare gain was achieved with compensation (3.63%).

For expatriates in the lower income quintiles, a subsidy reduction caused a reasonably high welfare gain in both scenarios. In contrast to the results for Kuwaiti national households and expatriate households in the higher quintiles, expatriates in the lower quintiles experienced larger welfare gains when the subsidy reduction was not accompanied by compensation. The gap between the two scenarios increased from the lower- to the mid-income expatriate groups.

These patterns of change in household welfare can be explained by differences in household shares in energy consumption, the differential impacts of the subsidy reduction on industries, skill and the distribution of employment by nationality, and income factor allocations to the households. These factors are separately discussed in the subsequent sections.

Household Energy Demand

The differential welfare impacts reported in the previous sections can be partly explained by the initial conditions and changes in energy demand by the corresponding households. Table 7 displays the change in energy demand in response to the subsidy reduction. Columns A and B present the initial conditions in the share of each household group in total energy consumption, and the energy share in each household consumption budget, respectively. To begin with, the share of household categories in total energy consumption (A), it is noted that Kuwaiti nationals mostly had a share in aggregate household final energy consumption that was at least three times larger than that of expatriate households.

About 73% of total final energy went to nationals, while the remaining 27% was shared among the expatriate households. It should be noted that expatriates constitute about 70% of the total population, which means a significant difference between the two resident populations in per-capita energy consumption. Within each group, households in the lower quintile had lower share in total energy consumption. Similarly, in terms of the share of the household budget expenditure on energy (column B), Kuwaiti national households allocated more of their budget to energy than expatriates did. Also, the expenditure on energy by households in the lower quintiles was much smaller than that of households in the higher quintiles in each category.

Subsidy reductions are bound to affect production activities, income generation, and hence, factor incomes and ultimately household income. These items are discussed in detail below. Here, it suffices to state that any additional household income is allocated to consumption through the Linear Expenditure System (LES) (Lluch, 1973). In the LES demand function, households commit a certain proportion of their consumption budget to satisfy subsistence requirements on consumer goods and services (including energy products) in the first instance, and then allocate the remaining marginal income (supernumerary income) on consumption of consumer products above the minimum requirement for subsistence.

The allocation of supernumerary income is determined by the Frisch parameter (displayed under Column C), which captures the stylized fact that poorer households allocate a higher the proportion of their supernumerary income to consumption beyond the subsistence level. The average size of the Frisch parameter for the Kuwaiti nationals was kept lower than the corresponding figure for the expatriate households, and the value of the Frisch parameter for the quintiles within each household category was inversely related to income level (as shown in the reference table).

The effect of the subsidy reduction on welfare in the two scenarios was determined by the initial conditions and the size of the Frisch parameter (discussed above), combination of direct and indirect energy price effects (discussed earlier), and income effects (discussed below). The household energy demand effects in the two scenarios are presented in columns D and E. The patterns of change in household energy consumption by household group and income quintile closely followed the changes in household welfare discussed in the preceding sections.

As discussed earlier, the effect of a subsidy reduction on household welfare was determined by the impact of the policy shock on household income. The household income effect was the final stage in the chain reaction triggered by the subsidy reduction shock. It is useful to begin the discussion by examining industry value-added effects or the process of income generation in production activities. Logically, factor income effects come next, and last, allocation of factor income to households. These items are discussed in this order in the following subsections.

Table 7. Household energy demand effects

Income by Nationality	Household Share in Energy Consumption (%) (a)	Energy Consumptions Share in Household Budget (%) (b)	Frisch Parameter (c)	Change in Energy Consumption (%)	
				Without Compensation (d)	With Compensation (e)
Nationals					
Quintile 1	11.2	5.5	-2.0	-2.05	-0.59
Quintile 2	13.6	6.7	-1.8	-2.92	-1.01
Quintile 3	15.4	7.6	-1.6	-2.80	-1.11
Quintile 4	15.4	7.6	-1.4	-3.09	-1.44
Quintile 5	16.8	8.3	-1.2	-3.46	-1.68
Expatriates					
Quintile 1	3.3	1.6	-3.0	-0.69	-0.55
Quintile 2	4.3	2.1	-2.7	-0.61	-0.56
Quintile 3	4.1	2.0	-2.4	-0.36	-0.49
Quintile 4	5.2	2.6	-2.1	-1.04	-0.45
Quintile 5	10.6	5.2	-1.8	-1.42	-0.44

Source: Authors' Calculation

Industry Value-Added

The role of compensation was even more pronounced in industry value-added effects. For instance, industry groups encountering contractions without compensation experienced expansions with compensation. This is the root explanation for the corresponding reversals household welfare positions with compensation. In other words, if energy users were compensated for losses in welfare (households) or revenues (industries), then even the energy sectors would receive a positive stimulus from the shock received from reductions in energy subsidy.

Table 8. Industry value-added effects

	Sectoral Share in GDP	Changes From Base Year Values (%)	
		Without Compensation	With Compensation
Public	**72.40**	**-6.39**	**0.79**
Energy	58.50	-8.26	0.90
Manufacturing	0.29	5.04	0.98
Services	13.61	1.38	0.34
Private	**27.60**	**4.83**	**2.09**
Manufacturing*	3.71	7.77	-2.26
Services	23.89	4.37	2.77

*Includes agriculture.

Table 8 presents the effects of the 25% subsidy on sectoral value-added at broad industry aggregate levels (further details are presented in Appendix–I). Because the purpose of discussing industry value-added effects was to trace welfare effects back to industries, it was appropriate to classify the broad industry groups into public and private ownerships, which in turn are firmly linked to employment by nationality group.

The first column displays sectoral value-added shares in the baseline SAM. The public sector has a disproportionally large share in gross value-added (GVA) in the Kuwaiti economy (72%), with the private sector contributing the remaining proportion (28%). Energy (oil production, primary and secondary, plus power plants) dominates the public sector, and hence the entire economy, contributing 59% to GVA. It is important to note that public sector manufacturing has a negligible share (only 0.3%). Service dominates the private sector. These baseline conditions are critical to understanding distributional outcomes of a subsidy reduction.

Public sector value-added contracted by 6.4% on average. This is the net effect of sharp declines in the energy sector (-8.3%). There were only two subsectors in public sector manufacturing: food processing and petrochemicals, both of which experienced a positive stimulus, with an average increase of 5%. The private sectors were better off when the subsidy reduction was without compensation. In this scenario, the private sectors expanded, with manufacturing increasing by 7.8% and services increasing by 4.4%. The average increase in the private sector was 4.8%.

In the models, a subsidy reduction with compensation reversed the fortunes of the public and private industries. Compensation favored the public sectors; industrial GVA increased on average by 0.8% from the baseline. Ironically, a relatively larger stimulus went to public energy and public manufacturing, but a smaller stimulus went to public services. The stimulus to the private sector became smaller compared to the scenario with no compensation, but even with compensation the private sector received a much larger stimulus (2.1% on average), and private sector services expanded by 2.8%. One curious difference was that private manufacturing, which experienced the largest expansion without compensation, became the only sector to experience contraction (-2.3%) when the subsidy reduction was accompanied by compensation.

If the subsidy reduction was accompanied by no compensation, then public industries contracted more than private industries. On the other hand, if the subsidy reduction was accompanied by compensation, then the contractionary effects of the subsidy reduction on public industries became less pronounced but the contractionary effects on private industries were magnified.

The explanation for this symmetric effect on public and private industries is the fact that the bulk of the subsidies were allocated to public industries. If there were no compensation, then subsidy withdrawal would have a lasting effect on public industries. However, if compensation were to take place, then the demand stimulus would restore benefits to the public sector. On the other hand, if no compensation was made, then resource relocation from public to the private sector would take place and the private sector would become a beneficiary.

Factor Employment and Factor Income Effects

It should be noted that given the factor market assumption, the economy-wide demand for each factor category remains as in the baseline. To understand the manner in which the shock reverberates throughout industry groups, it is important to refer back to the nested structure as in Figure 1, where energy demand and factor demand are specified as substitutes. An increase in energy price is bound to cause some substitution away from energy to factors, but the extent to which factor quantity is employed would depend on the scale of contraction in that industry.

The largest declines in factor demand occurred in the energy sectors. As the power plants experienced the biggest shock, demand for all factor categories showed double digit declines. The petroleum product branch of manufacturing encountered a similar but slightly lower decline in factor demand than the power plants. On the other hand, chemical manufacturing experienced a modest increase in factor employment in both scenarios.

The preceding section discussed the asymmetric public and private sector impacts of a subsidy reduction with or without compensation. The contrasting effects on sectoral gross value-added were translated into factor incomes by nationality depending on the relative size of the impacts, whether the impacts were contractionary or expansionary, and the relative share of the specific factor employed in the corresponding sectors.

The distribution of the employed labor force by nationality and industry (described in Table 6) is shown in two columns headed ES (%), in bold font. The percentage shares in the two columns (under "public sectors" and "private sectors") add up to one hundred. In other words, the two columns represent the entire employed labor force of 2.4 million people in the baseline. About 74% of the labor force is employed in the private sector, and the remaining proportion is employed in the public sector. On the other hand, the expatriates constitute 79% of the employed labor force, the Kuwaiti national labor force accounts for only 21%.

Almost all of the nationals are employed in the public sector (17%). Only 4% of people are employed in the private sector. On the other hand, 70% of the expatriates are employed in the private sector, and only 9% of expatriates are employed in the public sector. In terms of industrial distribution, the bulk of the nationals are employed in public sector services (14.5%).

Similarly, 58% of labor-employed labor force are expatriates working in private sector services. It is now appropriate to link the foregoing discussion to the asymmetric impacts of a subsidy reduction on the public and private sectors, with and without compensation (displayed in Table 8). Given the concentration of the national labor in the public sector, and that the subsidy reduction affected the public sector more severely, it followed that compensation favored the national households whose welfare was firmly linked to public sector activities. The opposite was true for expatriate households, whose welfare depended on employment in the private sector.

A subsidy reduction accompanied by compensation would partially mitigate the relative advantage of the private sector, while the public sector would regain a previously established advantage. Regardless, the relative efficiency in the resource allocation effect of the subsidy reduction remained. Hence, the private sector expanded even with compensation (though by a smaller proportion) and the overall aggregate effect of the subsidy reduction with compensation was positive, as discussed in the subsequent section.

Household Income Effects

The columns under "Factor income" (Table 10) translate the effects discussed in the previous table The factor income effect was critically dependent on the sector of employment. Employment of the skilled Kuwaiti labor force was concentrated in the energy industries, primary and secondary oil, and electricity generation and distribution. These sectors received the policy shock, and its effect was much larger than that on any other sector. Therefore, the brunt of the policy shock could be expected to fall on variables linked to those sectors.

Table 9. Factor employment and income effects

	Public Sectors					Private Sectors				
	ES (%)	Change in Employment (%)		Change in Factor Income (%)		ES (%)	Change in Employment (%)		Change in Factor Income (%)	
		SRNC	SRWC	SRNC	SRWC		SRNC	SRWC	SRNC	SRWC
Energy										
Labor - Nationals										
Skill level 1	**0.02**	-10.37	2.80	-7.67	4.52					
Skill level 2	**1.69**	-9.53	1.43	-7.50	1.81					
Skill level 3	**0.58**	-11.15	1.33	-9.00	1.52					
Skill level 4	**0.54**	-10.39	1.65	-9.48	2.70					
Labor - Expatriates										
Skill level 1	**0.08**	-11.42	5.32	-8.09	7.46					
Skill level 2	**0.32**	-11.19	1.88	-4.42	1.56					
Skill level 3	**0.07**	-12.37	1.09	-5.53	-0.32					
Skill level 4	**0.13**	-10.63	1.01	-4.91	0.29					
Capital		-7.19	0.69	-8.27	0.81					
Manufacturing										
Labor - Nationals										
Skill level 1	**0.00**	3.21	1.35	6.99	1.32	**0.01**	2.73	-2.56	5.70	-2.20
Skill level 2	**0.04**	4.11	1.21	5.60	1.53	**0.17**	6.38	-3.10	7.09	-2.40
Skill level 3	**0.01**	4.32	1.33	5.30	1.37	**0.06**	7.25	-2.69	7.43	-2.25
Skill level 4	**0.01**	4.81	1.04	4.56	1.80	**0.01**	9.32	-3.81	8.20	-2.67
Labor - Expatriates										
Skill level 1	**0.06**	3.93	-1.04	8.89	-0.79	**1.62**	0.86	-1.93	6.22	-2.68
Skill level 2	**0.06**	3.08	-0.95	10.23	-0.93	**3.70**	-1.63	-1.79	5.92	-2.84
Skill level 3	**0.00**	3.48	-0.72	9.60	-1.28	**0.11**	-0.05	-0.87	6.60	-2.52
Skill level 4	**0.01**	3.61	-0.88	9.38	-1.03	**0.43**	0.43	-1.50	6.75	-2.74
Capital		5.71	0.97	3.70	0.96		11.81	-3.50	8.27	-2.10
Services										
Labor - Nationals										
Skill level 1	**0.14**	-0.97	0.25	2.79	0.14	**0.23**	1.38	-0.27	1.47	0.68
Skill level 2	**5.13**	0.10	0.14	1.56	0.37	**2.38**	6.06	-1.11	3.28	0.44
Skill level 3	**1.35**	0.32	0.23	1.30	0.21	**0.73**	7.73	-1.31	3.88	0.13
Skill level 4	**7.86**	0.53	-0.07	0.41	0.60	**0.17**	7.20	-1.63	3.26	0.03
Labor - Expatriates										
Skill level 1	**0.84**	-1.30	0.37	3.78	-0.09	**37.42**	0.01	0.07	5.53	0.17
Skill level 2	**1.64**	-1.99	0.47	5.05	-0.17	**21.06**	0.60	0.25	6.58	3.86
Skill level 3	**1.63**	-1.27	0.59	4.94	-0.70	**1.46**	2.00	-0.65	5.44	-0.38
Skill level 4	**3.85**	-1.66	0.50	4.25	-0.38	**4.37**	1.73	-0.32	5.16	1.04
Capital		0.80	0.50	-1.01	0.81		9.71	-0.85	3.83	3.28

Source: Authors' Calculation.

Notes: ES= baseline economy-wide employment share (%); SRNC=subsidy reduction without compensation; SRWC = Subsidy reduction with compensation

Table 10. Household income effects

	Factor Income		All Incomes	
	Without Compensation	With Compensation	Without Compensation	With Compensation
Nationals				
Quintile 1	-4.02	1.13	-3.23	1.37
Quintile 2	-3.85	1.11	-3.23	1.22
Quintile 3	-3.71	1.10	-3.23	1.24
Quintile 4	-3.24	1.05	-2.61	1.37
Quintile 5	-3.32	1.06	-3.01	1.28
Expatriates				
Quintile 1	4.66	0.12	1.27	1.24
Quintile 2	4.72	0.81	1.95	1.46
Quintile 3	4.94	1.53	3.02	1.72
Quintile 4	0.33	1.35	0.41	1.90
Quintile 5	-1.01	1.28	-1.30	1.79

When the subsidy reduction was accompanied with compensation, household factor income effects were consistently positive for all households. Factor income effects were progressive for Kuwaiti households, with lower-income Kuwaiti households gaining more than those in the higher-income quintiles, but regressive for expatriate households.

The expatriate labor force—in particular, the less skilled and employed in the private sector—were not firmly connected to the public sector or to the energy industries that experienced contractions. The private sector received a positive stimulus through factor price effects, and hence, the employment of factors expanded. As a result, expatriate factor income increased, and this included labor income received by unskilled Kuwaiti employees. The contractionary effect on factor incomes mostly disappeared because the subsidy reduction was accompanied by compensation. This outcome influenced factor employment effects across the industrial sectors.

The columns under "All incomes" incorporated income effects coming through all channels, both directly through household factor income effects and indirectly through effects on transfers. For national households, the inter-institutional transfers may reduce impacts of adverse effects without compensation and positive income effects with compensation.

Aggregate Economic and Environmental Effects

Given that the primary purpose of this study was to examine distributional effects, the discussion so far has focused on explaining the household welfare effects of a subsidy reduction. In this section, a summary is presented about the simulation results related to aggregate economic and environmental outcomes (Table 11).

Without compensation, the real GDP (i.e., nominal GDP deflated by the overall price changes) fell by 3.2%. However, this outcome was reversed in models with compensation, where the real GDP increased marginally (by 0.14%). The reason for this result is that energy users were compensated for losses of welfare or revenues. Nominal GDP dropped by a smaller proportion without compensation (-0.78%) but it rose by a greater proportion than the real GDP with compensation (2.94%). This can be explained by the fact that the subsidy reduction caused an increase in the general price level, which deflated the nominal GDP and caused the difference between real and nominal GDP effects.

Table 11. Aggregate economic and environmental effects

Description/Scenario	Without Compensation	With Compensation
Real GDP	-3.20	0.14
Nominal Variables		
GDP	-0.78	2.94
Household Consumption Expenditure	-1.53	1.34
Government Consumption Expenditure	1.17	-0.77
Gross Fixed Capital Formation	24.55	-7.44
Exports	-4.80	1.58
Imports	10.89	-3.97
Government Budget Deficit	-3.44	1.72
Balance of Payments	-26.29	9.07
Household Welfare	-2.60	1.85
CO_2 Emissions	-10.99	0.95

Aggregate household expenditures and government expenditures changed in opposite directions in both scenarios. With no compensation, the government expenditure on goods and services rose because the government macro-closure rule allowed it to adjust freely, and government savings was obtained as a residual. The gain from the subsidy reduction was proportionately allocated to services. By contrast, the expenditure on government services declined when the government compensated households. Household expenditure fell without compensation but rose when compensation payments were made. Gross fixed capital formation was determined using flexible investment closure; i.e., expenditure on private investment in capital goods was allowed to adjust freely, but the household savings ratio was fixed.

The price-increase effects of a subsidy reduction would make domestic products less competitive, which would mean fewer exports (mostly non-oil) and more imports in scenarios without compensation. However, these effects were reversed in scenarios with compensation. Possible explanations for the latter result could be the stimulus to the domestic economy, more production through full-capacity utilization and hence lower cost of production, and a balance of payment effects on mirror export and import effects.

Finally, the subsidy reduction was expected to have environmental effects, measured by CO_2 emissions. Without compensation, CO_2 emissions fell by about 11%. The product subsidy reduction caused marginal improvements in resource allocation, and compensation provided further stimulus; hence GDP increased in both nominal and real terms. Similarly, CO_2 emission marginally rose from the baseline level (by about 1% in models with compensation), implying persistent economic and environmental trade-offs.

The aggregate effects reported in the preceding paragraphs roughly followed the findings of other studies. The impact of a subsidy reduction on GDP has always been mixed (Breisinger, Mukashov, Raouf, & Wiebelt, 2019; Mundaca, 2017). Similarly, the existence of trade-offs between economic and environmental effects have been reported by many studies (Lin & Ouyang, 2014; Wang & Zhang, 2016). The role of compensation in realizing the economic benefits of a subsidy reduction without adversely affecting household welfare reiterates the fact that welfare is recognized in the literature (Acharya & Sadath, 2017; Breton & Mirzapour, 2016; Farajzadeh & Bakhshoodeh, 2015; Husaini *et al*., 2019; Rentschler, 2016).

CONCLUSION

This study applied a CGE model, calibrated to Kuwaiti data. The model was used to quantify the economy-wide impacts of a 25% subsidy reduction on all energy products (oil, gas, and electricity). At the aggregate level, a subsidy reduction with compensation led to improvements in representative household welfare, aggregate GDP, and a decline in CO_2 emissions. The aggregate macroeconomic and welfare effects were consistent with those reported in previous studies (Gelan, 2018b).

The focus of this study was to measure the distributional effects of a subsidy reduction. The results illustrate the complexity of examining distributional outcomes of public policy measures in the Kuwaiti economy. In a typical economy, distributional effects require disaggregation of households by income group, usually quintiles, and employment by skill levels. In the Kuwaiti context, there is an additional segmentation for both households and employment. Accordingly, this study applied a suitably structured SAM with ten household groups (quintiles, or five income classes for each nationality) and eight employment categories (four skill groups for each nationality). This segmentation reflects one of the most detailed household and factor classifications in existing applied CGE models.

The simulation results revealed unique distributional effects. The relationship between a subsidy reduction and the welfare of the Kuwaiti national household was mostly unambiguous. Kuwaiti households experienced a welfare decline if the subsidy reduction was not accompanied by compensation. However, Kuwaiti households experienced a welfare gain if the subsidy reduction was accompanied by compensation.

The impact of the subsidy reduction on the welfare of expatriate households showed a different pattern of results. Expatriate households corresponding to most income groups experienced a welfare gain, regardless of whether the subsidy reduction was accompanied by compensation.

For Kuwaiti nationals, a subsidy reduction without compensation was mostly regressive, with lower-income groups experiencing larger welfare losses than higher income groups. By contrast, a subsidy reduction with compensation showed a progressive pattern of welfare changes, with lower-income groups gaining more than higher income groups. The pattern of welfare change for expatriate household groups was ambiguous, unlike the results for Kuwaiti national households. For higher-income groups, welfare gains were greater without compensation compared to with compensation. Regressive patterns dominated, with the lower-income groups gaining less welfare than the higher-income groups in scenarios, particularly households in quintiles 1 to 3.

This study traced the channels through which household welfare changes occurred in response to the chain of reactions triggered by a subsidy reduction shock. The subsidy reduction more adversely affected the public sector, which included the energy sectors. Employment of Kuwaiti nationals is concentrated in these sectors. Substantial reductions in activities in these sectors means factor income.

Hence, factor income to Kuwaiti households dropped, reducing the household consumption budget, consequently adversely affecting Kuwaiti national household welfare. However, compensation not only re-instated household welfare, but actually caused it to rise from the baseline level. The source of these welfare gains was in the resource allocation effect of the subsidy reduction, resources being released from the less-efficient public sectors to the private, sectors. Regardless of compensation, expatriate household welfare improved in both scenarios.

This simulation experiment revealed important insights into policy synergy, linking Kuwait's broader development strategies. For instance, the subsidy reduction had symmetric public-private impacts, implying that subsidy reductions have synergetic outcomes, and contributing to Kuwait's medium- to long-term development objective to redress existing public-private sector imbalances.

Similarly, the patterns of sectoral employment and factor income effects revealed in this study indicated further policy framing through which a subsidy reduction would contribute to labor market reforms. This is one issue on the reform agenda, which Kuwaiti authorities are currently preoccupied.

Other countries may draw important insight from the synergetic policy outcomes, and the asymmetric public-private impacts in Kuwait. In designing development policies and long-term development strategies, policy makers often apply policy instruments in isolation, without considering the direct and indirect effects that have compounding influences on long-term development outcomes.

DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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KEY TERMS AND DEFINITIONS

Calibrate: A procedure of feeding parameters and baseline database to equations of a mathematical model to specify and bench-mark a numerical computable general equilibrium.

Computable General Equilibrium (CGE): An economy-wide mathematical model that utilizes actual economic data to estimate reaction of an economic system to changes in policy, technology, or other external factors.

Distributional Effects: Differential outcomes of policy implementations in terms of final benefits and cost allocations to members of society often classified by income groups.

Feedback Effects: The process of self-influence that takes place in an economic system through interactions between different markets.

Partial Equilibrium: Economic analysis confined to relationships between variables in a single market, assuming conditions in other markets remain unchanged.

Policy Synergy: Coordination in design multiple policies to improve efficiency in their implementations and achieve optimal outcome.

Social Accounting Matrix (SAM): A comprehensive economy-wide database recording data about all transactions between institutions in a specific economy for a specific period of time, usually a year.

APPENDIX 1: INDUSTRIAL VALUE-ADDED EFFECTS

Table 12.

		BASE	Without Compensation	With Compensation
PB40_A	Electricity	1.08	-14.18	1.07
PB23_A	Petroleum products	3.30	-12.54	10.53
PB11_A	Crude petroleum and natural gas	54.12	-7.88	0.31
PR66_A	Insurances	0.15	-3.47	-1.73
PR19_A	Leather	0.00	-2.02	1.59
PR70_A	Real estate	6.71	-1.66	0.65
PR65_A	Finance	4.90	-1.08	0.03
PB6074_A	Economic services	1.18	-0.54	1.09
PR18_A	Wearing apparel nes	0.11	-0.37	-1.70
PR91_A	Membership organizations nes	0.02	-0.34	0.87
PR80_A	Education	0.37	0.16	2.12
PR67_A	Auxiliary to financial intermediation	0.09	0.77	0.00
PR92_A	Recreational and cultural	0.07	0.80	0.53
PB80_A	Education	4.15	0.91	0.40
PR85_A	Health and social work	0.30	1.18	-0.28
PR63_A	Auxiliary transport activities	0.57	1.26	1.02
PB75_A	Public administration and defence	6.06	1.48	0.34
PR93_A	Private households for own use	0.17	1.71	0.81
PB55_A	Hotels and restaurants	0.06	1.73	0.48
PR25_A	Rubber and plastic products	0.07	1.86	4.70
PR17_A	Textiles	0.02	2.37	3.12
PB90_A	Sewage and sanitation	0.17	2.58	-0.18
PB92_A	Recreational and cultural	0.33	2.96	-0.15
PB85_A	Health and social work	1.27	3.02	-0.09
PB91_A	Membership organizations nes	0.39	3.13	-0.19
PR01 _A	Agriculture	0.25	3.40	-1.28
PR95P_A	Private households' employers	1.20	3.56	0.09
PR21_A	Paper and paper products	0.05	3.82	0.71
PR90_A	Sewage and sanitation	0.15	3.90	-0.01
PR64_A	Post and telecommunications	2.41	4.14	-2.68
PR22_A	Publishing	0.11	4.18	1.12
PB24_A	Chemicals and chemical products	0.21	4.40	1.93
PR62_A	Air transport	0.05	4.82	7.06
PR74_A	Other business activities	0.79	4.85	-0.65

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Table 12. Continued

		BASE	Without Compensation	With Compensation
PR15_A	Food products and beverages	0.32	5.05	-0.37
PR24_A	Chemicals and chemical products	1.85	6.10	-1.55
PR29_A	Machinery and equipment nes	0.03	6.65	-3.37
PB15_A	Food products and beverages	0.08	6.66	-1.42
PR60_A	Land transport	0.17	7.08	0.53
PR51_A	Wholesale trade	0.85	7.15	-2.15
PR34_A	Motor vehicles	0.01	8.36	-2.55
PR52_A	Retail trade	1.98	8.49	-2.01
PR61_A	Water transport	0.02	10.24	58.64
PR36_A	Furniture	0.10	10.71	1.60
PB52_A	Retail trade	0.02	10.96	-2.66
PR20_A	Wood products	0.02	11.76	-1.21
PR50_A	Sales and repair of motor vehicles	0.19	13.38	-3.27
PR3133_A	Electrical and precision equipment	0.18	14.33	-13.44
PR27_A	Basic metals	0.08	16.15	-4.88
PR55_A	Hotels and restaurants	0.56	16.88	-4.94
PR37_A	Recycling	0.05	16.93	-5.99
PR28_A	Fabricated metal products	0.15	17.16	-4.46
PR26_A	Other non-metallic mineral products	0.25	18.00	-5.57
PR7172_A	Renting equipment and machinery	0.31	20.49	-7.08
PR35_A	Transport equipment	0.04	20.81	-6.65
PR45_A	Construction	1.74	24.50	-7.96

APPENDIX 2: DESCRIPTION OF THE CGE MODEL EQUATIONS

Parameters and Variables

Indices

A, AP Industries
C, CP Products
$CT \in C$ Transaction services
$CD \in C$ Domestic products
$NENG \in C$ Non-energy commodities
$NEL \in C$ Non-electricity energy products
INSD,INSDP Domestic institutions
$INSDNG, INSDNGP \in INSD$ Nongovernment domestic institutions
$H, HP \in INSDNG$ Households

CES Function Exponent or Elasticity Parameters

ρ_veg Exponent of value added-energy aggregation function
ρ_en Exponent of electricity and fuels aggregation function
ρ_opg Exponent of elements of fuel energy aggregation function
ρ_f Exponent of factor aggregation function
ρ_ac Exponent of output aggregation function
ρ_t Exponent of export-domestic supply function
ρ_q Exponent of import-domestic demand function

Share Parameters

δ_ac Commodity share in activity output
δ_f Value-added share in value added-energy composite
δ_t Exports share in domestic output
δ_el Electricity share in energy composite
δ_f Factor share in value added
δ_q Import share in domestic demand
δ_opg Fuel energy in non-electricity energy demand
θ Product share in industry output
ive Value added-energy composite share in activity output
inta Non-energy intermediate input composite share in activity output
ica Product share in non-energy intermediate input composite
shif Share of institutions in factor income
shii Share in institutional transfers

SHIFT Parameters

α_veg Shift parameter in labor and value added-energy aggregation function
α_en Shift parameter in electricity and other energy aggregation function
α_opg Shift parameter in fuel energy aggregation function
α_f Shift parameter in factor demand aggregation function
α_ac Shift parameter in commodity output aggregation function
α_t Shift parameter in export-domestic supply function
α_q Shift parameter in import-domestic demand function

Other Parameters

γ Subsistence requirement in linear expenditure system of household consumption
β Marginal share in the linear expenditure of household consumption
ε Carbon content of fuels
φ Energy consumption conversion factor from value (in KD) to quantity (in Joules)

Tax or Subsidy Rates

sd Net subsidy rate
ta Output tax or subsidy rate
tm Import duty rate
te Export duty rate

Exogenous Variables

cwts Commodity weights in consumer price index
dwts Commodity weights in producer price index
CO_2 Carbon dioxide emissions
icd Transaction costs per unit of domestic sales
ice Transaction costs per unit of exports
icm Transaction costs per unit of imports
pwe Exogenous export price in foreign currency units
pwm Exogenous import price in foreign currency units
qfs Economy-wide factor supply
qg Exogenous government expenditure
qinv Exogenous investment expenditure
trnsfr Transfers
wfdist Factor price distortion factor

Table 13. Endogenous variables

CPI	Consumer price index
DPI	Index for domestic producer prices
EG	Total current government expenditure
EH	Household consumption expenditure
EXR	Exchange rate
FSAV	Foreign savings
GADJ	Government demand scaling factor
GSAV	Government savings
HSAV	Household savings
IADJ	Investment demand scaling factor
PA	Output price of activity
PDD	Demand price of commodities produced, and sold domestically
PDS	Supply price of commodities produced, and sold domestically
PE	Price of exports
PEN	Electricity-other energy composite price
PINTA	Price of intermediate aggregate

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Table 13. Continued

PM	Price of imports
PQ	Domestic imports composite price
PVA	Price of value added
PVE	Value added-energy composite price
PX	Composite commodity output price
PXAC	Producer price of activity-commodity
QA	Level of domestic activity
QD	Quantity of domestic sales
QE	Quantity of exports
QEN	Electricity-other energy composite quantity
QF	Factor demand
QG	Quantity of government consumption
QH	Quantity of household consumption
QINT	Quantity of intermediate demand
QINTA	Quantity of aggregate intermediate input
QINV	Quantity of fixed investment demand
QM	Quantity of imports
QNEL	Oil and petroleum composite quantity
QQ	Aggregate commodity supply to domestic market
QT	Transaction demand
QVA	Quantity of aggregate value added
QVE	Value added-energy composite
QX	Quantity of aggregate marketed commodity output
QXAC	Quantity of commodity-activity output
TRII	Inter-institutional transfers
WALRAS	Savings-investment imbalance (should be zero)
WF	Factor price
YF	Factor income
YG	Current government revenues
YI	Institutional income
YIF	Institutional income factor income

Table 14. Equations for the CGE model

A1	Price Block	
A1.1	$PM_C = pwm_C(1+tm_C)*EXR + \sum_{CT} PQ_C * icm_{CT,C}$	Import prices
A1.2	$PE_C = pwe_C * EXR + \sum_{CT} PQ_{CT} * ice_{CT,C}$	Export prices
A1.3	$PDD_C = PDS_C * (1+sd_C) + \sum_{CT} PQ_{CT} * icd_{CT,C}$	Demand price of domestic goods
A1.4	$PQ_C * QQ_C = PDD_C * QD_C + PM_C * QM_C$	Absorption
A1.5	$PX_C * QX_C = PDS_C * QD_C + PE_C * QE_C$	Marketed output value
A1.6	$PA_A = \sum_C \theta_{A,C} * PXAC_{A,C}$	Activity price
A1.7	$PA_A(1-t_a) * QA_A = PVE_A * QVE_A + PINTA_A * QINTA_A$	Price of value-added
A1.8	$PINTA_A = \sum_{NENG} ica_{C,A} * PQ_{NENG}$	Comp. intermediate input price
A1.9	$CPI = \sum_C cwts_C * PQ_C$	Consumer price index
A1.10	$DPI = \sum_{CD} dwts_{CD} * PDS_{CD}$	Producer price index
A2	**Production Block**	
A2.1	$QINTA_A = inta_A * QA_A$	Aggregate demand for non-energy intermediate goods
A2.2	$QVE_A = ive_A * QA_A$	Energy-value-added aggregate
A2.3	$QVE_A = \propto\_v_A * \left[\delta\_v_A * QVA_A^{-\rho\_veg_A} + (1-\delta\_v_A) * QEN_A^{-\rho\_veg_A}\right]^{\frac{-1}{\rho\_veg_A}}$	Energy-value-added aggregation
A2.4	$QVA_A = \left[\propto\_v_A^{(-\rho\_veg_A)} * \left(\frac{\delta\_v_A PVE_A}{PVA_A}\right)^{\frac{1}{1+\rho\_veg_A}}\right] * QVE_A$	Value-added aggregate
A2.5	$QEN_A = \left[\propto\_v_A^{(-\rho\_veg_A)} * \left\{\frac{(1-\delta\_v_A) PVE_A}{PEN_A}\right\}^{\frac{1}{1+\rho\_veg_A}}\right] * QVE_A$	Energy-aggregate
A2.6	$QEL_A = \propto\_en_A * \left[\delta\_el_A * QINT_{el,A}^{-\rho\_en_A} + (1-\delta\_el_A) * QNEL_A^{-\rho\_en_A}\right]^{\frac{-1}{\rho\_en_A}}$	Electricity-fuel aggregation $\delta\_el_A > 0$

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Table 14. Continued

A2.7	$QINT_{el,A} = \left[\propto\_el_A^{(-\rho\_en_A)} * \left(\frac{\delta\_el_A PEN_A}{PQ_{el}}\right)^{\frac{1}{1+\rho\_enA}}\right] * QEN_A$	Electricity demand δ_el_A>0
A2.8	$QNEL_A = \left[\propto\_en_A^{(-\rho\_en_A)} * \left\{\frac{(1-\delta\_el_A)PVE_A}{PNEL_A}\right\}^{\frac{1}{1+\rho\_en_A}}\right] * QEN_A$	Fuel demand δ_el_A>0
A2.9	$QEN_A = QINT_{el,A} + QNEL_A$	Energy aggregate δ_el_A=1 or δ_el_A=0
A2.10	$QNEL_A = \propto\_opg_A * \sum\left(\delta\_opg_{nel,A} * QINT_{el,A}^{-\rho\_opg_A}\right)^{\frac{-1}{\rho\_opg_A}}$	Fuel aggregation $\delta\_neln_{el,A}$>0
A2.11	$QINT_{el,A} = \left[\propto\_opg_A^{(-\rho\_opg_A)} * \left(\frac{\delta\_opg_A PNEL_A}{PQ_{el}}\right)^{\frac{1}{1+\rho\_engA}}\right] * QNEL_A$	Electricity demand $\delta\_neln_{el,A}$>0
A2.12	$QVA_A = \propto\_f_A * \sum_F\left(\delta\_f_{F,A} * QF_{F,A}^{-\rho\_f_A}\right)^{\frac{-1}{\rho\_f_A}}$	Factor aggregation
A2.13	$WF_F * wfdist_{F,A} = PVA_A * QVA_A * \left[\frac{\delta\_f_{F,A} QF_{F,A}^{-(\rho\_f_A+1)}}{\sum_F \delta\_f_{F,A} QF_{F,A}^{-(\rho\_f_A+1)}}\right]$	First order condition for factor aggregation
A2.14	$QINT_{NENG,A} = ica_{NENG,A} * QINT_A$	Demand for non-energy intermediate products
A3	**Commodity Supply and Demand Block**	
A3.1	$QXAC_{A,C} = \theta_{A,C} * QAA$	Commodities' output by activities
A3.2	$QX_C = \propto\_ac_C \sum_A\left(\delta\_ac_C QXAC_{A,C}^{-\rho\_ac_C}\right)^{\frac{-1}{\rho\_ac_C}}$	Output aggregation
A3.3	$PXAC_{A,C} = PX_C * QX_C * \left[\frac{\delta\_ac_{A,C} QXAC_{A,C}^{-(\rho\_ac_C+1)}}{\sum_C \delta\_ac_{A,C} QXAC_{A,C}^{-(\rho\_ac_C+1)}}\right]$	First order condition for output aggregation
A3.4	$QX_C = \propto\_t_C * \left[\delta\_t_C * QE_C^{-\rho\_t_C} + (1-\delta\_t_C) * QD_C^{-\rho\_t_C}\right]^{\frac{-1}{\rho\_t_C}}$	CET transformation δ_t_C>0
A3.5	$\frac{QE_C}{QD_C} = \left(\frac{PE_C}{PDS_C} * \frac{1-\delta\_t_C}{\delta\_t_C}\right)^{\frac{1}{\rho\_tC-1}}$	Export supply δ_t_C>0

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Table 14. Continued

A3.6	$QX_C = QD_C + QE_C$	Export–domestic aggregation δ_t_C=0 or δ_t_C=1
A3.7	$QM_C = \propto\_q_C * \left[\delta\_q_C * QM_C^{-\rho\_q_C} + \left(1-\delta\_q_C\right) * QD_C^{-\rho\_q_C}\right]^{\frac{-1}{\rho\_q_C}}$	CET transformation δ_t_C>0
A3.8	$\frac{QM_C}{QD_C} = \left(\frac{PM_C}{PDD_C} * \frac{1-\delta\_t_C}{\delta\_t_C}\right)^{\frac{1}{\rho\_t_C - 1}}$	Armington function δ_q_C>0
A3.9	$QQ_C = QD_C + QM_C$	Import-domestic commodity demand ratio δ_q_C=0 or δ_q_C=1
A3.10	$QT_C = icm_C * QM_C + ice_C * QE_C + icd_C * QD_C$	Demand for transaction services
A4	**Income and Expenditure Block**	
A4.1	$YF_F = \sum_A WF_F * wfdist_{F,A} * QF_{F,A}$	Economy-wide factor income
A4.2	$YIF_{INSD,F} = shif_{INSD,F} * YF_F$	Allocation of factor income to domestic institutions
A4.3	$YI_{INSDNG} = \sum_F YIF_{INSDG,F} + \sum_{INSDNGP} TRII_{INSDG,INSDNGP} + trnsfr_{INSDG,"ROW"}$	Total income of nongovernmental domestic institutions
A4.4	$TRII_{INSDNG,INSDNG} = \left[1 - \sum_{INSDNG} shii_{INSDNG,H} * \left(1-mps_H\right) * \left(1-tins_H\right)\right] * YI_H$	Transfers between nongovernmental institutions
A4.5	$EH_H = shii_{INSDG,INSDNGP} * \left(1-mps_{INSDNGP}\right) * \left(1-tins_{INSDNGP}\right) * YI_{INSDNGP}$	Household expenditure on final consumption
A4.6	$PQ_C QH_{C,H} = PQ_C \gamma_{C,H} + \beta_{C,H} * \left(EH_H - \sum_{CP} PQ_{CP} \gamma_{CP,H}\right)$	LES function
A4.7	$QINV_C = IADJ_{C,H} * qinv_C$	Investment demand
A4.8	$QG_C = GADJ_{C,H} * qg_C$	Government demand
A4.9	$YG = \sum_F YIF_{\mathrm{GVT},F} + \sum_A ta_A PA_A QA_A + \sum_C tm_C pwm_C QM_C EXR + \sum_C sd_C PQ_C QQ_C + \sum_{INSDNG} tins_{INSDNG} YI_{INSDNG} + trnsfr_{GVT,ROW} EXR$	Government revenues
A4.10	$EG = \sum_C PQ_C QG_C + \sum_{INSDNG} trnsfr_{INSDNG,GVT}$	Government expenditure
A5	**System Constraints**	
A5.1	$\sum_F QF_F = qfs_F$	Economy-wide factor supply

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Table 14. Continued

A5.2	$QQ_C = \sum_A QINT_{C,A} + \sum_H QH_{C,H} + QG_C + QINV_C + QT_C$	Domestic commodity demand
A5.3	$\sum_C pwm_C * QM_C = \sum_C pwe_C * QE_C + \sum_{INSD} trnsfr_{INSD,ROW} + FSAV$	Current account balance
A5.4	$YG = EF + GSAV$	Government savings
A5.5	$\sum_C mps_{INSDNG} * \left(1 - tins_{INSDNG}\right) YI_{INSDNG} + GSAVFSAV * EXR = \sum_C PQ_C * QINV_C + WALRAS$	Saving-investment balance
A6	**Energy Consumption and CO_2 Emissions**	
A6.1	$FUEL_{C11G} = \varphi_{C11G} * QQ_{C11G}$	Domestic consumption of gas in Joules
A6.2	$CO2F_{C11G} = \varepsilon_{C11G} FUEL_{C11G}$	CO_2 emissions from gas consumption in millions of tons
A6.3	$FUEL_{C11C} = \varphi_{C11C} * QQ_{C11C}$	Domestic consumption of crude oil in Joules
A6.4	$CO2F_{C11C} = \varepsilon_{C11C} * \left(FUEL_{C11C} - \varphi_{C11C} * QINT_{C11C,A23}\right)$	CO_2 emissions from crude oil consumption in millions of tons
A6.5	$FUEL_{C23} = \varphi_{C23} * QQ_{C23}$	Domestic consumption of refined oil in Joules
A6.6	$CO2F_{C23} = \varepsilon_{C23} FUEL_{C23}$	CO_2 emissions from refined oil consumption in millions of tons
A6.7	$CO2E_{A40} = \sum_{NEL} \varepsilon_{NEL} * \varphi_{NEL} * QINT_{NEL,A40}$	CO_2 emissions in electricity production in millions of tons
A6.8	$CO2A_A = \sum_{NEL} \varepsilon_{NEL} * \varphi_{NEL} * QINT_{NEL,A}$	CO_2 emissions by activity A in millions of tons
A6.9	$CO2H_H = \sum_{NEL} \varepsilon_{NEL} * \varphi_{NEL} * QH_{NEL,H}$	CO_2 emissions by household H in millions of tons

APPENDIX 3: ACRONYMS

Table 15.

Acronym	Definition
IMF	International Monetary Fund
GDP	Gross Domestic Product
TPES	Total primary energy supply
toe	Tons of oil equivalent
IEA	International Energy Agency
TFC	Total final consumption
CGE	Computable general equilibrium
SAM	Social accounting matrix
CES	Constant Elasticity of Substitution
CET	Constant Elasticity of Transformation
LDs	Demand for labor by skill type
Ws	Average wage by skill type
LD	Aggregate demand for labor
WL	Economy-wide average wage
KD	Capital stock
UCK	User cost of capital
OECD	Organization for Economic Co-operation and Development
KD	Kuwaiti Dinar
LES	Linear expenditure system
ES	Employment share

Chapter 5
Oil Price Shocks and Income Inequality:
Evidence From the US

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ABSTRACT

This study, using the local projections, investigates linear and nonlinear impulse responses of the United States (US) household income inequality to oil price shocks. Oil price shocks are disaggregated according to the origin to test the dynamic response of income inequality to oil price structural shocks which are contingent on the status of oil dependence in individual US states. The results, based on the linear projection model, show that oil supply shocks lead to higher income inequality in the short term, but lower-income inequality in the medium and long terms. Moreover, economic activity shocks and oil inventory demand shocks mainly exert negative impacts on income inequality over time. Both positive and negative effects of oil consumption demand shocks on income inequality are observed. The nonlinear impulse response results reveal some evidence of heterogeneous responses of income inequality to oil price shocks between high- and low-oil-dependent US states.

INTRODUCTION

A growing literature reports that oil price shocks can affect the wider economy through multiple channels (Herrera *et al*., 2019, for reviews of the relevant literature). Oil shocks can have a big impact on many macroeconomic variables, including employment, economic growth, interest rate, foreign exchange rate, inflation, asset prices, economic uncertainty, etc., (Chisadza *et al*., 2016; Gupta *et al*., 2020, 2021; Ji *et al*., 2020; Shahzad *et al*., 2019; Sheng *et al*., 2020, 2021; Bayramov, 2022). In the meanwhile, a related stream of literature finds evidence of a close relationship between changes in macroeconomic

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factors and household income inequality (Balcilar *et al*., 2018, 2020; Berisha *et al*., 2020; Deyshappriya, 2019; Maestri & Roventini, 2012; Kilinc-Ata, 2022). This linkage provides various transmission mechanisms through which oil price shocks can influence income inequality. For example, the contractionary monetary policy to curb the inflation pressure caused by rising oil prices can raise the observed income inequality in the economy (Coibion *et al*., 2017; Mumtaz & Theophilopoulou, 2018). Recent studies also suggest that inequality can be affected by macroeconomic uncertainty over time (Fischer *et al*., 2021; Theophilopoulou, 2021). Fischer *et al*. (2021) show evidence for a dynamic relationship between household income inequality and macroeconomic uncertainty in the US and highlight the importance of uncertainty in affecting household income distributions. Theophilopoulou (2021) examines the responses of income inequality to uncertainty in the UK and find that macroeconomic uncertainty contributes significantly to the variations in income inequality. Given the close link between uncertainty and oil price shocks as reported by previous studies (Bernanke, 2006; Kang *et al*. 2017; Sheng *et al*., 2020; Su *et al*. 2018), theoretically, the impacts of oil price shocks can also transmit via the uncertainty channel on income inequality.

Although existing literature has reported growing empirical evidence for the impacts of oil shocks on the economy (Gupta *et al*. 2020, 2021; Sheng *et al*. 2020, 2021), no studies so far have investigated the impacts of oil price shocks on income inequality. A good understanding of the factors that affect income inequality, and underlying mechanisms that cause changes in income inequality, prove to be important to policymakers since existing literature has highlighted the linkage between income inequality and the causes of crises (Stiglitz, 2012; Van Treeck, 2014). Note that, although the United States (US) is often praised as a land of equal opportunity for all, the past three-and-a-half decades have seen a rising trend of growing income inequality (Çepni *et al*., 2020). Hence, the factors that drive inequality is an equally important question for the US, just like any other economy in the world.

Against this background, the main research objective of this study is to investigate the direct impacts of oil price shocks on income inequality in the US. The study attempts to fill the gap in the literature by using a newly constructed, large panel dataset for the US at the state level, which includes the growth rate of real income, employment growth, unemployment rate, and a survey-based measure of income inequality based on the work of Fischer *et al*. (2021). The use of a panel dataset aids in accounting for the existence of large heterogeneities between regions of a big country (such as the US), while the availability of data for a long-time span in the US, results in a large panel dataset. Apart from the variables mentioned above, this study also includes a set of aggregate macroeconomic variables at the country level, including the interest rate, inflation rate, and a ratio of budget deficit to GDP as a measure of fiscal policy in the US. These variables are considered as common factors driving the US business cycles.

Following a seminal work of Baumeister and Hamilton (2019), oil price shocks are disentangled into the oil supply shocks, economic activity shocks, oil inventory shocks, and oil consumption demand shocks. Baumeister and Hamilton (2019) highlight the importance of disaggregating oil price shocks by origin and report a larger contribution of oil supply shocks to historical oil price movements comparing to the findings in earlier studies (Kilian, 2009; Kilian & Murphy, 2012, 2014). Since not all oil price shocks are alike, it is important to distinguish the nature of oil price shocks according to their origin, e.g., whether they are driven by supply- or demand-side factors, as their impacts on income inequality can be dependent on it. Besides, as stressed by Kilian (2009), each type of oil price shock has different impacts on US macroeconomic aggregates and hence income inequality, since oil price movements can not only be caused by fluctuations in oil production, but also changes in global demand, and precautionary and speculative motives of oil traders.

Moreover, oil price shocks can lead to a transfer of income from oil-importing states to oil-exporting states. Given the evidence of the differential influence of oil price shocks between oil exporters and importers (Baumeister *et al*., 2010; De Michelis *et al*., 2020; Sheng *et al*., 2020), oil dependency can play an important role in affecting the heterogeneous impacts of oil price shocks on income inequality in individual US states. To the best of the authors' knowledge, this is the first attempt in the literature to study the effects of various structural oil shocks on income inequality across 50 US states while considering the heterogeneity in the oil dependency of each state. Given that individual US states differ in terms of their oil dependence, this study analyses the heterogeneous impacts of the oil shocks on income inequality by estimating nonlinear impulse response functions (IRFs) using local projections for panel data, and by making the IRFs contingent on the dependence of oil. The study tests both linear and nonlinear impulse responses of inequality to oil shocks by using the local projections method of Jordà (2005). This study also examines whether the responses of income inequality to oil price shocks are regime-dependent on the oil dependence of US states. Oil dependency is calculated as the difference between oil consumed and oil produced over oil consumed in each US state. Following the work of Auerbach and Gorodnichenko (2013) and Jordà *et al*. (2020), the smooth transition function approach is used to switch the oil dependence of US states into high- and low- regimes.

BACKGROUND

This section provides a review of the relevant literature and sets the scene for a better understanding of the discussions presented in the rest of the chapter by exploring the transmission mechanisms of oil price shocks to the economy and the linkages between macroeconomic factors and income inequality.

The Transmission Mechanisms of Oil Price Shocks to the Economy

Existing literature provides insights on the impacts of oil price shocks on the economy through multiple transmission mechanisms. Baumeister *et al*. (2018) and Herrera *et al*. (2019) show that oil price shocks impact the economy via the discretionary income effect channel. The discretionary income effect of the purchasing power loss due to an unexpected increase in the price of imported oil can decrease the real domestic consumption of goods and services and exert an adverse effect on real GDP. Higher oil prices and fuel costs tend to reduce household disposable income and dampen consumer spending (Rafay & Farid, 2015). Moreover, an unexpected rise in oil prices can reduce the aggregate economic output as it raises the cost of production.

Hamilton (1988) suggests another transmission channel through which costly labour market reallocation can amplify the effects of oil price shocks on the economy and lead to changes in unemployment. By constructing a theoretical model of unemployment and the business cycle, Hamilton (1988) shows that, in the presence of labour market reallocation frictions, seemingly small disruptions in supplies of primary commodity goods such as energy could be the cause of fluctuations in aggregate employment and could have a surprisingly large effect on real economic output.

Moreover, Davis and Haltiwanger (2001) stress the important re-allocative consequence of oil price shocks. Through the re-allocative channel, oil price shocks can adversely affect the closeness of the match between the desired and actual distributions of factor inputs (such as labour and capital) and trigger considerable reallocation of resources across sectors. For example, after an increase in oil prices, resources could be relocated away from the sectors that heavily use energy to those that rely less on energy as the expenditures on energy-intensive durables goods are reduced. A reallocation could also occur within the same sector (e.g., the automobile industry) when consumers switch to more energy-efficient durables goods (Bresnahan & Ramey, 1993). The costly intra-sectional and inter-sectoral reallocations of resources would amplify the adverse effect of oil price shocks on economic activity, leading to a rise in unemployment.

Furthermore, the impacts of oil price shocks can be amplified through the operating cost channel where consumers postpone or forgo the purchases of energy-using durables in response to an unexpected oil price increase (Edelstein & Kilian, 2009). For example, consumers may delay or stop spending on motor vehicles following a hike in oil prices. In addition, household consumptions could decrease after oil price shocks as consumers perceive a great possibility of future unemployment and income losses and raise their precautionary savings. The precautionary saving effect indicates greater uncertainty about the prospects of future job security, in which case unexpected increases in oil prices could lead to a reduction in consumer expenditures (Rafay *et al.,* 2015).

A related line of literature also stresses that shifts in expenditure patterns can be driven by the uncertainty effect. When oil price shocks are associated with high uncertainty about the present value of future cash flows, a rise in uncertainty will result in a decrease in investment expenditures. Also, consumers may be pessimistic about the future economic outlooks in periods of high uncertainty caused by oil price shocks and may curtail their consumption expenditures (Bernanke, 2006). In brief, oil price shocks that are associated with high uncertainty may lead to a delay or decline in consumption and investment expenditures, and thus may lead to a decrease in aggregate output.

The Linkages Between Macroeconomic Factors and Income Inequality

Existing literature on the macroeconomic determinants of inequality largely focuses on the relationship between income distribution and other macroeconomic variables such as economic growth, interest rate, inflation, and unemployment. The research that specifically studies the relationship between macroeconomic factors and inequality are historically relatively restrictive in the economic literature due to the limited data availability of inequality measurements (Deyshappriya, 2019). However, the recent developments of econometric methods allow researchers to conduct inequality-related studies utilising various newly constructed inequality datasets for comprehensive analysis.

Using a longitudinal dataset that includes 33 Asian economies from 1990 to 2013, Deyshappriya (2019) finds that inflation and unemployment are the main macroeconomic factors that drive income inequality in Asian countries. The study shows that inflation negatively affects the income share of the lower-income groups, while it benefits the richest group and widens the income gap between the rich and the poor. Also, unemployment increases income inequality as the income sources are more restrictive to the lower-income groups who have no, or a little accumulated wealth in contrast with the higher-income groups.

Grounding on different measures of inequality time series obtained from the Review of Economic Dynamics (RED database), Maestri and Roventini (2012) study time-series properties of inequality series and macroeconomic series for a set of the Organisation for Economic Co-operation and Development (OECD) countries. The research confirms a positive correlation between unemployment and inequality and highlights that unemployment is an important channel for the transmission of business cycles to inequality. In addition, Maestri and Roventini (2012) report inequality time series in most countries are counter-cyclical (except for Germany). However, the study reports mixed results about the correlations between inflation and income inequality. The results show that income inequality is negatively correlated with inflation in Canada, but positively in the US, Germany, and Sweden.

By building a country-level panel dataset that consists of data on income inequality, real interest rates, inflation, and real GDP growth, Berisha *et al*. (2020) investigate the impact of macroeconomic factors on income inequality with a special focus on Brazil, Russia, India, China, and South Africa (the BRICS countries) over a sample period from 2001 to 2015. The study finds that increases in inflation and real GDP growth lead to increases in income inequality, implying that economic growth and inflation over the last two decades has largely benefited the higher-income groups in the upper end of the income distribution. The study also finds some evidence that lower real interest rates have contributed to an increase in income inequality in the BRICS countries.

By constructing a state-level panel dataset over the period from 1976 to 2007, Balcilar *et al*. (2018) analyse the relationship between inflation and income inequality in the US across 50 states. The research shows a nonlinear relationship that exists between income inequality and inflation. The results indicate that the effects of inflation on income inequality are heterogeneous and contingent on the level of the inflation rate. Balcilar *et al*. (2018) report that an increase in inflation reduces income inequality when the inflation level is low, but it raises income inequality while the inflation level is high. In other words, a positive relationship between income inequality and inflation is observed when inflation is above a threshold level (e.g., about 3 per cent as suggested by Balcilar *et al*., 2018). Below this threshold level of the inflation rate, an increase in the inflation rate decreases income inequality.

DATA AND METHODOLOGY

To capture oil price shocks, this study uses the methodology developed by Baumeister and Hamilton (2019) and disentangles oil shocks according to their origins into four components. The four oil structural shocks (namely, the oil supply shock (OSS), oil-specific consumption demand shock (OCDS), economic activity shock (EAS), and oil inventory demand shock (OIDS) are obtained from the estimation of a structural vector autoregressive (SVAR) model[1]. To capture household income inequality across the states in the US, a survey-based measure of inequality following the work of Fischer *et al*. (2021) is employed. The inequality measure is constructed using household income data in the integrated Public-Use Microdata Series (IPUMS) datasets. The household income is equalised on a square root scale, which divides household income by the square root of household size, to take household sizes into account. It includes all types of total pre-tax income and losses in a household. The Gini coefficient is then used as a scalar measure of household income inequality.[2] The dataset is at the quarterly frequency and the sample period is ranged from 1985: Q1 to 2017: Q2.[3]

The linear model for calculating the impulse response functions (IRFs) using the LPs method of Jordà (2005) can be defined as follows:

$$Y_{i,t+s} = \alpha_{i,s} + \beta_s X_t + \epsilon_{i,\ t+s}, \text{for } s = 0, 1, 2, \ldots H \quad (1)$$

where $Y_{i,t}$ represents the growth rate of income inequality in state i at time t, s is the length of forecast horizons up to the maximum forecast horizon H,[4] $\alpha_{i,s}$ measures the fixed effect and β_s captures the responses of income inequality at time t + s to an identified oil price shock (denoted by X_t) at time t. The impulse response functions are derived from a series of β_s that are estimated separately by the simple ordinary least squares (OLS) regression method at each horizon (s).[5]

This study also examines if the impact of oil shocks on inequality growth rates is regime-dependent and contingent on the status of oil dependence across the states of the US. Equation 1 can be modified into a regime-dependent model where IRFs are depending on the status of oil dependence of each state (Auerbach & Gorodnichenko, 2013; Jordà et *al.,* 2020). A smooth transition function is included in a nonlinear model to distinguish the states in a high oil dependence regime from those in a low oil dependence regime. The nonlinear model is specified as follows:

$$Y_{i,t+s} = \left(1 - F\left(z_{t-1}\right)\right)\left[\alpha_{i,s}^{High} + \beta_s^{High} X_t\right] + F\left(z_{t-1}\right)\left[\alpha_{i,s}^{Low} + \beta_s^{Low} X_t\right] + \epsilon_{i,t+s},$$

for s=0,1,2,…,h (2)

$$F\left(z_t\right) = \exp\left(-\gamma z_t\right) / 1 + \exp\left(-\gamma z_t\right), \gamma > 0\,, \quad (3)$$

where $z_{i,t}$ represents a switching variable measuring the oil dependence of US states. $z_{i,t}$ is normalised to have zero mean and unit variance, with a positive value of $z_{i,t}$ indicating high oil dependence, and a negative value otherwise. The smooth transition function $F(z_{i,t})$ is bounded between 0 and 1, with values close to 1 corresponding to the low oil dependence regime, and 0 otherwise.

The models specified in Equations 1 and 2 are further extended by adding a set of aggregate macroeconomic variables at the country level as the control variables. These variables are considered as the common factors that drive US business cycles and thus affect income inequality across the states in the US. Also, the models control for the growth rate of real income, employment growth, and the unemployment rate at the state level. The models can be re-specified as follows:

$$Y_{i,t+s} = \alpha_{i,s} + \beta_s X_t + \gamma_{i,s} Z_{i,t} + \epsilon_{i,t+s}, \text{for } s = 0,1,2,\ldots H \quad (4)$$

$$Y_{i,t+s} = \left(1 - F\left(z_{t-1}\right)\right)\left[\alpha_{i,s}^{High} + \beta_s^{High} X_t\right] + F\left(z_{t-1}\right)\left[\alpha_{i,s}^{Low} + \beta_s^{Low} X_t\right] + \gamma_{i,s} Z_{i,t} + \epsilon_{i,t+s},$$

for s=0,1,3,…,H (5)

where $Z_{i,t}$ is a vector of control variables, which include the growth rate of real income, employment growth, and the unemployment rate at the state level, and interest rate, inflation rate, and a ratio of budget deficit to GDP as a measure of fiscal policy in the US at the country level.

RESULTS

This section presents the empirical results of the study. The figures display the estimated impulse response of income inequality growth rates to the four structural oil shocks over 24 quarters for the models specified in Section 2. The 95% confidence bands are calculated based on panel-corrected standard errors.

Figure 1. Responses of income inequality to the oil price shocks
Note: OSS represents oil supply shocks; EAS represents global economic activity shocks; OIDS represents oil inventory demand shocks; OCDS represents oil-specific consumption demand shocks.

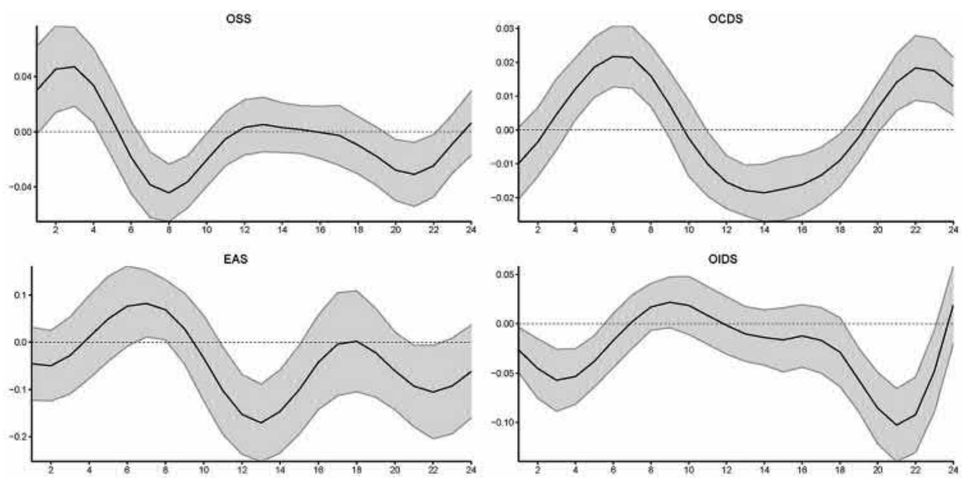


Figure 1 shows the impact of oil supply shocks (OSS) leads to a rise in income inequality in the short term, peaking after three quarters, but then declining sharply to low levels in the medium- to long- term. Given the evidence of the positive relationship between OSS and uncertainty as reported by Kang *et al*. (2017), Su *et al*. (2018) and Sheng *et al*.(2020), it is noteworthy that this pattern is generally consistent with empirical evidence provided for the US by Fischer *et al*. (2021) and for the UK by Theophilopoulou (2021), who find that, although uncertainty contributes significantly to the variations in income inequality, the responses of income inequality to uncertainty are positive in the short term, falling to low levels in the medium- and long- terms. Income inequality rises in the short term immediately after the OSS shock can be associated with the finding from existing literature that workers in lower-income households are at greater risk of unemployment and potential income loss, compared to those in higher-income households, during a period of high economic uncertainty (Berisha *et al*., 2020).

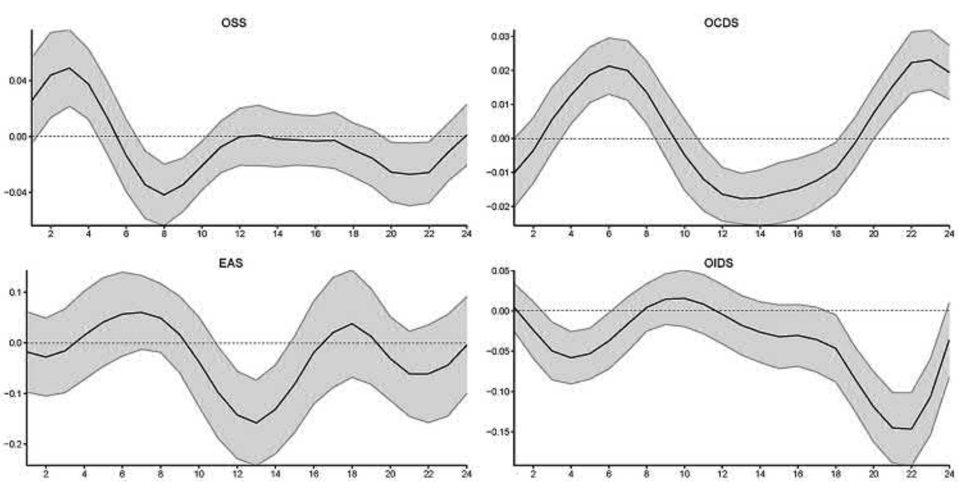
It is found that income inequality mainly reacts negatively to the economic activity shocks (EAS) and oil inventory demand shocks (OIDS). This finding aligns with existing literature that reports negative responses of uncertainty to EAS (Antonakakis *et al*., 2014; Kang & Ratti, 2015; Kang *et al*., 2017; Sheng *et al*., 2020) and OIDS (Sheng *et al*., 2020). The results show that positive EAS, which is normally associated with higher global aggregate demand, lower economic uncertainty, and a positive outlook for the macro economy, tend to lower income inequality.

Also, despite its speculative nature and negative impacts on economic activity, OIDS tend to reduce income inequality. This decline in income inequality could result from the Federal Reserve's monetary response of decreasing interest rates to stimulate economic growth and fight against the negative economic impact of higher oil prices caused by OIDS. Existing literature shows that expansionary monetary policy and a lower interest rate could benefit the borrower in lower-income families and reduce income inequality since the households at the bottom of the income distribution tend to have greater debt burdens and fewer savings compared to those at the top of the income distribution (Doepke & Schneider, 2006; Mumtaz & Theophilopoulou, 2018).

Lastly, the results show some positive and statistically significant responses of income inequality to oil consumption demand shocks (OCDS) in the 4th – 8th and 21st – 24th quarters and some negative and significant responses in the 12th and 18th quarters. The switching in the direction of OCDS impact on income inequality seems to be consistent with the mixed results of the previous studies about the relationship between OCDS and uncertainty. For example, Kang and Ratti (2015) and Kang *et al*. (2017) find that OCDS trigger significant increases in uncertainty, while Sheng *et al*. (2020) report negative responses of uncertainty to OCDS.

Figure 2 presents the estimated nonlinear IRFs of income inequality to the structural oil shocks over 24 quarters by distinguishing the status of oil dependence in individual states in the US into high- or low-oil dependence regimes in the model specified in Equations 2 and 3.

Figure 2. Responses of income inequality to oil price shocks in high- (h) and low- (l) oil dependence states
Note: See Notes to Figure 1. Oil Dependence: oil consumed minus oil produced as a percentage of oil consumed, with h and l corresponding to high- and low- levels of oil dependence respectively.



The nonlinear impulse response results (as shown in Figure 2) show some evidence of heterogeneous responses of income inequality to oil price shocks between high- and low-oil dependence US states. Compared to low-oil dependence states, the results show that income inequality is more sensitive to OCDS in high-oil dependence states. This finding seems to be in line with Sheng *et al*. (2020) who report uncertainty in high-oil dependency economies (i.e., oil importers) tends to be more affected by oil price shocks than low-oil dependency economies (i.e., oil exporters). Moreover, the results show positive and statistically significant impulse responses of income inequality to OSS in the short term in the low-oil dependence states, and negative and statistically significant responses in the medium term in the high-oil dependence states. As shown in Figure 2, OSS has statistically significant and positive impacts on income inequality in the 3rd and 4th quarter for high-oil dependence states, whereas the impacts turn negative between the 6th and 8th quarter for the low oil dependence states. Lastly, the nonlinear results show more evidence for the negative response of income inequality to EAS and OIDS in both high- and low-oil dependence states.

To test if the results reported in Figures 1 and 2 are robust to the influence of common factors that drive the US business cycles, this study includes a set of control variables, including the interest rate, inflation rate, and a ratio of budget deficit to GDP as a measure of fiscal policy in the US at the aggregate country level, into the models specified in Equations 1 – 3. The study also controls for the growth rate of real income, employment growth, and the unemployment rate in the US at the state level. Figures 3 and 4 report the estimated IRFs of income inequality to oil shocks over 24 quarters using the models specified in Equations 4 – 5.

It is found that income inequality's response to all four types of oil price shocks is robust to the influence of US aggregate variables and the state-level control variables for both linear and nonlinear models. The patterns of IRFs reported in Figures 3 and 4 are qualitatively similar to those reported in Figures 1 and 2, respectively.

Figure 3. Responses of income inequality to the oil price shocks with control variables
Note: See Notes to Figure 1.

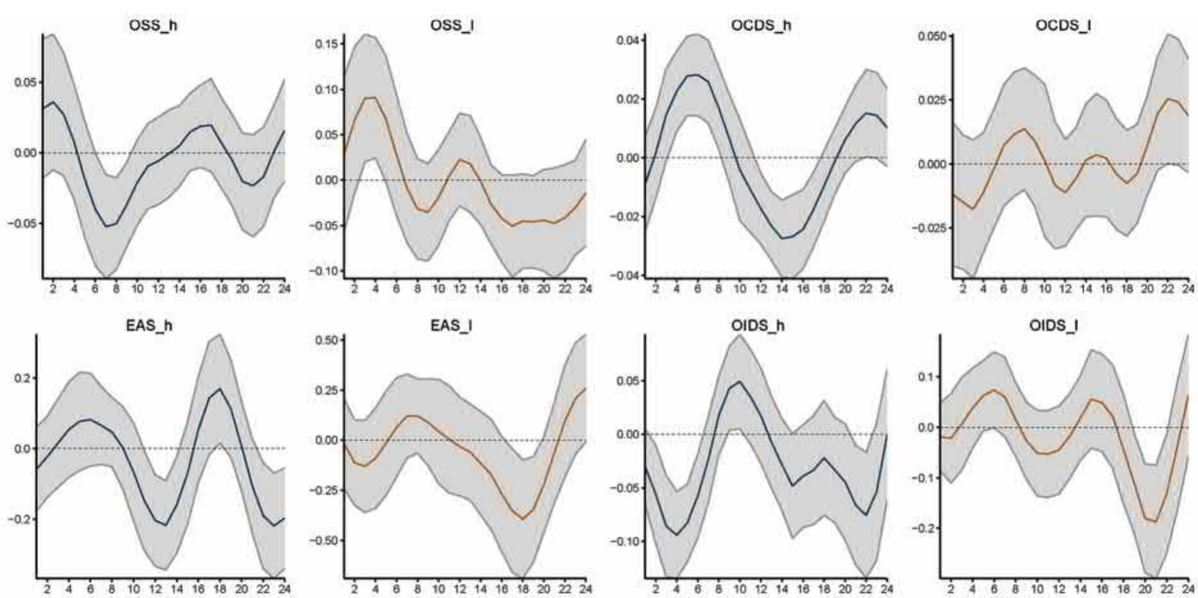
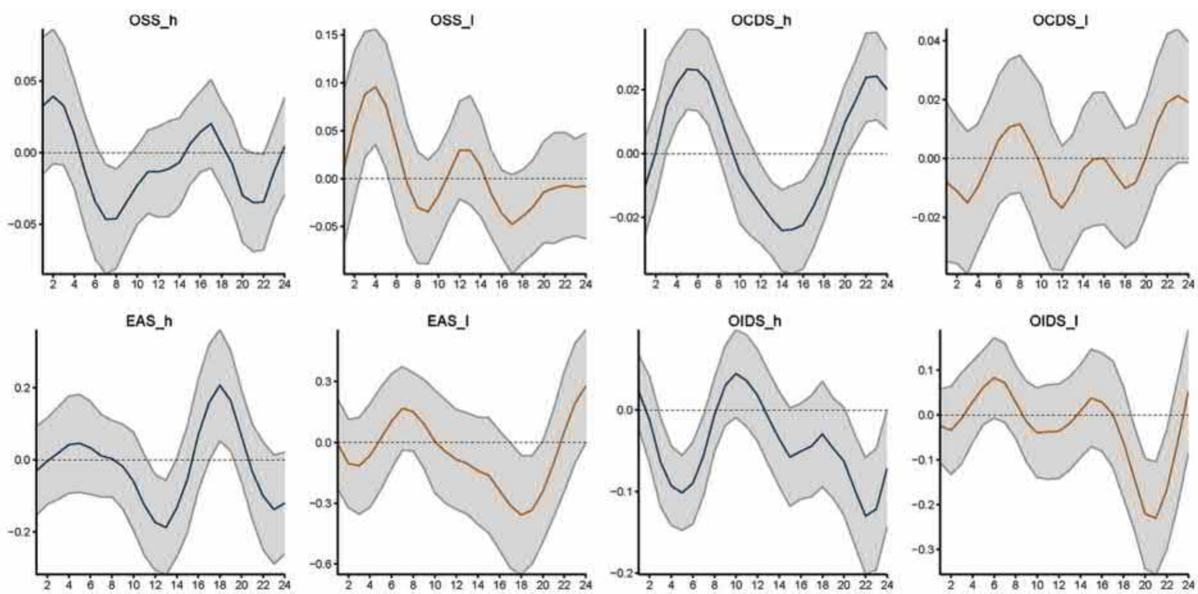


Figure 4. Responses of income inequality to oil price shocks in high (h) and low (l) oil-dependence states with control variables
Note: See Notes to Figure 2.



CONCLUSION

This study investigates the impacts of oil price structural shocks on household income inequality in the US. By estimating both linear and nonlinear impulse response functions using the local projections (LPs) method for panel data, this study sheds light on the dynamic responses of income inequality to various types of oil price structural shocks, contingent on the status of oil dependence in individual US states. The study considers the origin of oil price shocks when examining their impacts on US household income inequality using the state-level panel data. The results show that oil supply shocks (OSS) lead to higher income inequality in the short term, but lower-income inequality in the medium- and long- term. Moreover, economic activity shocks (EAS) and oil inventory demand shocks (OIDS) mainly exert negative impacts on income inequality over time, while both positive and negative effects of oil consumption demand shocks (OCDS) on income inequality are observed. The nonlinear impulse response results reveal some evidence of heterogeneous responses of income inequality to oil price shocks between high- and low-oil dependence US states. It is found that the changes in income inequality are more sensitive to OCDS in high-oil dependence states than in low-oil dependence states. OSS tend to have positive and statistically impacts on income inequality in the low-oil dependence states in the short term, but negative and statistically significant impacts in the high-oil dependence states in the medium term. However, the results show that the impulse responses of income inequality to EAS and OIDS are less affected by the status of oil dependence in US states. The results are also robust to the influence of macroeconomic common factors that drive business cycles in the US (such as the interest rate, inflation rate, and a ratio of budget deficit to GDP as a measure of fiscal policy) and the state-level control variables (such as the growth rate of real income, employment growth, and the unemployment rate in individual US states).

DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints, and they are not responsible for any duty of care in this regard.

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KEY TERMS AND DEFINITIONS

Economic Activity Shocks: The oil aggregate demand shocks that are driven by global real economic activity.

Linear and Nonlinear Impulse Responses: The linear and nonlinear impulse responses that are computed based on the local projection's method of Jordà (2005).

Local Projections: A method that computes impulse responses and estimates parameters locally at each period of interest.

Oil Consumption Demand Shocks: The oil-market specific demand shocks that are driven by oil-specific demand.

Oil Dependence: The dependence of oil in individual US states, calculated as the oil consumed minus oil produced as a percentage of oil consumed.

Oil Inventory Demand Shocks: The speculative demand shocks that are resulting from an increase in oil inventory demand.

Oil Supply Shocks: The structural oil price shocks that are emerging from a disruption in oil supply.

ENDNOTES

1 The production of global crude oil, the real price of oil, real economic activity, and crude oil inventories can be incorporated into the structural vector autoregression (SVAR) model of Baumeister and Hamilton (2019) to produce the oil supply, oil consumption demand, economic activity, and oil inventory shocks, respectively. The raw data are available at the quarterly frequency and downloadable from the databases of the Federal Reserve Bank of St Louis, the US Energy Information Administration (EIA), the Federal Reserve Economic Data (FRED) and the OECD Main Economic Indicators (MEI). The updated series of structural oil shocks are directly downloadable from the website of https://sites.google.com/site/cjsbaumeister/research.

2 See Fischer *et al*. (2021) for more details about the procedure of constructing income inequality measure.

3 The authors would like to thank Professor Florian Huber for kindly providing us with the inequality dataset.

4 The maximum length of forecast horizons is set to 24 months in this research, corresponding to a 2-year forecast horizon.

5 See Jordà (2005) for detailed discussions about the LPs method.

Chapter 6
FDI, Energy Consumption, and Institutional Quality:
The Case of Africa

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ABSTRACT

Being economic boosters, foreign direct investment (FDI) and financial sector development (FSD) are highly recommended for developing countries. It is therefore critical and important to examine the impact of both FDI and FSD on energy consumption. This chapter examines the link between FDI, FSD, and energy consumption in Africa and also the role of institutional quality in this context. The results establish that both FDI and FSD have a significant positive impact on energy consumption. It is also established that there is an inverse relationship between institutional quality and energy use. Finally, it is proved that quality institutions moderate the link between FDI, FSD, and energy use in Africa.

INTRODUCTION

Studies in the past and recent times have both found strong and compelling reasons for the need to attract foreign direct investment (FDI) into economies and the need to develop one's financial sector. For instance, studies have documented that the inflows of FDI into economies positively supports the growth of innovation, increase in adaptation of CSR, enhancement in skills and talents development, increased productivity and enhanced good corporate governance and all these finally propel economic growth for a nation (Borio, 2011; Nasir, Ali and Khokhar, 2014; Nyeadi *et al.,* 2020; Albuquerque & Neves, 2021;

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Hanefah *et al*., 2020). The inflows of FDI can also increase the financial morsel and innovative levels of host countries so as to enable them adopt energy saving technologies as well as the adoption of cleaner energy means so as to enhance the life and environment of host economies (Polat, 2018).

It is however argued that inflows of FDI may not only put so much pressure on energy consumption in developing countries that are currently battling with energy supply and environmental problems but it will lead to increase in the consumption of non-renewable energy which has a lot of negative consequences on the environment (Polat, 2018). This argument supports the Pollution Haven Hypothesis which argue that FDI may be a way of outsourcing "dirty industries" to developing countries as developing countries have softer environmental laws and enforcement (Polat, 2018). This therefore increases the chances of energy consumption and the use of more non-renewable energy in developing countries with the inflows of FDI.

A number of empirical studies have concluded that FDI inflows introduces energy savings in host countries thereby improving local environment. These studies support the environmental halo effect hypothesis of FDI (Jiang *et al*., 2014; Azam *et al*., 2015; Doytch and Narayan, 2016). There are also studies on the other hand that support the Pollution Haven Hypothesis demonstrating that inflows of FDI leads to higher energy consumption (Jebli *et al.,* 2019; Khandker, *et al.,* 2018).

On the side of financial sector development (FSD), countless studies have documented the positive link between the development of one's financial sector and energy consumption (Yue *et al*., 2019; Saini and Nego, 2018; Beladi *et al.,* 2013). However, micro-economic theories posit that FSD lowers household budget limits as it makes available several means of accessing financing at lower interest rates and makes one's investment more liquid. This limitless access to finance also leads to increase in household consumption such as the use of automobiles, housing, electrical appliances which obviously lead to increase in household consumption of energy (Sadorsky, 2012). Notwithstanding the above argument, it is noted just like FDI, FSD can also propel the adoption of technologies that reduce energy consumption or shifts consumption to clean energy (Rezagholizadeh *et al.,* 2020). In their study using Iranian economy, Rezagholizadeh *et al.,* (2020) concluded that FDS leads to higher consumption of renewable energy which helps to reduce environmental hazards.

From the above, it is noticeable that there is inconclusiveness in both theory and empirical front on the link between FDI, FSD and energy consumption nexus. This therefore means more research works are needed on this link so as to shed more light on the link. This study therefore intends to fill this gap by comprehensively examining the separate impact of FDI inflows and FSD on the amount of energy consumed in Africa. Besides, the moderating role of institutional quality on the FDI, FSD and EC link in Africa will be explored. To the best of knowledge, this is the first study in Africa that will examine in a comprehensive manner the above link using panel corrected standard errors (PCSE) and seemingly unrelated regression (SUR) estimation techniques. Besides, this study has extended the literature beyond other previous studies by also investigating the moderating role of institutional quality on the above nexus in Africa. Findings therefore have a lot of policy implications to African economies.

TRENDS OF FDI FLOW IN AFRICA

As indicated earlier, FDI flow into Africa was abysmal until the beginning of the 21st century, when a massive increase was recorded in its flow. From table 3 below, one can see that the inflows into the region were less than $7 billion per annum before the year 2000. This figure rose to an average of $30.7

billion per annum from 2000 to 2009. This further increased to $43.6 billion in 2010 and continued to rise until 2012, when an inflow of $55.2 billion was recorded. It, however, dropped to $52.2 billion in 2013 but returned to a higher figure of $58.3 billion in 2014. Another drop has been recorded in 2015, with a figure of $54 billion. The drop in 2012 for the continent can be attributed to the drops recorded in North Africa and Middle Africa. While North Africa recorded a reduction from $15.6 billion in 2012 to $12.7 billion in 2013, flow to Middle Africa dropped from $1.8 billion in 2012 to as low as $0.5 billion in 2013. The drop in these sub-regions can be attributed to the unstable political environment recorded in these places during the said period.

However, with the exception of these two sub-regions (Middle Africa and North Africa), all the other sub-regions experienced some decline in the flow of FDI in 2015 that led to a total decline for the whole continent. West Africa experienced the biggest drop in 2015. The drop in FDI flow in 2015 could be attributed to the drop in the prices of commodities and oil and gas, which receive the highest capitalization flow of FDI in Africa. Interestingly, while the flow of FDI to the whole world also showed a decline in 2013 just like Africa, in 2015 both the developing world and the world as a whole recorded increased FDI flows, except for Africa, Latin America, and the Caribbean regions where FDI inflows declined.

On average, the developing economies of the world as a whole, accounted for about 37.6% of the world inflows of FDI. Africa's share of the world FDI flows is only 3.28%, despite its improvement in FDI attraction over the years, whereas the Asia Pacific region, and Latin America and the Caribbean, have a share of 24.07% and 10.71% respectively of the world FDI, as shown in table 4. Therefore, in comparison with the developing economy as shown in figure 1, Africa's share is only 9.32% while Asia and the Pacific, and Latin America and Caribbean, accounted for 62.87% and 29.70% respectively. It is worth noting that whereas Africa and Latin America and Caribbean both showed a decline in 2015, Asia and the Pacific showed an increase. This same pattern could be observed in the year 2013. It implies that while the African and Latin American and Caribbean FDI inflows are more vulnerable to the world commodities markets, Asia and the Pacific inflows are not influenced by the commodities market to the same extent. It also means that FDI inflows for Africa, Latin America and Caribbean are more into the primary sectors of their economies.

Figure 1. Share in total developing countries (%), 1970-2015
Source: Computed from UNCTAD Database, 2016

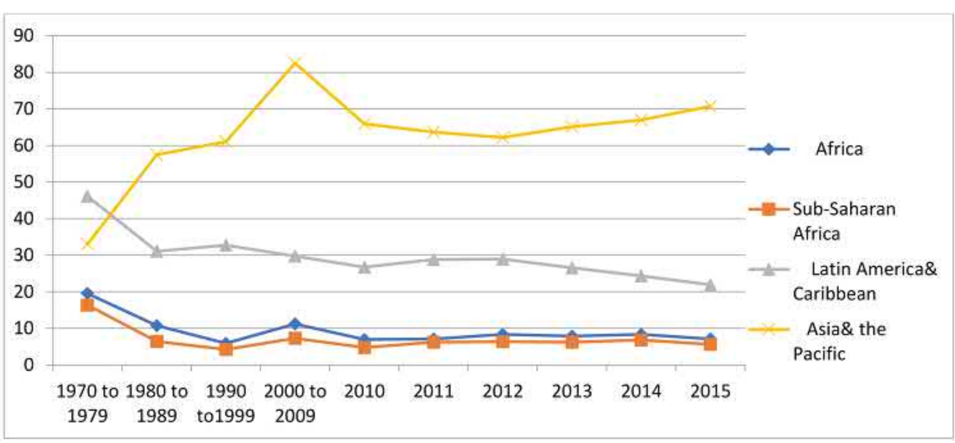


Table 1. FDI flows and shares to developing regions, 1970-2015(billions of US dollars)

	Average per Period				2010	2011	2012	2013	2014	2015
	1970 to 1979	1980 to 1989	1990 to 1999	2000 to 2009						
World	23.8	92.9	397.7	1,080.5	1,388.8	1,566.8	1,510.9	1,427.2	1,276.9	1,762.2
DE	5.8	20.5	114.9	272.7	625.3	670.1	658.8	662.4	698.4	764.7
Africa	1.1	2.2	6.8	30.7	43.6	47.8	55.2	52.2	58.3	54.1
SSA	0.9	1.3	4.8	19.9	29.9	41.9	41.9	41.1	47.6	42.9
EA	0.1	0.2	0.9	3.3	6.7	10.1	14.5	14.8	16.8	13.9
MA	0.2	0.3	0.7	3.9	4.3	4.2	1.8	0.4	10.5	14.0
NA	0.2	0.9	2.0	12.1	15.7	7.5	15.5	12.8	12.0	12.9
SA	0.05	0.1	1.0	4.9	4.8	6.9	6.4	9.6	6.8	3.3
WA	0.5	0.7	2.1	6.5	12.0	18.9	16.8	14.5	12.1	9.9
LAC	2.6	6.3	37.6	81.0	167.1	193.3	190.5	176.0	170.2	167.5
AP	1.9	11.7	70.2	225.0	412.4	426.7	409.5	431.4	467.9	540.7

Source: Computed from UNCTAD Database, 2016

Note: DE is Developing Economy, SSA-Sub-Saharan Africa, EA-Eastern Africa, MA-Middle Africa, NA-Northern Africa, SA-Southern Africa, WA-Western Africa, LAC-Latin America and the Caribbean, AP-Asia and the Pacific

Table 2. Share of country groups in world FDI (%), 1970-2015

	Average per Period				2010	2011	2012	2013	2014	2015	1970-15 Average
	1970 to 1979	1980 to 1989	1990 to 1999	2000 to 2009							
DE	24.18	22.06	28.88	25.24	45.03	42.77	43.60	46.41	54.70	43.39	37.63
Africa	4.72	2.37	1.71	2.84	3.14	3.05	3.65	3.65	4.57	3.07	3.28
SSA	3.96	1.41	1.22	1.84	2.15	2.68	2.77	2.88	3.72	2.43	2.51
EA	0.53	0.16	0.23	0.30	0.48	0.64	0.96	1.03	1.31	0.79	0.64
MA	0.73	0.36	0.18	0.36	0.31	0.27	0.12	0.03	0.82	0.80	0.40
NA	0.77	0.96	0.51	1.12	1.13	0.48	1.03	0.89	0.94	0.73	0.86
SA	0.19	0.12	0.26	0.46	0.35	0.45	0.42	0.68	0.54	0.19	0.37
WA	2.19	0.76	0.53	0.60	0.86	1.21	1.12	1.02	0.95	0.56	0.98
LAC	11.15	6.85	9.46	7.51	12.03	12.34	12.61	12.33	13.33	9.51	10.71
AP	7.99	12.68	17.64	20.82	29.69	27.23	27.11	30.23	36.64	30.69	24.07

Source: Computed from UNCTAD Database, 2016

Note: DE is Developing Economy, SSA-Sub-Saharan Africa, EA-Eastern Africa, MA-Middle Africa, NA-Northern Africa, SA-Southern Africa, WA-Western Africa, LAC-Latin America and the Caribbean, AP-Asia and the Pacific

ENERGY CONSUMPTION AND FINANCIAL SECTOR DEVELOPMENT IN AFRICA

Energy consumption in Africa as seen in figure 2 below shows that African consumption of energy is above the energy consumption levels of the least developed world in general. Placing Africa into sub-

Saharan and North Africa, it is realized that North Africa's level of consumption does not only exceed that of Sub-Saharan Africa, but it is far above all the sub-groupings of the world. When it comes to energy consumption in Africa, there is a clear distinction between Sub-Saharan Africa and the North Africa. While the North Africa is even above the world consumption level, Sub-Saharan Africa is only second to South Asia with low consumption levels. The high level of consumption in North Africa can possibly be attributed to two reasons. As compared with Sub-Saharan Africa, North Africa and Middle East countries are more industrialized countries and hence have more access and use of energy than sub-Saharan Africa. Secondly, it is possible that inefficiencies in the use of energy is high and that has triggered the consumption level. This is possibly the case as Middle and North Africa have got a consumption level even above the world consumption. For the very low consumption levels in sub-Saharan Africa, this can be as a result of lack of industrialization and possible lack of access to energy in the region.

Financial sector development trend has been shown here in figure 3. It is proxied by credit made available to the private sector. As shown in the figure below, East Asia and Pacific which was placed second to Middle East and North Africa in energy consumption is leading the group in financial sector development with very high figures than the rest of sub-regions. It is even above the world levels. It is interesting to note that while sub-Saharan Africa financial sector development by way of credit made available to private sector over the years have been declining slowly, the direct opposite has been the case for Middle East and North Africa. This could be possibly due to the industrialization drive in Middle East and North Africa championed by the private sector. It is also worth noting that the Latin America and the Caribbean have also experienced increase in their private sector access to finance.

Similarly, this could be attributable to vigorous industrialization being undertaken through the private sector. It is worth mentioning that the East Asia and Pacific region has recorded higher credit access even far above the whole world figures while the regions including Middle East and North Africa and sub-Saharan Africa are recording very low access as compared to the world figures. While the world and East Asia and Pacific are recording above 120%, the rest of the regions are recording below 60% with the highest ever recorded among them being around 59% which is sub-Saharan Africa in 2004 to 2007. Sub-Saharan Africa, however, took a dive in 2008 onwards and has since not recovered in access to finance by the private sector. One could attribute this dive to problem of financial crisis which took place around 2007 and 2008 in the world. The low levels of access to finance goes to support why most firms in developing world lack access to finance to propel growth in their operations. It therefore means that financial sector development in the developing world including Africa is very low and infantile in nature.

INSTITUTIONAL QUALITY IN AFRICA

Institutional quality as defined by quality of governance is made up of rule of law, control of corruption, political instability, regulatory quality, governance effectiveness and voice accountability (Amjad *et al.*, 2021). Figure 4 shows the average institutional quality for 44 countries taken from 2004 to 2018. From the figure, it is noticed that institutional quality is very low in Africa. With the exception of Botswana, South Africa, Namibia and Ghana, the rest of the 44 countries have their indicators below 50%. Among all the countries, Botswana is ranked first with 72.2% while the lowest ranked country is Congo DRC with 4.04%. To analyses the trends, the top 5 countries and the last 5 countries for 2004, 2011 and 2018 are considered in constructing figure 5.

Figure 2. Energy consumption levels

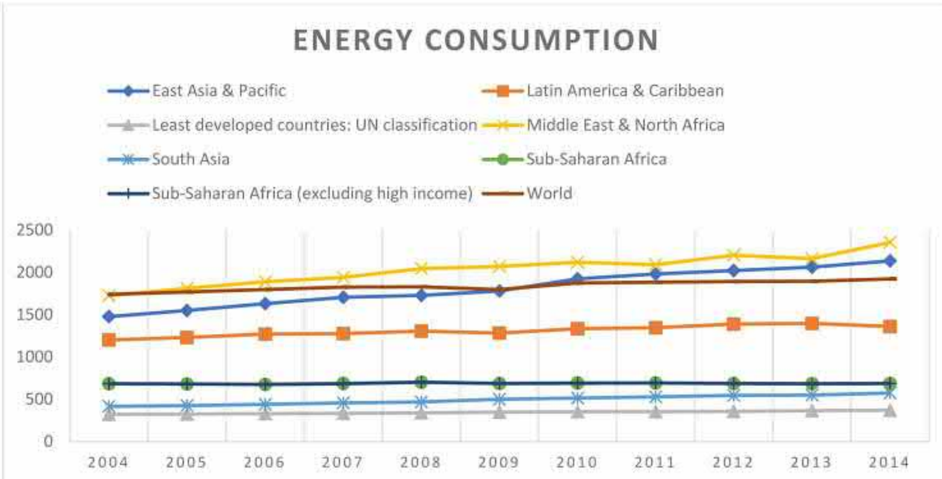
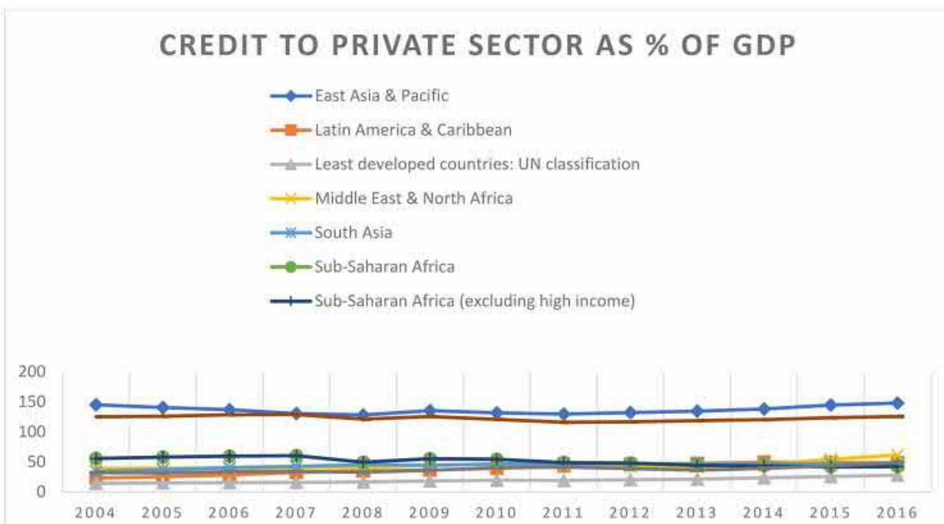


Figure 3. Financial sector development levels



The trend in Africa as shown among the selected countries is not a smooth one but an undulating one in nature. Among the top-ranking countries, with the exception of Namibia, have all witnessed decline which is a worrying situation. It is only Namibia which has consistently improved from 59% in 2004 to 61% in 211 and remained at 61% in 2018. While Ghana recorded an increase and subsequent decrease in 2018, Botswana, South Africa and Tunisia have all experienced a continued decrease for the period. This story is not different from the least ranked countries. While Zimbabwe and Congo DRC saw a marginal increase in 2018, the remaining countries witnessed a decrease in the numbers. One would have expected a great marginal improvement in institutional quality among African countries over the period but this is not the case as some countries have even witnessed worsening cases of their institutional quality over time.

Figure 4. Average institutional quality in Africa

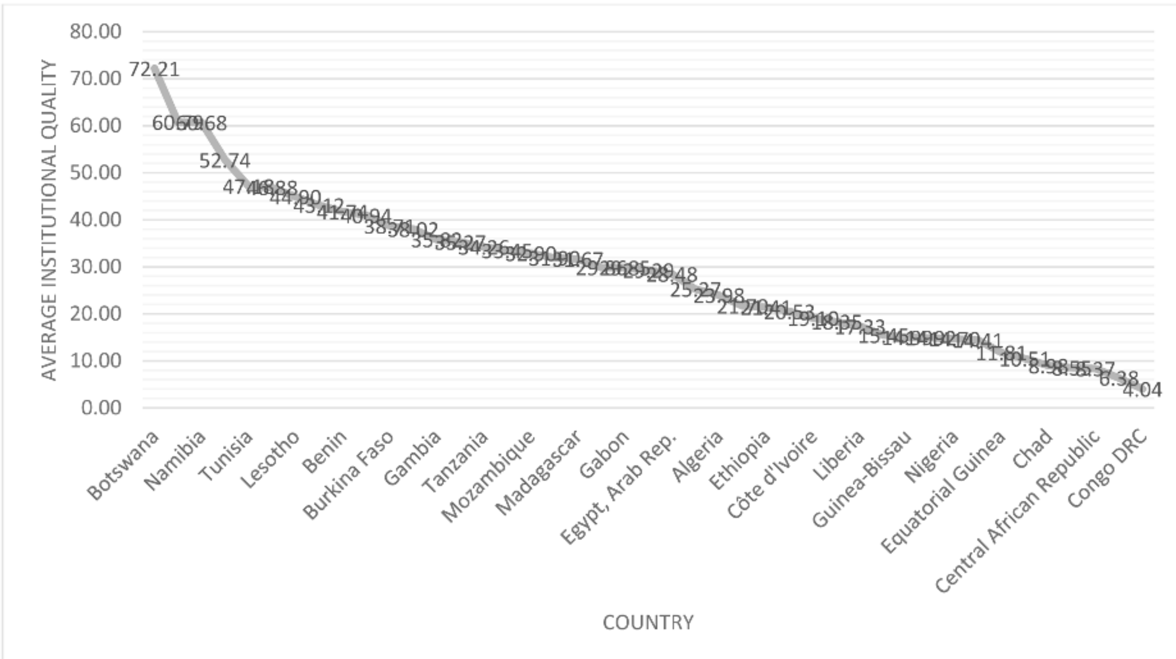
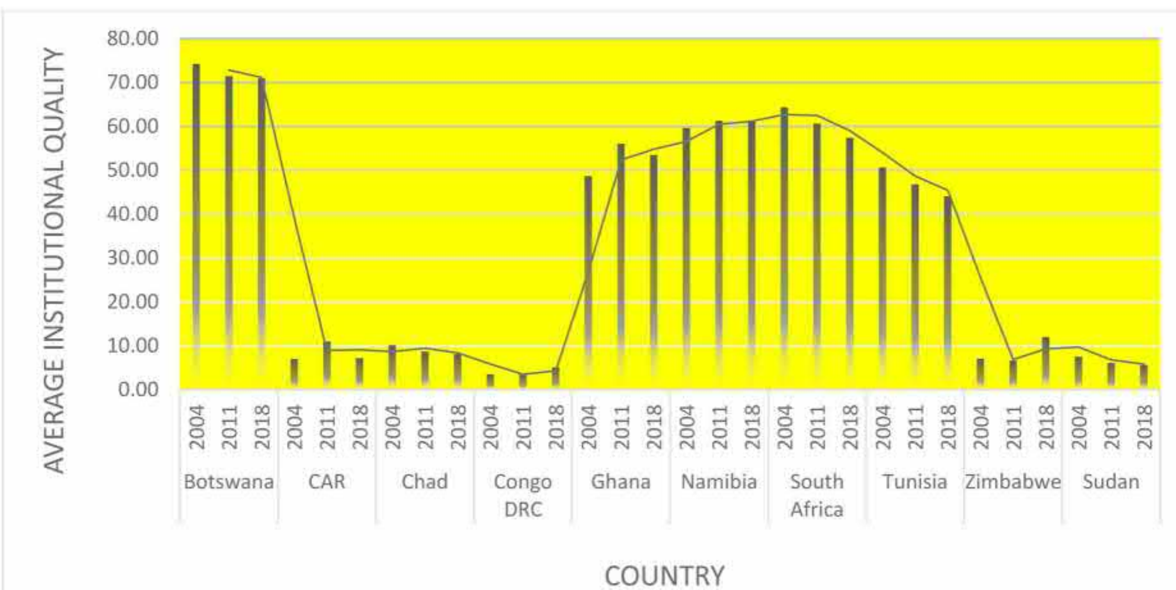


Figure 5. Trends of institutional quality in selected countries in Africa



LITERATURE REVIEW

Theoretical Link Between FDI, FSD and Energy Consumption

Generally, the finance-energy consumption debate is guided by a classical Cobb & Douglas (1928) production function, which views energy consumption as a function of income and prices. Studies on the nexus between foreign direct investment, financial sector development and energy consumption are guided by three competing theories. On one hand, the 'finance-energy consumption growth theory postulates that a positive nexus exist between financial sector development and energy consumption (Sadorsky, 2010, 2011[1]). According to Zhang (2011), a well-developed financial sector spurs production and consumption activities, thereby increasing the need for more energy. Besides, as financial sector development promotes expansion in the scale and scope of financial services provision in an economy, both production and consumption rise, increasing overall energy demand among market participants. For instance, Sadorsky (2010) argue that as financial sector develops more and more, there is easy and cheaper access to credit and finances by households. With available funds, individuals are able to acquire more luxurious chattels like automobiles, electrical appliances etc. for household usage and some possibly acquiring big houses leading to more consumption of energy by the households. At the firm level too, organizations are able to access funds at cheaper cost and therefore increasing their capital base which leads them into the acquisition of complex machines, equipment and automobiles used in the firms. All these cause the possible increase in energy consumption with advancement in the financial sector. Therefore, financial sector development is seen as a promoter of energy consumption through the channels of production and consumption. Well-developed financial systems promote increased lending to firms and households, thereby increasing the availability and consumption of goods and services that require more energy to run (Chang, 2015).

In contrast, other scholars argue that greater financial sector development and FDI inflows reduces energy consumption (Tamazian *et al.*, 2009; Shahbaz *et al.,* 2013b, 2017). According to this 'finance-energy conservation' view, a well-developed financial sector promotes the adoption of more energy substitution products that reduces overall energy consumption. They further argue that the advancement in financial sector promotes innovation and energy-efficient technology adoptions that reduces overall energy consumption in an economy. A third strand of the literature support a quadratic relationship, arguing for an inverted U-shaped relationship between finance and energy consumption (Shahbaz *et al.*, 2013; Chang, 2015; Charfeddine and Khediri, 2016). This theory suggests that initial increases in financial sector development inflows promotes energy consumption up to a point and beyond that threshold, further increases in financial sector development inflows result in a reduction in energy consumption through adaptation of so-called energy conservation technologies.

Similarly, the theoretical link between FDI and energy consumption (EC) has been a mix one. While a school of thought believes that FDI increases energy consumption, others on the contrary argue that FDI saves energy. The positive link is believed to exist due to the view that inward FDI which usually flow from advanced world to developing world serves as a way of outsourcing 'dirty industries' to host economies due to the weak environmental laws and enforcement in developing countries (Polat, 2018). It is argued that new investment opportunities that are restricted in advanced countries due to strict environmental laws and the needed compliances, look for opportunities in developing world because of relaxed environmental laws and compliances in developing countries (Walter and Ugelow, 1979). Besides, most developing countries receive FDI into capital intensive industries which are usually pollution-intensive industries such as mining, drilling and manufacturing thus increasing the level of energy consumed by the economies receiving such FDI.

This belief supports the Pollution Haven Hypothesis (PHH) which argues that FDI moves into developing countries due to stringent environmental laws and enforcements that are required in advanced countries. While environmental laws and enforcement tend to be soft and relaxed in developing countries, they are very strict in advanced countries thereby increasing the cost of production in advanced countries (Levinson and Taylor, 2008). This PHH thus predicts a positive relationship between FDI and EC. According to Kim (2019), this situation is made worst, as developed countries are obliged to reduce more of the CO_2 emission. This has therefore enhanced the outsourcing of these dirty industries into developing world. Sarkodie and Strezov (2019) supported this theory by arguing that polluting industries move towards countries with less stringent environmental laws with cheaper production cost.

On the contrary, the proponents of FDI-EC negative link believe that the inflow of FDI into host countries reduce energy consumption as firms from developed countries move into developing world do so along with the strict environmental enforcements and compliance that they have cultivated at home countries so as to make an impact in their operations in their host countries. Technological advancements play an important role (Rafay, 2109). Apart from being strict in complying with environmental regulations, FDI led firms, which have more exposure to efficient energy technology and also have more capital base can adopt very effective energy saving technology in their operations so as to reduce the consumption of energy. Besides, the inflow of FDI can lead to the diffusion of technology to host countries arising from spillover effect from FDI led firms. As FDI led firms adopts energy saving processing and technology, due to competition among other non-FDI firms, the host country firms may also be compelled to also adopt efficient ways of doing things in order to succeed in the competition. In supporting this view, Stavropoulos *et al*., (2018) argue that the influx of FDI into developing countries could help promote both industrial competitiveness and environmental quality.

This view strongly lends it support to the Pollution Halo Hypothesis (PH) which believes that FDI has negative relationship with energy consumption as FDI led firms diffuse their modern and efficient production techniques into the host economies thereby reducing energy use and pollution (Zhang and Zhou, 2016). Besides, with the influx of FDI into developing countries, host firms may be forced to innovate in order to stay competitive and this can call for better and efficient ways of doing things that can reduce energy consumption in the system. It particularly noted that influx of FDI to poor countries helps in transfer of technology and management practices which cause lower carbon emission in developing countries (Zarsky, 1999).

Lastly, the so-called ‘neutrality’ view postulates that no significant nexus exist between FDI, financial sector development and energy consumption. According to this hypothesis, well developed financial systems and the ability of a country to attract FDI has no consequence for energy consumption in the economy (Çoban and Topcu, 2013; Kahouli, 2017; Charfeddine and Kahia, 2019; Yue *et al.*, 2019; Denisova, 2020). This theory suggests that whether investment capital originates from within a well-developed financial system or from outside the domestic economy through FDI inflows or not is deemed unimportant for determining the level of energy consumption in an economy.

Empirical Link Between FDI, FSD and Energy Consumption

The empirical literature on the nexus between FDI, financial sector development and energy consumption is replete with polemics. Similar to the theoretical literature, there is a lack of consensus regarding the nature of the relationship between finance and energy consumption and this ambiguity is seen in both single country and cross-country studies. Proponents of the finance-energy consumption growth theory, argue that a significant positive nexus exist between financial sector development and energy consumption. According to Sadorsky (2011), banking sector development is significantly and positively associated with greater scale and scope of energy consumption in Central and Eastern European Frontier Markets. Improvements in banking services leads to better economic allocation and higher productivity in the domestic economy, thereby promoting higher energy consumption. Similarly, Le (2016) found a positive causal nexus between financial sector development and energy consumption in middle-income Sub-Saharan African economies. In an earlier study, Islam *et al.* (2013) found positive benefits of financial sector development for energy consumption in Tunisia. Using VAR model on a Chinese Economy, Zeng *et al.* (2020) also noted the positive link between FDI and energy consumption China. Similar results were found by Fung (2009), Bekhet *et al.* (2017), Kahouli (2017), Saud *et al*. (2018); Liu *et al.* (2018) and Rezagholizadeh *et al.* (2020) among others.

In contention, several recent empirical studies found evidence suggesting that financial sector development reduces energy consumption significantly (Tamazian *et al.*, 2009; Shahbaz *et al.*, 2013b). For instance, Ouyang and Li (2018) found a significant negative relationship between financial, sector development and energy consumption in China. Similarly, Shahbaz *et al.* (2013) found that financial sector development reduced energy consumption in South Africa. Similar Charfeddine and Khediri (2016) found evidence challenging the idea that financial sector development spurs energy consumption in United Arab Emirates. In his study using eighty-five developed and developing countries, while FDI reduces energy consumption in developed countries it has no effect on energy consumption in developing countries. Indeed, Charfeddine and Khediri (2016) among others provide evidence to suggest that financial sector development initially spurs energy consumption at the initial stages and beyond a certain threshold, further development of the financial sector promotes the adoption of energy-conservation and thus reduces overall energy consumption. Also, many studies like Riti *et al.* (2017) found no significant relationship between financial sector development and energy consumption.

There is also an unresolved contention in the literature about the nature of the relationship between FDI and energy consumption. Three folds of arguments are identified. First, the FDI-energy consumption growth model advocate for a positive significant nexus between increases in FDI inflows and energy consumption. According to Mohamed and Mamat (2016) foreign direct investment inflows promotes industrial development and spurs energy consumption. Shahbaz and Lean (2012) examined this link in Tunisia using ARDL model and concluded that financial sector development in Tunisia leads to more consumption of energy in the country. Similarly, Yue *et al.* (2019) studied twenty-one transitional countries and realised that financial development in these countries impacts positively on energy consumption in these countries. A plethora of other empirical studies support this view (Sadorsky, 2011; Yue Ting *et al.*, 2011; Çoban and Topcu, 2013). In contrast, several recent studies contend that greater FDI inflows decreases energy consumption by providing opportunities for the diffusion of energy-efficient technology rich and technologically advanced economies to poorer countries. In support of this view, Sadorsky (2011), Çoban and Topcu (2013), Jiang *et al.* (2014), Azam *et al.* (2015) and Doytch and Narayan (2016) all found evidence supporting a significant negative relationship between FDI inflows and energy consumption. Other studies also found no significant nexus between FDI and energy consumption (Hübler and Keller, 2010; Sadorsky, 2010; Lee, 2013). For example, Chang (2015) found no significant relationship between FDI and energy consumption in 53 countries studied.

In conclusion, the theoretical and empirical literature on the nexus between financial sector development, FDI and energy consumption contentious at best. Moreover, there is a paucity of studies examining these relationships in Africa. To the best of the authors' knowledge, no single study in Africa have examined the effect of institutional quality on the financial sector development, FDI and energy consumption nexus. However, given the vital role played by quality of institutions in determining the way and manner financial resources are channeled into economic activities, it is critical that African leaders are provided with the empirical evidence on the relationship between FDI inflows, financial sector development and energy consumption. This is even more critical as energy consumption growth is usually associated with higher CO_2 and other pollutants emissions. Weak institutions may limit the transmission of benefits from financial sector development and FDI inflows to energy consumption/conservation. It is therefore imperative that African leaders and policy makers are provided with the empirical links between these variables to guide policy initiatives that will ensure optimal environmental benefits from greater financial sector development and FDI inflows.

Empirical Link Between Institutional Quality and Energy Consumption

Institutional quality such as regulatory quality, governance effectiveness, control of corruption and political instability are important factors of energy consumption and hence determinants of environmental quality (Panayotou, 1997; Ibrahim and Law, 2016). Zakaria and Bibi (2019) posit that institutions can determine the impact of capital flows on environmental quality in developing economies as these institutions have the choice of being strict with their environmental laws and policies so as to have quality environment or relax their environmental laws and policies and have their environment quality reduced with the inflows of capital. It is argued that well-functioning quality institutions enhance environmental quality in developing countries (Panayotou, 1997). This argument is premised on the belief that quality institutions improve environmental quality by reducing opportunism and fostering cooperative attitudes among agents.

Uzar (2020) examined the link between institutional quality and energy consumption using both developed and developing countries on a data ranging from 1990-2015. This study concluded that institutional quality positively affects the consumption of renewable energy. This implies that where there are well functioning institutions put in place, the environment is protected with the consumption of clean energy. Fredriksson and Svensson (2003) established that high level of corruption and political stability led to weak environmental policies. They argued that in such economies, politicians focus on maximizing their interest as against trying to enact policies that will respond to the preferences of the people. Besides, with high corruption, strictness on environmental policy adherences is reduced drastically through the lobbying by traditional energy companies.

Again, Mehrara *et al.* (2015) discovered that inefficient regulatory qualities ignited by high level of corruption and rent-seeking activities will lead to the reduction in the investment in productive areas like renewable energy by companies thus jeopardizing the environmental quality with high energy consumption. Using 71 developing and developed countries between 1990 and 2016, Shah *et al.* (2020) realized that both non-renewable and renewable energy significantly cause environmental degradation with the absence of institutional quality. Hunjra *et al.* (2020) studied 5 countries in South Asia to examine the role of quality institutional on the link between FSD and environmental sustainability. From their study, institutional quality was found to moderate the negative impact of financial development on environmental sustainability (Rafay, 2022). From these empirical evidence, institutional quality is seen as a catalyst of quality environmental existence. This implies that quality institution can moderate any possible negative link between financial sector development and FDI and energy consumption.

METHODOLOGY

Data and Variables

The data for the study on this book chapter comes from three main sources. These are World Bank African Development Indicators, World Bank Governance Index and International Monetary Fund. The study uses data covering the period, 2004-2018 for 44 African countries. The choice of these countries is purely based on the availability of data on chosen variables for the specified period of the study. Dependent variable, energy consumption is represented by energy use in kg oil equivalent as used by previous studies (Polat, 2018 and Yue *et al.,* 2019). For dependent variables, two of them are the main variables of focus i.e., foreign direct investment and financial sector development. FDI is measured here as the net inflows of foreign direct investment. This variable is used as a predictor of energy consumption as inflows of FDI into an economy has greater potential of exerting greater pressure on energy consumption in such countries than before as their firm activities increase in numbers hence demanding more energy use. This also worsen by the Pollution Haven Hypothesis which believes that inflows of FDI does not only increase energy consumption but it increases the consumption of non-renewable energy which has negative consequences on the environment (Polat, 2018).

In a contrary view, it is argued that as the inflows of FDI boast the financial base of firms, firms will be better placed to innovate more so as to reduce energy consumption or use better sources of energy (Polat, 2018). Either positive or negative impact of FDI is expected on energy consumption in Africa. Second main independent variable is financial sector development which is proxied by two variables following the presets of earlier studies (Polat, 2018; Ntow_Gyamfi, *et al.,* 2020). First FSD is measured by domestic credit provided by banks as percentage of GDP and secondly general domestic credit to the private sector is used as percentage of GDP. Just like the FDI-energy nexus, there are contrary views of the FSD-energy consumption link. While it is believed that the advancement of the financial sector development makes access to finance easier to consumers thus making the consumer to increase its desire and use for items such as TV, automobiles, electrical appliances hence, his demand for energy to power these items increase correspondingly (Sadorsky, 2012).

However, as the sector also advances, it makes it possible to innovate to reduce energy consumption or adopt cleaner usage (Rezagholizadeh *et al.*, 2020). Significant positive or negative relationship is expected between FSD and energy consumption in Africa. Apart from the two main independent variables, other included variables are population, GDP per capita growth, financial openness, electricity price, governance effectiveness and regulatory quality as control variables (Saini and Nego, 2018; Yue *et al.,* 2019; Polat, 2018; Jebli *et al.,* 2019). The full description of all the variables with their sources are indicated in the table 3.

Table 3. Description of variables

Symbol	Variable	Definition	Source
EC	Energy consumption	Energy use (in kg oil equivalent)	World Bank, African Development Indicators 2021
FDI	Foreign direct investment	Net foreign direct investment inflows as percentage of GDP	International Monetary Fund 2021
DOMCREDB	Financial sector development	Domestic credit given by the banks as percentage of GDP	World Bank, African Development Indicators 2021
DOMCRED	Financial Sector development	Domestic credit to private sector as percentage of GDP	World Bank, African Development Indicators 2021
OPEN	Financial openness	Volume of trade as a percentage of GDP	World Bank, African Development Indicators 2021
POP	Total population	Midyear population (number)	World Bank, African Development Indicators 2021
GGDP	Economic growth	Percentage Change in GDP per capita	GDP per capita growth
EP	Electricity price	Consumer price index (annual %)	International Monetary Fund 2021
GE	Institutional quality	Governance effectiveness index(percentile rank 0-100)	World Bank Governance index, 2021
RQ	Institutional quality	Regulatory quality index (percentile rank 0-100)	World Bank Governance index, 2021

Estimation Technique

Based on the preceding discussions on the theoretical link between FDI and energy consumption and FSD and energy consumption and following the works of Yue *et al*. (2019), Polat (2018) and Rezagholizadeh *et al.* (2020), the following is the adopted panel data model.

$$EC_{it} = \lambda + \psi FDI_{it} + \beta CV_{it} + \varepsilon_{it} \tag{1}$$

Where the dependent variable, *EC* is the energy consumption; λ is a common fixed effect term; *FDI* is net FDI values inflows rather than in stock; C*V* is the composite of other variables included as control variables. ψ and β are the parameters of FDI and control variables respectively while ε is error term. The subscription i r*e*fers to the countries under the study while t d*e*notes the year.

To explore the FSD-energy consumption link, the equation is modified as follows:

$$EC_{it} = \lambda + \psi FSD_{it} + \beta CV_{it} + \varepsilon_{it} \tag{2}$$

Where *FSD* represent financial sector development while the other variables remain the same as in equation (1) above. Equation (2) can further be restated as seen in equation (3) and (4). Where DOMCREDB represents financial sector development measured by domestic credit given by banks while DOMCRED is the financial sector development measured by domestic credit to private sector.

$$EC_{it} = \lambda + \psi DOMCREDB_{it} + \beta CV_{it} + \varepsilon_{it} \quad (3)$$

$$EC_{it} = \lambda + \psi DOMCRED_{it} + \beta CV_{it} + \varepsilon_{it} \quad (4)$$

To explore the moderating effect of quality institutions on the link between FDI and EC and FSD and EC in Africa, an interactive variable to equations (1), (3) and (4) is added to generate the following equations:

$$EC_{it} = \lambda + \psi FDI_{it} + \psi(FDI * GE)_{it} + \psi(FDI * RQ)_{it} + \beta CV_{it} + \varepsilon_{it} \quad (5)$$

$$EC_{it} = \lambda + \psi DOMCREDB_{it} + \psi(DOMCREDB * GE)_{it} + \psi(DOMCREDB * RQ)_{it} + \beta CV_{it} + \varepsilon_{it} \quad (6)$$

$$EC_{it} = \lambda + \psi DOMCRED_{it} + \psi(DOMCRED * GE)_{it} + \psi(DOMCRED * RQ)_{it} + \beta CV_{it} + \varepsilon_{it} \quad (7)$$

Where GE and RQ represent governance effectiveness and regulatory quality respectively. FDI*GE(RQ) is the interaction term of FDI and institutional quality whereas DOMCREDB(DOMCRED)*GE(RQ) are the interaction terms for financial sector development and institutional quality. The other variables are the same as defined in the previous equations.

To estimate the above equations, Panel Corrected Standard Errors (PCSE) is used. In carrying out this, Beck and Katz (1995) argued that the best way is to estimate the coefficients by OLS and then compute Panel Corrected Standard Errors (PCSEs). In this method, the Ω is an NT x NT block diagonal matrix with ∑, an N x N matrix of contemporaneous correlations along the diagonal. OLS residuals, denoted ei,t for firm i at time t are used to estimate the elements of ∑:

$$\sum\nolimits_{i,j} = \frac{\sum_{t=1}^{T} e_{i,t} e_{j,t}}{T} \quad (8)$$

Then the standard errors of the coefficients are computed using the square roots of the diagonal elements of

$(X^1 X)^{-1} X^1 \hat{\Omega}$ X(X1X)-1

Where X denotes the NT x NT matrix of stacked vectors of explanatory variables, Xi,t. Though the parameters are the same as in the FGLS, PCSEs has better small sample properties and thus produces more reliable standard errors than FGLS. In estimating equations, the Beck and Katz's two-step is used. Panel corrected standard errors (PCSEs) estimator as follows:

$$\hat{\beta} = (\tilde{X}'\tilde{X})^{-1} \tilde{X}^1 \tilde{y} \quad (9)$$

$$Var(\hat{\beta}) = (\tilde{X}^1\tilde{X})^{-1}(\tilde{X}^1\tilde{\Sigma}\tilde{X})(\tilde{X}^1\tilde{X})^{-1} \quad (10)$$

Where $\tilde{X}$ and $\tilde{y}$ are the Prais-transformed vectors of the explanatory and dependent variables and $\tilde{\Sigma}$ is the estimator of the Σ. The PCSE is adopted because it is very useful in estimating linear models where the disturbances are assumed to be either heteroscedastic across panels or heteroscedastic and contemporaneously correlated across panels. Besides, PCSE provides consistent and efficient results whether or not the number of firms are less or equal to the time dimension or the number of firms is greater than the time dimension (Reed and Ye, 2011). Endogeneity tests are conducted to control for the likely endogeneity.

Additionally, regression (SUR) estimator is employed as an alternate estimator for robustness. The SUR also enables us to correct for any endogeneity issues.

In carrying out SUR estimation, the common multiple equation structure is used which is outlined by Greene (2003) as follows:

$$Y_{1it} = X_{1it}\beta_{1it} + \varepsilon_{1it} \quad (11)$$

$$Y_{2it} = X_{2it}\beta_{2it} + \varepsilon_{2it} \quad (12)$$

$$\vdots$$

$$Y_{Mit} = X_{Mit}\beta_{Mit} + \varepsilon_{Mit} \quad (13)$$

Where the assumption is that Y is a dependent variable, X is the vector of explanatory variables while ε is an unobservable error term. The variable i =1,…. N and t =1, ….T. There are M equations and NXT observations. The use of the SUR is motivated by the fact that efficiency is gained in the estimation by combining information on different equations. Besides, the SUR imposes and tests restrictions that involve parameters in different equations.

FINDINGS AND DISCUSSIONS

Descriptive Statistics

From the table below are descriptive statistics presented on variables. With energy consumption, it is noted that it has a standard deviation of 0.4177 indicating a very similar level of energy consumption in the continental. There is not much variation in the level of energy consumed by African countries. This can be attributed greatly to the agrarian and raw materials-based economy operated by most African countries, which does not require so much of energy. Notwithstanding this, evenly spread in the consumption of energy in the region, some countries' consumption is very minimal as compared to their GDP. This is seen in the minimum level of consumption which is stands at 0.0104 while the highest consumption figure is 3.6211. The inflows of FDI into the continent on the other hand shows a very different picture.

There is a very big gap between countries in the region as far the inflows of FDI into the region is concerned. While the highest recipient country recorded 83.2670, the lowest country recorded 0.0031which shows a very fast variation in the inflows. This is not surprising as a few countries including Nigeria, South Africa, Egypt, Morocco, Mozambique, DR Congo and Ghana contribute to more than half of all the inflows into the region. It shows that some countries within the region attracts very low inflows into their economies. There is not much different with this trend in the financial sector development. The two measures of financial sector development, DOMCREDB and DOMCRED present similar outcomes. These can be seen in the high standard deviation figures of 18.8712 and 26.8569 for DOMCREDB and DOMCRED respectively. Therefore, expect similar impact of FDI and FSD on EC is expected.

One of the variables that need commentary is the financial openness. It has the highest standard deviation of 41.3989 with a mean average of 72.4737. It shows on the average many countries in Africa are open to international trade except a few which are not open. As a matter of fact, the lowest figure here is zero meaning some countries have not still open up for international trade. Other variables of interest here are the institutional quality measured by the governance effectiveness and regulatory quality. These two measures both have average means of 27.7765 and 29.9576 respectively for GE and RQ. This shows on the average that African countries are recording below the average on the scale of 0 to 100. It is only a few countries that are recording above average in these two variables.

Table 4. Summary statistics

Variable	Obs.	Mean	Std. Dev	Min.	Max
EC	660	0.4459	0.4177	0.0104	3.6211
FDI	660	7.3476	10.2710	0.0031	83.2670
DOMCREDB	660	20.4070	18.8712	0.9347	106.2603
DOMCRED	660	22.5612	26.8569	1.0952	160.1248
POP	660	2.34e+07	3.05e+07	716,949	1.96e+08
OPEN	660	72.4737	41.3989	0	347.9965
GE	660	27.7765	19.7831	0.9479	81.7307
RQ	660	29.9576	18.5096	0.4808	83.6538
EP	660	7.6154	11.1069	-76.7294	156.9625
GGDP	660	4.7360	7.2852	-62.0759	123.1396

Correlation Matrix

The table below shows correlation levels among independent variables in models. From the correlation matrix shown in the table, it is seen that most of the variables have some kind of relationship which is either positive or negative in nature. The only relationships that present a very high coefficient above 0.7 are DOMCREDB and DOMCRED (0.93) and GE and RQ(0.89) As a result, these variables are not placed into one model. It therefore means that any combination in variables with the exception of these two mentioned combinations will not pose any problem in models.

Table 5. Correlation matrix

	1	2	3	4	5	6	7	8	9
FDI(1)	1.00								
DOMCREDB(2)	0.12*	1.00							
DOMCRED(3)	0.19*	0.93*	1.00						
GGDP(4)	0.02	-0.08*	-0.07*	1.00					
EP(5)	0.19*	-0.14*	-0.10*	-0.05	1.00				
POP(6)	0.66*	0.03	0.09*	0.06	0.16	1.00			
OPEN(7)	-0.07*	0.13*	0.07*	-0.03	-0.04	-0.34*	1.00		
RQ(8)	-0.07*	0.64*	0.59*	0.01	-0.13*	-0.06	-0.03	1.00	
GE(9)	-0.04	0.69*	0.64*	0.02	-0.07*	-0.01	-0.03	0.89*	1.00

FDI and Energy Consumption: The Role of Quality Institutions

The results for PCSE regression on FDI and energy consumption are shown in table 5 while SUR results for the same link are shown on table 6. Models 1 and 2 from table 5 show the regression without the interaction term. From these results, foreign direct investment is positively significant with energy consumption. This indicates that the inflows of FDI into African economies impacts positively on energy consumption. Any inflows of FDI therefore leads to corresponding increase in energy consumption. This goes to support earlier findings which concluded that inflows of FDI leads to more consumption of energy (Fung, 2009; Liu *et al.,* 2018; and Rezagholizadeh *et al.*, 2020). This is possible because the inflows if FDI enhances the capital base of firms making them able to acquire more energy consuming items such as automobiles, factory machines, equipment and other electrical gadgets. This results also goes to buttress the Pollution Haven Hypothesis which believes that inflows of FDI to developing countries become sources of outsourcing dirty industries to host countries (Polat, 2018).

On the contrary, quality institutional variables, governance effectiveness and regulatory quality are both found to be significantly negative with energy consumption. This inverse relationship between institutional quality and energy consumption shows that efficient and effective government institution are helpful in reducing the consumption of energy in Africa. Though institutional quality is relatively low in Africa, it is noted here as a factor in bringing sanity in energy consumption. Wastages and loses in energy consumption that occur due to indiscipline and non-compliance behavior of people and institutions are reduced drastically when government institutions that are in charge of monitory and enforcing laws are up to their task.

As expected, there is also a direct positive relationship between population and energy consumption. Any increase in population leads to an increase in energy consumption. This is obvious as increase in population calls for more household consumption of energy in those more household items that are powered by energy are demanded with the increase in population. One of the control variables which is also significant and hence has impact on energy consumption is financial openness. It however has an inverse relationship with the use of energy. It supports the findings of Yue *et al.* (2019). Having also realized that governance effectiveness and regulatory quality brings about efficient use of energy while FDI inflows increases the consumption of energy in Africa, it is decided to interact the governance effectiveness and regulatory quality with FDI separately to observe their outcomes. The results of the interactions are shown in model 3 and 4 of table 5. From the results, both regulatory quality and governance effectiveness which represent institutional quality when interacted with FDI, leads to reduction in energy consumption in Africa. It therefore means that countries that have strong and efficient institutions that attract FDI brings about efficiency in their energy consumption. Thus, for countries to benefit fully from FDI, it is paramount that proper and well-functioning government institutions are put in place. All these results especially the main variables of interest are still consistent in the second estimator (SUR) regression results shown in table 6.

Table 6. PCSE regression on FDI and energy consumption

	Model 1	**Model 2**	**Model 3**	**Model 4**
Independent Variables	EC	EC	EC	EC
FDI	0.0040**	0.0052**	0.0199***	0.0099***
	(0.0020)	(0.0021)	(0.0054)	(0.0030)
GGDP	0.0007	0.0004	0.0003	0.0008
	(0.0020)	(0.0019)	(0.0017)	(0.0019)
EP	0.0042	0.0039	0.0036	0.0041
	(0.0037)	(0.0034)	(0.0035)	(0.0038)
logPOP	0.0628***	0.0514**	0.0807***	0.0854***
	(0.0176)	(0.0202)	(0.0144)	(0.0154)
OPEN	-0.0025**	-0.0025**	-0.0021**	-0.0023**
	(0.0010)	(0.0011)	(0.0010)	(0.0010)
GE	-0.0040***			
	(0.0004)			
RQ		-0.0054***		
		(0.0008)		
FDI_RQ			-0.0005***	
			(0.0001)	
FDI_GE				-0.0002***
				(5.69e-05)
Constant	55.86***	54.16***	58.07***	58.91***
	(9.154)	(9.726)	(6.934)	(7.754)
Year dummy	Yes	Yes	Yes	Yes
Country Dummy	Yes	Yes	Yes	Yes
Observations	321	321	321	321
R-squared	0.304	0.323	0.332	0.285
Number of Countries	32	32	32	32

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7. SUR regression on FDI and energy consumption

	Model 1	Model 2	Model 3	Model 4
Independent Variables	EC	EC	EC	EC
FDI	0.0040*	0.0052*	0.0199***	0.0099**
	(0.0035)	(0.0035)	(0.0046)	(0.0043)
GGDP	0.0007	0.0004	0.0003	0.0008
	(0.0022)	(0.0021)	(0.0021)	(0.0022)
EP	0.0042***	0.0039***	0.0036**	0.0041***
	(0.0014)	(0.0014)	(0.0014)	(0.0014)
logPOP	0.0628**	0.0514**	0.0807***	0.0854***
	(0.0252)	(0.0251)	(0.0242)	(0.0250)
OPEN	-0.0025***	-0.0025***	-0.0021***	-0.0023***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)
GE	-0.0040***			
	(0.0009)			
RQ		-0.0054***		
		(0.0010)		
FDI_RQ			-0.0005***	
			(9.51e-05)	
FDI_GE				-0.0002***
				(8.84e-05)
Constant	55.86***	54.16***	58.07***	58.91***
	(12.95)	(12.78)	(12.69)	(13.14)
Year dummy	Yes	Yes	Yes	Yes
Country Dummy	Yes	Yes	Yes	Yes
Observations	321	321	321	321
R-squared	0.304	0.323	0.332	0.285

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

FSD and Energy Consumption: The Role of Quality Institutions

Second task in this chapter is to explore separately the link between financial sector development and energy consumption in Africa. To do this, another set of regression is used using panel corrected standard errors and seemingly unrelated regression and the results are shown below in tables 7 and 8. Again, PCSE results are relied on for interpretation of results as both estimators present consistent results. The financial sector development is proxied by credit given by local banks (DOMCREDB) and credit in general given to the private sector (DOMCRED). Models 1 and 2 of table 7 show the domestic credit given by local banks and energy consumption link without any interaction terms. From these results, DOMCREDB has significant positive impact on energy consumption in Africa. An increase in financial sector development through bank efficiency leads to more energy consumption. Again, institutional quality variables represented by RQ and GE are seen to have inverse relationship with energy consumption. This indicates that good and efficient institutions save energy consumption.

Again, DOMCREDB is interacted with both RQ and GE to see if the institutional quality will moderate the impact of FSD on energy consumption. After interacting with both, it is realized as shown in models 3 and 4 of table 7 that interaction terms have yielded inverse relation with energy consumption. It therefore shows that though advancement in financial sector brings about increase in energy consumption, when financial advancement takes place in economies that have good institutions where law enforcement and machinery are effective, energy consumption is reduced. Again, the alternative measure of FSD is examined using credit to the private sector (DOMCRED). The results are shown in table 9 of the PCSE. It started by running first two models without any interaction. Just like the bank sector development, DOMCRED is found to significantly positive with energy consumption at 1%. Apart from the direct relationship also found here, the coefficients in these models (0.145 and 0.119) are higher than the coefficients in the DOMCREDB(0.115 and 0.0941). This implies that the general financial sector development has more impact on energy consumption than development in the banking sector alone. This is obvious because, the development in the banking sector alone has limitations for access to finance especially to the non-banked group hence fewer people or firms will be able to increase their demand on energy consuming products. However, where there is general advancement and efficiency in financial sector, access to funds and liquidity go up which certainly stimulates the need for energy at both the household level and the corporate front. It therefore means that while the advancement in banking sector alone increases energy demand, the well-functioning whole financial sector calls for more demand in energy consumption in Africa. Again, DOMCRED is interacted with GE and RQ separately and the results are shown in models 3 and 4 of table 9. Just like the previous interaction, an inverse relationship is found here with energy consumption. It is noticed again that the coefficients for the interaction terms with DOMCRED are higher (-0.0021 and -0.0020) than the interactive terms with DOMCREDB (-0.0017 and -0.0016). This means the energy saving impact of DOMCRED_RQ (GE) is more than DOMCREDB_RQ (GE).

Table 8. PCSE regression on FSD (Bank) and energy consumption

	Model 1	Model 2	Model 3	Model 4
Independent Variables	EC	EC	EC	EC
logDOMCREDB	0.115***	0.0941***	0.121***	0.126***
	(0.0364)	(0.0346)	(0.0436)	(0.0434)
GGDP	0.0021	0.0017	0.0020	0.0021
	(0.0021)	(0.0021)	(0.0021)	(0.0021)
EP	0.0072***	0.0069***	0.0069***	0.0070***
	(0.0017)	(0.0017)	(0.0017)	(0.0017)
logPOP	0.0496***	0.0518***	0.0580***	0.0578***
	(0.0187)	(0.0188)	(0.0188)	(0.0187)
OPEN	-0.0029***	-0.0028***	-0.0023***	-0.0022***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)

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Table 8. Continued

	Model 1	Model 2	Model 3	Model 4
GE	-0.0069***			
	(0.0013)			
RQ		-0.0068***		
		(0.0014)		
logDOMCREDB_RQ			-0.0017***	
			(0.0004)	
logDOMCREDB_GE				-0.0016***
				(0.0003)
Constant	68.46***	62.44***	61.94***	66.26***
	(13.21)	(13.03)	(13.22)	(13.42)
Year dummy	Yes	Yes	Yes	Yes
Country Dummy	Yes	Yes	Yes	Yes
Observations	311	311	311	311
R-squared	0.325	0.319	0.305	0.308

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9. SUR regression on FSD (bank) and energy consumption

	Model 1	Model 2	Model 3	Model 4
Independent Variables	EC	EC	EC	EC
logDOMCREDB	0.115***	0.0941***	0.121***	0.126***
	(0.0359)	(0.0341)	(0.0430)	(0.0427)
GGDP	0.0021	0.0017	0.0020	0.0021
	(0.0020)	(0.0020)	(0.0021)	(0.0021)
EP	0.0072***	0.0069***	0.0069***	0.0070***
	(0.0016)	(0.0016)	(0.0017)	(0.0017)
logPOP	0.0496***	0.0518***	0.0580***	0.0578***
	(0.0184)	(0.0185)	(0.0186)	(0.0184)
OPEN	-0.0029***	-0.0028***	-0.0023***	-0.0022***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)
GE	-0.0069***			
	(0.0013)			
RQ		-0.0068***		
		(0.0014)		
logDOMCREDB_RQ			-0.0017***	
			(0.0004)	
logDOMCREDB_GE				-0.0016***
				(0.0003)

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Table 9. Continued

	Model 1	Model 2	Model 3	Model 4
Constant	68.46***	62.44***	61.94***	66.26***
	(13.02)	(12.84)	(13.03)	(13.23)
Year dummy	Yes	Yes	Yes	Yes
Country Dummy	Yes	Yes	Yes	Yes
Observations	311	311	311	311
R-squared	0.325	0.319	0.305	0.308

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 10. PCSE regression on FSD and energy consumption

	Model 1	Model 2	Model 3	Model 4
Independent Variables	EC	EC	EC	EC
logDOMCRED	0.145***	0.119***	0.163***	0.171***
	(0.0383)	(0.0361)	(0.0474)	(0.0476)
GGDP	0.0025	0.0021	0.0024	0.0026
	(0.0022)	(0.0022)	(0.0022)	(0.0022)
EP	0.0064***	0.0058***	0.0054**	0.0058***
	(0.0020)	(0.0020)	(0.0021)	(0.0021)
logPOP	0.0616***	0.0642***	0.0728***	0.0729***
	(0.0204)	(0.0206)	(0.0205)	(0.0204)
OPEN	-0.0021***	-0.0020**	-0.0014*	-0.0014*
	(0.0008)	(0.0008)	(0.0008)	(0.0008)
GE	-0.0086***			
	(0.0015)			
	(0.0017)	(0.0017)	(0.0017)	(0.0017)
RQ		-0.0082***		
		(0.0015)		
logDOMCRED_RQ			-0.0021***	
			(0.0004)	
logDOMCRED_GE				-0.0020***
				(0.0004)
Constant	82.50***	73.79***	75.26***	81.70***
	(14.31)	(14.10)	(14.38)	(14.65)
Year dummy	Yes	Yes	Yes	Yes
Country Dummy	Yes	Yes	Yes	Yes
Observations	277	277	277	277
R-squared	0.332	0.323	0.307	0.311

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 11. SUR regression on FSD and energy consumption

	Model 1	Model 2	Model 3	Model 4
Independent Variables	EC	EC	EC	EC
logDOMCRED	0.145***	0.119***	0.163***	0.171***
	(0.0377)	(0.0355)	(0.0466)	(0.046)
GGDP	0.0025	0.0021	0.0024	0.0026
	(0.0021)	(0.0021)	(0.0022)	(0.0022)
EP	0.0064***	0.0058***	0.0054***	0.0058***
	(0.0020)	(0.0020)	(0.0020)	(0.0020)
logPOP	0.0616***	0.0642***	0.0728***	0.0729***
	(0.0201)	(0.0202)	(0.0202)	(0.0200)
OPEN	-0.0021***	-0.0020**	-0.0014*	-0.0014*
	(0.0008)	(0.0008)	(0.0008)	(0.0008)
GE	-0.0086***			
	(0.0015)			
RQ		-0.0082***		
		(0.0015)		
logDOMCRED_RQ			-0.0021***	
			(0.0004)	
logDOMCRED_GE				-0.0020***
				(0.0004)
Constant	82.50***	73.79***	75.26***	81.70***
	(14.07)	(13.87)	(14.15)	(14.41)
Year dummy	Yes	Yes	Yes	Yes
Country Dummy	Yes	Yes	Yes	Yes
Observations	277	277	277	277
R-squared	0.332	0.323	0.307	0.311

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

CONCLUSION AND POLICY RECOMMENDATIONS

Environmental pollution and its accompanied consequences in recent times are largely caused by human activities such as irresponsible agricultural activities, industrialization, urbanization and other economic activities that are connected to the utilization of unclean energies which FDI and FSD are of no exception. FSD and FDI can influence environmental quality due to their linkages with economic development and energy utilization. Financial sector development and FDI have become some of the topical issues that scholars and corporate boards have shown some interest. Though a number of studies have gone into these issues, less is seen on the financial sector development and FDI and their impacts on energy use in Africa. As a result, this book chapter is devoted to examining first the link between FDI and energy consumption, financial sector development and energy consumption in Africa. Secondly, to find out whether or not quality institutions in Africa play some role in these links. Using 44 African countries with an unbalanced panel ranging from 2004 to 2018, this study is able to confirm the Pollution Haven Hypothesis in Africa. The main findings of the study are: first, both FDI and FSD are found to have significant positive impact on energy consumption, second, both measures of institutional quality i.e., regulatory quality and governance effectiveness on the other hand are seen to have an inverse relationship with energy use in Africa and finally the interaction terms of the two main independent variables with regulatory quality and governance effectiveness lead to energy savings.

On the positive link between FDI and energy use, it is noticed to be a confirmation of the Pollution Haven Hypothesis. This theory believes that multinational corporations (MNCs) outsource "dirty industry" to developing countries. Developing countries in the world have become dumping grounds for most foreign used products which may not be allowed in the home countries. Thus, some of the MNCs take advantage of that to establish their businesses in developing countries so as to use these old and energy sucking items which certainly will lead to high energy consumption. Besides, it is noted that developed countries invest in host countries to avoid high cost of production at their home base (Yue *et al*., 2019). This is because most developed countries have high strict environmental requirements, which are costly to adhere to. These MNCs may therefore relax and not replicate such in their host countries given that developing countries have less strict environmental requirements. This certainly will lead to the adoption of techniques and processes that do not save energy.

The link between FSD and EC can be attributed to access to enhanced capital. In very efficient and well-functioning financial sector, not only are individuals and businesses able to access finance but also these finances are accessed at low cost. This therefore boast firms and individuals to be able to increase their demand for some luxury and energy consuming products which certainly leads to high energy consumption. Similarly, in an efficient financial sector, it is easy to transact in both the money and capital market hence there is high liquidity for both firms and individuals. This again makes it possible for firms and individuals to cash out from their investment at any time they need it and this again can induce consumption of energy consuming products.

These finding suggest that in as much as FDI inflows and financial sector development are very crucial for economic advancement, they could have very negative impact on the environment in the long run which could neutralize all the gains made on them. Already, some African countries are battling with energy crisis thus any development that will lead to wastage and an inefficient use of energy can be development retarding at the end. It is therefore recommended that for African economies to enjoy the full benefits of the inflows of FDI and financial sector advancement, institutions must be strengthened to enable them function effectively. When this happens, MNCs moving into African economies will try to carry along with them the strict compliance at home countries to host economies. This will lead to the adoption of energy saving technologies and the avoidance of waste in their operations at host economies. Again, if the institutions are working effectively, individuals and firms that have more access to finances due to the well-functioning of the financial sector will begin to comply with environmental laws and hence will begin to adopt energy saving live styles in their activities.

DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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ENDNOTE

1. Sadorsky (2010) found a positive nexus between stock market development and energy consumption while Sadorsky (2011) found a similar relationship between banking sector development and energy consumption in Central and Eastern European Frontier economies.

Chapter 7
Corporate Integrated Reporting:
An Overview of GRI Standards

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ABSTRACT

The goal of every company should not be profit exclusively but also public welfare and social responsibility. Traditional financial reporting of companies was not sufficient to monitor the sustainable development of companies and their impact on the wider community. The Global Reporting Initiative (GRI) was introduced to provide global guidelines to report social and environmental information. The emphasis is on reporting and measuring the level of corporate social responsibility (CSR). Reporting on CSR is necessary because companies need to be responsible for the implementation of its principles, aimed at protecting the interests of stakeholders. Mandatory GRI reporting increases social responsibility due to reduced business risk and enhanced business performance.

INTRODUCTION

There is a growing awareness of the need to protect the environment, care for the community and the protection of human rights and in general about the social responsibility of companies in conducting business activities. Over time, users are showing increasing interest in information about this segment of the company's business, social and environmental responsibility. By understanding the way, a company operates in the present and knowing the company's strategy, stakeholders can generate conclusions about the potential sustainability or unsustainability of the company's business in the long term and the company's ability to generate earnings and cash flows in the future (Albuquerque & Neves, 2021).

In order to meet the information needs of different users, at the national, regional and global level, an increasing number of companies compile and prepare integrated reports, or publish non-financial information in a separate, independent report. Disclosure of additional non-financial information increases the quality of corporate reporting and transparency of companies, and users gain a higher level of confidence in the business and business prospects of such companies. The data of the empirical research, on a sample of 852 respondents who are stakeholders in Croatian companies, on the importance of integrated

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financial reporting using GRI standards for long-term profitability of companies by creating added value of companies, which also means implementing a socially responsible business strategy. The effects of the corporate social responsibility strategy were examined using GRI standards.

SIGNIFICANCE AND TRENDS OF CORPORATE REPORTING

Integrated reporting is a process that involves financial and non-financial reporting in one report – an integrated report. Therefore, an integrated report is a report that should be made public and should be available to interested users, and it should include integrated financial and non-financial information about the company. Publishing a wider range of information about the company enables users of this information to make better business decisions, primarily about investments and financing.

Stakeholders want to have information based on which they can understand the business model, strategy, risks (including sustainability risks) and the enterprise management system. Understanding these categories helps stakeholders assess the company's capacity to create sustainable value in the short, medium and long term. In modern business conditions, responsible investment is based on investments that will result in positive social, environmental and economic outcomes as well as earnings, which is a significant departure from the "traditional" investment that was primarily aimed at earning investors or economic return (Couldridge, 2014). Research and analysis of the issue of integrated reporting, which is still insufficiently represented in the literature with special reference to international frameworks and GRI standards used as a basis for the preparation and publication of non-financial information, should not be neglected. Special attention should be paid to the disclosure of non-financial information, i.e., whether non-financial information is published in the form of a stand-alone report or in the framework of integrated corporate reports.

INTERNATIONAL REGULATORY FRAMEWORK FOR INTEGRATED REPORTING

Integrated reporting is a process of preparing and compiling financial and non-financial reports and publishing them in an integrated report. Financial reporting is mandatory, regulated and regulated by national legislation, and the International Financial Reporting Standards GRI and/or various national accounting standards are applied for the preparation of financial statements.

As there is no framework at national and international level that is prescribed as mandatory for the preparation of non-financial information and the preparation of non-financial reports, it is important to point out that in practice there are different approaches and frameworks for preparing non-financial reports. Relevant international frameworks for compiling non-financial reports are:

- GRI standards (GRI)
- International framework for the preparation of integrated reports (IR)
- Guidelines for multinational companies of the Organization for Economic Cooperation and development (OECD)
- ISO 26000 standard of the International Organization for Standardization
- Tripartite Declaration of Principles Relating to Multinational Societies and Social Policy of the International Labor Organization

- United Nations Global Compact (UNGC)

All of the above international frameworks govern the preparation and publication of non-financial information in a non-financial report. Standardized non-financial statements, and therefore integrated statements, do not yet exist in a standardized form. However, the most widespread framework for non-financial reporting today is the GRI standards developed by the Global Reporting Initiative, which represent the world's best practice in non-financial reporting by companies, and thus meet the information needs of various decision makers, investors and the market as a whole (Rafay & Farid, 2018). Standardization of non-financial reporting would make it possible to compare companies on issues related to economic, environmental and social criteria at both national and international levels.

The number of companies that publish non-financial reports is largely influenced by legislation, the fact whether the law prescribes the obligation to compile non-financial reports or they are prepared on a voluntary basis. In South Africa, the Institute of Directors adopted The third King Code of Governance Principles (King III) which entered into force on May 1, 2010, which made recommendations that all companies are required to apply and according to which all companies are in theory required to compile only integrated reports. In this sense, South Africa was the first country to introduce the obligation to compile and publish integrated reports for listed companies in response to social, political, environmental and economic challenges. The Johannesburg Stock Exchange continued to promote good corporate governance and included an obligation to compile an integrated report as a requirement for listed companies.

In the United States, non-financial reporting is not required by law, but most companies publish non-financial reports. In 2011, the Sustainability Accounting Standards Board - SASB was established. SASB adopts and develops accounting standards for seventy-nine industries, and the standards allow companies to disclose relevant and useful information more easily to all company stakeholders.

By Directive 2014/95/EU, the European Commission asked all Member States of the European Union to implement in their legislation new requirements according to which certain companies must also prepare non-financial reports. Directive 2014/95/EU applies to large companies and public interest entities that exceed the criterion of an average number of five hundred employees at the balance sheet date, and Directive 2014/95/EU makes non-financial reporting mandatory for accounting periods beginning on January 1, 2017, or during the calendar year 2017, which is also prescribed by the Republic of Croatia as an EU member.

In Japan, non-financial reporting is not required by law, however, the vast majority of companies still publish non-financial reports, but mostly in the form of separate non-financial reports, while integrated reporting is still in its infancy and few companies publish integrated reports (Ryall, 2015).

INTEGRATED REPORTING AND CORPORATE SOCIAL RESPONSIBILITY

Defining Corporate Social Responsibility

Corporate social responsibility is a practice through which companies manage their business in order to create a positive impact for society. It is based on the assumption of responsibility by a business organization for the impact of its operations on society and the environment, provided that these activities should be in accordance with the law, legal regulations, in accordance with the interests of society and based on ethical behavior.

The middle of the 20th century marked the beginning of the application of socially responsible business practices that companies include in their business and marketing activities in order to differentiate their offer from the offer of numerous competitors. The economy has also had an impact on the development of corporate social responsibility. Consumers have the opportunity to choose between a wide selection of various products, more precisely between different quality and price. Society's growing concern for environmental and social issues has prompted organizations to work with other businesses to work together to achieve some goal of common good for mutual benefit. Corporate social responsibility is not only a means by which a company will make a profit, but it is a practice that represents value and strategy.

Corporate social responsibility implies principles and determines the ways in which companies should act in accordance with the constant social changes of norms and rules (Bergant, 2022). The concept of CSR is based on the relationship between the business world and the social environment in which the company operates. Rapid industrialization and globalization have led to an alarming situation in terms of lack of awareness and concern for the local community and especially for the environment. CSR implies voluntary activities that go beyond the level of mandatory legal norms that companies are legally obliged to implement (Stipić, 2019; Albuquerque & Neves, 2021). Corporate social responsibility is an ethical and socially responsible attitude towards interest groups that are inside and outside the company. The goal of social responsibility is, while preserving profitability, to enable the creation of high living standards for interest groups (Hopkins, 2006).

Every company has certain responsibilities that need to be met, so four levels of corporate social responsibility can be defined:

1. In the first level, this responsibility is manifested through personal involvement, contribution and commitment of employees. They perceive CSR as part of their values through the organizational culture and mission of the company. Employees do not spread the idea of socially responsible behavior through typical communication channels but with a positive attitude and their enthusiasm. In this way, the incentive comes exclusively from within, more precisely from the company.
2. The second level includes the responsibility of the company to provide material and other needs from shareholders and workers to suppliers and customers. Compliance with them is mostly influenced by legal obligations and competition.
3. The third level is based on the achieved business results carried out by the companies in order to accomplish the primary tasks. It also includes caring for the best possible use of resources and avoiding any impact that is harmful to the environment. It is not enough to state that the level of pollution is below the prescribed level. Organizations are required to keep negative impacts to a minimum. To meet such requirements, it is necessary to assess the costs of benefits and the benefits of them.
4. The fourth level refers to the interaction between the business world and society as a whole. Businesses should direct their efforts outwards. In making decisions, organizations should be conscientious and judge the decisions of their actions both in the current business and in any future.

According to Carroll (2003), corporate social responsibility encompasses the economic, legal, ethical, and discretionary expectations that society has of organizations at a given time. Corporate social responsibility includes running a business so that it is economically viable, respects the law, and ethically and socially supports it. Being socially responsible, then means that cost-effectiveness and respect for the law are the most important conditions for discussing company ethics and the extent to which it supports society. In order for a conscientious businessperson to accept socially responsible business, it should be designed in such a way as to accept an entire range of business responsibilities. Here, it is suggested that four types of social responsibilities make up overall corporate social responsibility: economic, legal, ethical and philanthropic. All these types of responsibilities have always existed to some extent, but it is only in recent years that ethical and philanthropic functions have taken a significant place (Carroll Buchholtz, 2003; Rafay, 2022).

Socially responsible behavior has its advantages but also disadvantages. The advantages of this concept are greater concentration on the business itself so as to increase sales and market share. Its application strengthens the market position, creates a positive image of the organization. There is an increasing concentration on employees, their education, retention and motivation. Rational resource management reduces business costs. Most importantly, the implementation of all aspects of CSR achieves a positive financial result, but thus attracts financial analysts and potential investors. If a company creates a positive image of itself based on socially responsible behavior without a real intention to implement it, CSR is abused. The goal of such organizations is to create a free form of promotion, not to benefit society and have a positive impact on the environment.

Financial Reporting

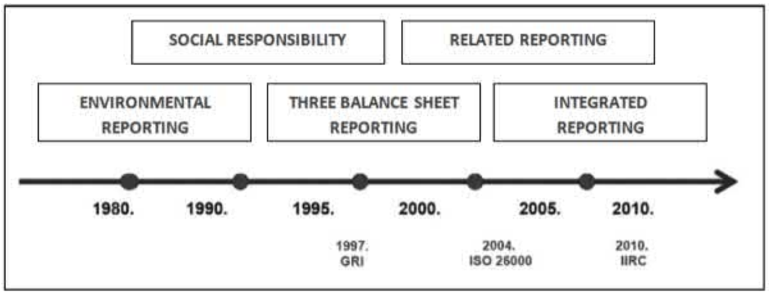
Entrepreneurial financial reporting is a system that allows insight, monitoring, interpretation and evaluation of business and financial condition of the company to make economic decisions. These are reports that relate to the entire business but also to individual areas and are prepared for different users. When compiling and processing them, the truthfulness of the presented data should be respected. The financial statements have been prepared in order to provide external users with an insight into the company's operations. External users are shareholders, investors, business partners, creditors, auditors, the public, etc. The financial statements are prepared for a specific business period, one business year. The group of basic financial statements consists of balance sheet, income statement, statement of changes in equity, statement of cash flows and notes to the financial statements. The elements of the financial statements are assets, liabilities, equity, income, expenses and financial result of operations.

Financial and non-financial reporting are an essential part of a company's overall business reporting. It is non-financial reports that contribute to an improved image and bring a competitive advantage to companies in the environment in which they operate.

Non-Financial Reporting

Unlike financial reporting, non-financial reporting is not strictly regulated by rules but is recommended to be in accordance with standards or international guidelines. Non-financial reporting has become an obligation of certain large companies and groups in the European Union with the adoption of the Non-Financial Reporting Directive 2014/95/EU, which entered into force in early 2017. This type of reporting is based on measuring physical performance indicators. Also, non-financial reporting is the process of preparing and publishing information related to the environment and social responsibility. This form of reporting is of immense importance to the corporate accounting system because it can be used to compare the way organizations operate. Non-financial reporting is a challenge because there are differences in the implementation of managerial attitudes about the usefulness of this type of practice.

Figure 1. Development of non-financial reporting



According to European Commission statistics, the number of companies publishing non-financial reports is rising sharply from 2,500 to 18,000 companies. In early 1997, the application of the GRI guidelines, as shown in Figure 1, first reported on social responsibility, and moved on to environmental reporting. In 2004, the ISO 26000 standard was developed - an international standard that provides instructions on a voluntary basis to organizations for managing socially responsible business. Then, in 2010, the IIRC made recommendations for the establishment and publication of integrated reports using GRI standards. SME are not obliged to compile non-financial reports (Husin & Haron, 2020), but according to the plan of the European Commission, the obligations of this type of reporting will be extended to them. It is also planned to extend the obligation for non-financial reporting to public interest entities: companies whose securities are traded on the regulated capital market of any EU Member State, banks, savings banks, housing savings banks, electronic money institutions, insurance companies, reinsurance companies, leasing companies, fund management companies, alternative investment funds, pension companies that manage mandatory pension funds, pension companies that manage voluntary pension funds, pension purchase companies, factoring companies, stock exchanges, central clearing and depository companies, operators the central state register, operators of the settlement and/or settlement system and operators of the Investor Protection Fund and other entities of public interest (Nikolov, 2021).

The content of non-financial reports is regulated by:

- Accounting law
- Directive 2013/34/EU
- Directive 2014/95/EU

Also, if an entrepreneur publishes a separate report with the same information required in the non-financial statements, relating to the same year, it is possible to exempt the entrepreneur from the obligation to compile a non-financial report. In order to achieve this, two conditions must be met:

- A separate report is published together with the financial report of the management
- A separate report is published on the website of the entrepreneur referred to in the management report, which is not older than six months from the balance sheet date

The separate reports used are the social responsibility report, the sustainability report and the integrated report. The Corporate Social Responsibility Report is a communication of an entrepreneur with stakeholders about his position in the market and his social and environmental impact. A sustainability report is a report on day-to-day business activities with respect to the environmental, social and economic framework. Integrated reports are defined as an improved and effective way of reporting to entrepreneurs in order to increase the quality of information flow and more productive distribution of capital.

Positive characteristics of non-financial reporting:

- Increased visibility, trust and credibility
- Increased transparency and credibility of the company's financial statements, which results in a higher level of trust of potential investors and access to the most favorable sources of financing
- Increased number of business opportunities due to improved capacity to engage in reliable supply chains
- Increased engagement of directors and managers
- Improved communication with shareholders
- Reduced risk and increased value of the company

The Directive requires companies to describe their business model, outcomes and risks of adopted policies related to mandatory topics, and encourages them to follow well-known reporting frameworks such as: Global Reporting Initiative (GRI), Environmental Management System and Independent Evaluation (EMAS), United Nations Global Compact (UNGC), Guiding Principles on Entrepreneurship and Human Rights for the Implementation of the UN „Framework Program on Protection", Respect and Assistance, Guidelines for Multinational Societies of the Organization for Economic Co-operation and Development (OECD), ISO 26000 International Organization for Standardization (ISO), Tripartite Declaration of Principles Relating to Multinational Societies and Social Policy of the International Labor Organization (ILO) or other recognized international frameworks.

Integrated Reporting

Integrated reporting is a combination of financial and non-financial information intended primarily for external stakeholders. However, it is also an effective management control tool because it encourages integrated, holistic thinking, strengthens the reputation and overall success of the company. Integrated or complete reporting is a reflection of global tendencies to combat risk in business relations through more transparent reporting of business results. Transparency is one of the principles of corporate governance (Hanefah *et al.*, 2020) which is highlighted for the last 10 or more years through various principles, guidelines, laws and the like, so the concept of integrated reporting is a product of the global association The International Integrated Reporting Council – IIRC.

More extensive and comprehensive information on how individual companies create their value over time enables more efficient decision-making by potential investors. It wants to show "holistic (integrated) thinking" about how management, with the help of other stakeholders, creates value for investors. Comprehensive thinking takes into account the connection and interdependence between a number of factors that affect the value creation of the company including the capital used by the company, the capacity it has, the way of creating a business model and strategy, and other activities and business results, outcomes expressed past, present and future capital.

Integrated reporting is important for today's management system, which should be based on sustainable or socially responsible business. Sustainability presupposes development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WECD, 1987). The concept of sustainability is very complex and dynamic, as IIRC is a global association of regulators, investors, companies, standard setters, accounting professions and various NGOs, whose main mission is to establish integrated reporting and thinking as norms within public and private sector business practice, with creating added value requires striking a balance between economic, environmental and social goals. From the aspect of the company, sustainability is referred to through the concept of socially responsible business, which means that in the business policy of the company for decision-making and planning must be within the framework of environmental and social requirements. At the same time, it imposes guidelines for sustainable business and the need for a unique and global reporting methodology, TBL concept – the basis for integrated reporting. The concept of triple bottom result or triple outcome, Triple Bottom Line - TBL (or People, Planet, Profit: concept-3P) starts from the premise that in conditions of sustainability economic or commercial aspects are not sufficient to assess business but it is desirable to act and report on environmental and social aspects of business. A broader understanding of this concept encompasses values, strategy, and business practices, as well as the way it is used to achieve economic, environmental, and social goals (Elkington, 2006). Due to the different understanding of the TBL concept, the practice so far has generated a number of reports under different names: sustainability report, corporate social responsibility report, corporate governance report, social report, triple bottom line report, 3P report, etc. What they all have in common is that in addition to the usual economic, mostly financial data and indicators, more and more data on environmental and social aspects and the way of management, Environmental, Social and Governance (ESG) are included. Reporting on the concept of a triple outcome or outcome was first set up, to link financial performance (profit) through the word bottom line and the need to respect and link environmental, social and social outcomes (Stipić, 2018). Today's requirements are that the business measurement system should take into account all the impacts that the company has on society, including human rights, freedom, equality, etc. The concept of integrated or complete reporting is based on the TBL concept and the current practice of informing about the financial results of operations but requires a complete presentation of financial and non-financial information. It should be emphasized that reporting on corporate social responsibility or social responsibility (CSR) differs from integrated or comprehensive reporting on two grounds: first, the content is not the same, and second, the purpose is different (Velte & Stawinoga, 2016).

Corporate social responsibility reporting covers the economic, environmental and social aspects of business and is intended for all direct and indirect stakeholders. The integrated reporting framework goes beyond these aspects and extends reporting to the value creation process. In this way, investors, which is the report is primarily intended, and other stakeholders would get an insight into how the company it creates added value over time and can subjectively judge based on insights into performance indicators and company plans how it will create value in the future. The main goal is to achieve the highest possible quality of reporting based on linking strategy, management and creating company results in the context of economic, environmental and social requirements. Although it is a complete report intended for everyone, investors are most interested in seeing this way of reporting as a key innovation that will enhance long-term investment.

APPLICATION OF GRI STANDARDS FOR INTEGRATED CORPORATE REPORTING

As already pointed out, many recommendations have been published in recent years for reporting on sustainability and implementing a corporate social responsibility strategy. The primary function is to make companies aware that in addition to their financial statements, they also create non-financial ones with an emphasis on achieving the economic, environmental and social effects of business. The Global Reporting Initiative (GRI) is an independent international organization that has introduced corporate reporting and corporate sustainability reporting since 1997, and GRI standards have been defined. The application of GRI standards raises socially responsible business to a higher level, especially in the area of comparability, reliability and credibility of this information.

There were several versions of the GRI standard. The guidelines referred to a set of reporting documents developed through international business advisory processes to assist in compiling sustainability reports and publishing environmental, social responsibility and governance (ESG) information, and were periodically revised to ensure that business and societal needs were met. 21st century. In Amsterdam in 2016, a decision was made to develop new standards for endurance reporting. The main goal was to create a standard that would be in line with the growing demands of users of non-financial information and to show such a way of reporting in the usual business practice. The new form of the GRI standard contains instructions and conclusions from the G4, but the structure has been simplified. The main goal of the transition to GRI Standards is to ensure the competitiveness of business operations, strengthen trust, reduce costs, develop a new vision and strategy, but ensure the development of business practices that are in line with global goals of sustainable development (IDOP, 2020).

Positive changes were achieved during the active application of GRI standards. A more meaningful change is that the standards give a clearer picture between what is required and what would be good. The content of the G4 has been completed, its use is simpler, clarity has been improved and standards are simpler. To avoid repetition some parts are connected or moved. Clarifications were offered for G4 elements that were more often problematic such as defining aspect boundaries or how to report on topics not covered by GRI standards. GRI standards have a modular structure and consist of three general standards that companies can apply. They report on thirty-five additional topics to choose from given a list of material aspects.

The content of the G4 has been redrafted so that it is clear what the company needs to report, what is recommended and what it does not have to, and what it can state in the reports. GRI was divided into six groups of indicators. These are: economic performance, environmental performance, labor performance, social performance and responsibility for products and services. Over time, this has changed, with GRI standards being divided into three modules and they make up thirty-five topics.

GRI standards are organized as modules, and three general standards and three standards covering specific topics have been developed. The general standards consist of three modules and are applicable to all organizations. These are GRI 101 basics, GRI 102 general disclosures and GRI 103 approach to management. Each of these standards contains information on a specific topic and it is used in conjunction with the GRI 103 standard. Within the thematically specific Standards, Standards have been developed that cover specific topics within three modules (Hladika & Valenta, 2017):

1. GRI 200 Economic Area
2. GRI 300 Environmental area

3. GRI 400 Social Area

GRI has identified several areas of business focus to accomplish its mission. Create market leadership by implementing sustainable business including collaboration with stakeholders to meet standard criteria. Make GRI standards a hub for sustainability reporting frameworks and initiatives and select opportunities for collaboration and partnership that serve the GRI's vision and mission. Also, by publishing the implemented GRI standards, companies more easily gain insight into the business and help them make business decisions for long-term sustainable development. Encourages the effective use of sustainability information to improve performance: it works with policy makers, stock exchanges, regulators and investors to achieve transparency and enable effective reporting.

Economic Module of GRI Standard – GRI 200

Economic module of the GRI Standard (GRI 200) – the economic area consists of the following standards (GRI, 2020a):

- GRI 201: Economic Performance
- GRI 202: Market Presence
- GRI 203: Indirect economic impacts
- GRI 204: Procurement Processes
- GRI 205: Fight against corruption
- GRI 206: Anti-competitive treatment

Economics can be defined as the science that studies how to use resources rationally among an unlimited number of permanent or potential needs. The subject of the study is actually what to produce, when, for whom, the study of price movements, unemployment, imports and exports and the like. The ultimate goal is to make a profit based on the actions taken by the company. Also, in 2019, a new standard "Taxes" was introduced (GRI, 2020a). It applies from January 1, 2021. The task of this chapter is the social module of the GRI Standard; therefore, the economic module will not be covered in detail.

Environmental Module of GRI Standard – GRI 300

GRI Standards Environmental Module (GRI 300 Module) – The environmental area consists of the following Standards (GRI, 2020a):

- GRI 301: Materials
- GRI 302: Energy
- GRI 303: Water
- GRI 304: Biodiversity
- GRI 305: Show
- GRI 306: Wastewater
- GRI 307: Environmental Compliance
- GRI 308: Supplier Environmental Assessment

The environment is the district in which the company conducts its business activities, more precisely in which the company exists. The company should primarily plan for the rational disposal of resources. This refers to the use of materials, energy, the impact of products and services. The entire business of the company should be in accordance with what this standard requires. In this way of reporting, organizations have directed their operations, which create a positive impact on the environment, reduce operating costs and reduce the consumption of natural resources. This standard is not a topic of work so it will not be defined in detail.

Social Module of GRI Standard – GRI 400

The social module of the GRI Standard, which deals with social issues, and the impact of companies on the wider community, consists of the following standards (GRI, 2020a):

- GRI 401: Recruitment
- GRI 402 Employee-Management Relationships
- GRI 403: Health and Safety in the Workplace
- GRI 404: Training and Education
- GRI 405: Diversity and Equal Opportunities
- GRI 406: Non-discrimination
- GRI 407: Freedom of Association and Collective Bargaining
- GRI 408: Child Labor
- GRI 409: Forced or compulsory labor
- GRI 410: Security Practices
- GRI 411: Rights of the domicile population
- GRI 412: Human Rights
- GRI 413: Local Communities
- GRI 414: Supplier Assessment in terms of social relations
- GRI 415: Public Policies
- GRI 416: Customer Health and Safety
- GRI 417: Marketing and Product Labeling
- GRI 418: Customer Privacy
- GRI 419: Socio-economic compliance

The GRI Standard social module is the most comprehensive module because it consists of nineteen related standards that are divided into forty topics. They provide answers to social issues, employees and their rights (health and social care), describe relationships with local communities, bribery and the fight against corruption.

The International Integrated Reporting Council (IIRC) in its study *Realizing the benefits: The impact of Integrated Reporting* describes how the business practice and experience of the *International Integrated Reporting Council Pilot Program*. This report is in line with the initial survey from 2014 which aimed to investigate and explain the integrated reporting process that the company is going through. Integrated reporting was initiated by the International Council on Integrated Reporting (IIRC), which aims at a cohesive and effective approach to corporate reporting in order to improve the quality of information and enable a more efficient and productive allocation of capital. The integrated report aims to explain to investors how a company creates value over time. This integrated reporting procedure represents the connection of financial values with business values from the field of society and the environment. Integrated reporting allows a company to show how its business strategy, management and financial performance contribute to the society, environment and economy within which it operates.

EMPIRICAL RESEARCH

Over the last twenty years, the concept of sustainable business has increasingly penetrated the consciousness of management structures, and due to the growing emphasis on the need for transparency, include information that indicates the attitude and policy of management and owners on environmental, social and social aspects of business. The benefits for the governance structure are a better understanding of the strategy within environmental, social and economic impacts: greater scrutiny for risk reduction; coping with resource constraints; greater opportunity for investment; lower costs. It is important to mention the benefits for shareholders: better business knowledge, more indicators of long-term sustainable business, greater trust based on transparency, etc. The modern global environment requires companies to pay special attention to social values and define a long-term strategy. They pay special attention to the concept of corporate social responsibility and reporting on the implementation of the CSR strategy. Maintaining a competitive position in the market is possible only by formulating a corporate social responsibility strategy where the mission and vision strive to achieve defined goals of sustainable development, compiling and publishing integrated reports according to GRI Standards.

Goals and Hypotheses of the Research

To emphasize the importance of implementing a corporate social responsibility strategy, an empirical study was conducted on the importance of integrated reporting using GRI standards as a factor in creating added value for companies. Therefore, the following hypotheses form the basis of this research:

H1: Environmental aspects of corporate social responsibility significantly contribute to the creation of added value of companies

H2: Social aspects of socially responsible business significantly contribute to the creation of added value of companies

H3: Business and economic aspects of socially responsible business significantly contribute to the creation of added value of companies

H4: The level of development of reporting on the sustainability of Croatian companies is at a satisfactory level and is a positive factor in creating added value of companies

Method of Research

The research described below is based on empirical testing on a sample of 852 subjects, target groups. By defining the research goal and appropriate hypotheses, primary data were collected using survey questionnaires and interview protocols in the period from March 1 to April 30, 2021. They were created using the web tool Google Docs and the survey was conducted via electronic communication media (e-mail and social networks), while the interview protocols were done in person. As this research includes an analysis of the impact of integrated reporting on the implementation of the corporate social responsibility strategy on the creation of added value of companies, the coverage of large and medium-sized companies in the Republic of Croatia was determined. This survey included ninety-three large enterprises and sixty-nine medium-sized enterprises. The identification and classification of variables defined the dependent variable value added of the company (Y), and as an occurrence was measured by the value-added indicator (variable VA) by calculating the realized value added of large and medium-sized companies in the selected sample. The value-added indicator of the company was calculated from the financial statements of the company as of 31 December 2019, which were taken from the official website of the Croatian Chamber of Commerce (access to https://digitalnakomora.hr/home). Based on the set research hypotheses, for the auxiliary hypotheses the independent variables obtained from the survey questionnaire or the target group interview protocol are as follows:

- company management for the environmental aspect of corporate sustainability (variable ECOLO)
- employees of the company for the social aspect of corporate sustainability (variable SOCIO)
- buyers and suppliers for the economic aspect of enterprise sustainability (variable ECONO)
- the academic community to determine the degree of compilation of integrated reports or sustainability reports (variable IREPORT)

The survey questionnaire for each of the provided samples and the interview protocol, the survey asked the respondents for answers on the implementation of the CSR strategy from the economic, social, environmental aspects and the assessment of the degree of integrated reporting. Then, through statistical data processing, statistical program SPSS 17.0, correlation and regression analysis, conclusions were reached on the impact of the implementation of economic, social, environmental aspects and the degree of integrated reporting on the creation of added value of enterprises.

Results

Based on the collected research data and their statistical processing, the research results on the confirmations of the research hypotheses were obtained. The next part of the paper presents the results of research and data processing.

Table 1. Regression model ECOLO and VA – model summary

Model Summary[b]					
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Durbin-Watson**
1	,396[a]	,156	,149	11,56478	1,452

a. Predictors: (Constant), ECOLO
b. Dependent Variable: VA

The regression models of the independent variable ECOLO and the dependent variable VA show a positive moderately significant statistical correlation from the obtained correlation coefficient R (0.421), while the determination coefficient shows that this strength is relatively weak, i.e., 15.6% of variations in the dependent variable are the result of variations of the independent variable. With the level of significance ($p < 0.001$), a significant statistical correlation is visible. Durbin-Watson does not indicate the existence of an autocorrelation of relation errors.

Table 2. Regression model ECOLO and VA – ANOVA

ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2951,652	1	2951,652	22,069	,000[a]
	Residual	15915,545	119	133,744		
	Total	18867,197	120			

a. Predictors: (Constant), ECOLO
b. Dependent Variable: VA

Analysis of the F ratio with the number of degrees of freedom and the corresponding level of significance ($F1, 119 = 22,069$; $p < 0.001$) confirms that there is a statistically significant contribution that the independent variable ECOLO predicts the dependent variable VA. That is, the implementation of environmental responsibility of the company significantly contributes to the creation of added value of the company. Further study of the regression model shows that when companies do not implement environmental responsibility, then they do not realize the added value of the company ($a = -25.874$; $ECOLO = 0$; $p < 0.001$).

Table 3. Regression model ECOLO and VA – coefficients

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-25,874	7,089		-3,650	,000
	ECOLO	7,683	1,635	,396	4,698	,000

a. Dependent Variable: VA

By analyzing the standard coefficient ($\beta = 0.396$), because the variables obtained are obtained by different measurement scales, the positive direction of the regression line is visible. A statistically significant contribution to the regression model was found for the independent ECOLO variable with a given significance level ($t = 4.698$; $p < 0.001$). The overall analysis of the regression model of the independent variable (ECOLO) of the environmental responsibility of companies and the value of the dependent variable (VA) value added of companies shows their positive statistically significant correlation. Hypothesis H1 Environmental aspects of corporate social responsibility significantly contribute to the creation of added value of the company has been confirmed. It is concluded that reporting on the implementation of environmental responsibility of companies positively statistically significantly contributes to the creation of added value of companies.

Table 4. Regression model SOCO and VA – model summary

Model Summary[b]					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,363[a]	,132	,126	11,16374	1,364

a. Predictors: (Constant), SOCO
b. Dependent Variable: VA

After determining the reliability of the measuring instrument and the previously rejected null hypothesis, it was approached calculation of a simple regression model for the social responsibility variables SOCO and value-added VA. From the above regression model on the statistical significance of the relationship between corporate social responsibility and value-added creation of the company from the correlation coefficient (0.363) it is positive and significantly moderate, and with the coefficient of determination (0.132) with a significance level of $p < 0.001$. Durbin-Watson (1,364) tells us that there is no autocorrelation of relation errors.

Table 5. Regression model SOCO and VA – ANOVA

ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2967,751	1	2967,751	23,813	,000[a]
	Residual	19566,778	157	124,629		
	Total	22534,529	158			

a. Predictors: (Constant), SOCO
b. Dependent Variable: VA

The analysis of the regression model (ANOVA) from the F ratio, with the number of degrees of freedom (1,157) and the appropriate level of significance, confirms that there is a statistical significance of the contribution of social responsibility to creating value added ($F1, 157 = 23,813$; $p < 0,001$). This is supported by the obtained constant ($a = -15,417$; $SOCO = 0$; Sig. <0,001) from which it is evident that the non-implementation of socially responsible business will result in financial losses, i.e., not the creation of value added of companies.

Table 6. Regression model SOCO and VA – coefficients

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-15,417	4,167		-3,700	,000
	SOCO	4,990	1,023	,363	4,880	,000

a. Dependent Variable: VA

As the independent variable SOCO was obtained from the Likert scale and the dependent variable VA by calculation from the financial statements of the company from the regression model analyzed the standard coefficient ($\beta = 0.363$) which tells us the positive direction of the regression line while the independent variable SOCO has a statistically significant contribution to the regression model ($t = 4.880$; $p < 0.001$). In accordance with the conducted regression analysis of SOCO and VA, it can be said that the report on the implementation of social responsibility towards its employees and socially vulnerable groups of companies significantly contributes to the realization of value added of companies. Based on the above hypothesis, it is confirmed that H2 Social aspects of corporate social responsibility significantly contribute to the creation of value addition for the company.

Table 7. Regression model ECONO and VA – model summary

Model Summary[b]					
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Durbin-Watson**
1	,421[a]	,177	,171	11,92015	1,545

a. Predictors: (Constant), ECONO
b. Dependent Variable: VA

Demonstration of hypothesis H3 was performed by a regression model to examine the relationship between the implementation of economic responsibility and the creation of added value of the enterprise. It is evident from the correlation coefficient R that there is a positive significant correlation between the variables ECONO and VA (0.421). The coefficient of determination is closer to zero, which means that the model is not well representative, i.e., this significant statistical correlation is shown by 17.7% of variations in the dependent variable with the result of variations of the independent variable. Durbin-Watson has a value closer to two which indicates the absence of autocorrelation of relation errors.

Table 8. Regression model ECONO and VA – ANOVA

ANOVA[b]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	4093,564	1	4093,564	28,810	,000[a]
	Residual	19040,043	134	142,090		
	Total	23133,607	135			

a. Predictors: (Constant), ECONO
b. Dependent Variable: VA

From the analysis of the variance of the regression model (ANOVA) on the existence or non-existence of differences between the population averages, with the determined level of significance $p < 0.001$ which is less than the default 0.05 and the number of degrees of freedom ($F_{1, 134} = 28.101$) it can be seen that the regression model is statistically significant. It is evident from the constant of the model that if companies do not exercise economic responsibility towards stakeholders, then they do not realize the value added of companies (a = -15,914; ECONO = 0; Sig. <0.001). Further analysis studies the standardized coefficient because these are different measurement scales for the dependent variable VA and the independent variable ECONO. Thus, the positive direction of the regression line is seen, i.e., the β indicator is statistically significant (p <0.001) and it is concluded that the contribution of the independent variable to the regression model is statistically significant.

Table 9. Regression model ECONO and VA – coefficients

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-15,914	4,129		-3,854	,000
	ECONO	5,599	1,043	,421	5,367	,000

a. Dependent Variable: VA

Preliminary statistical processing and analysis of data for the variables ECONO and VA show a positive significant statistical correlation between economic responsibility and the creation of added value of enterprises (0.421). According to the above test results, hypothesis H3 was confirmed. Integrated reporting on the business and economic aspect of corporate social responsibility significantly contributes to the creation of added value of companies.

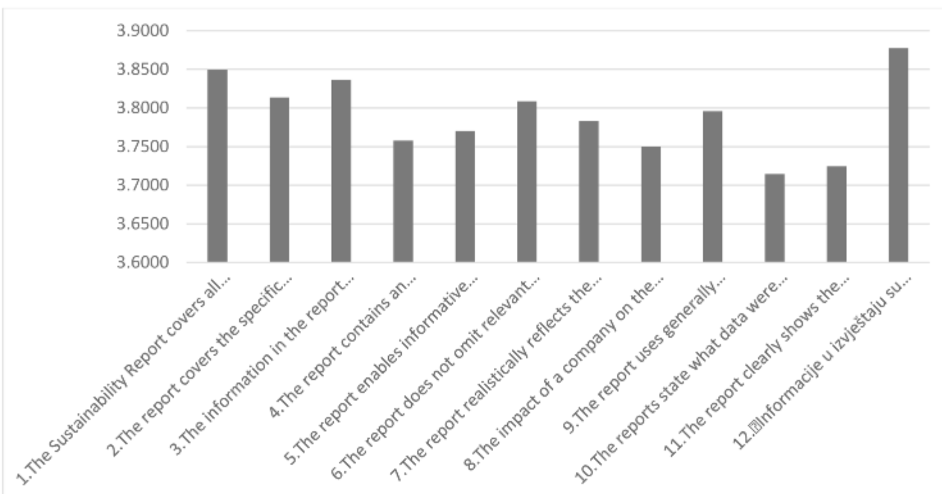
According to the Accounting Act, reporting on corporate social responsibility is mandatory in the Republic of Croatia for all large and medium-sized enterprises of significant economic interest. However, according to the currently valid regulations, the absence of such reporting does not bear any sanctions of the legislative bodies, i.e., the reporting on sustainability is exclusively on a voluntary basis. Therefore, there is a need to set a fourth hypothesis: The level of development of reporting on the sustainability of Croatian companies is at a satisfactory level and is a positive factor in creating added value of companies.

The answers to the questions from the survey questionnaire on the level of corporate reporting on corporate social responsibility are shown in the following chart, and the questions asked are:

1. The Sustainability Report covers all aspects of corporate social responsibility (economic, social and environmental) and social responsibility procedures towards all stakeholders
2. The report covers the specific priorities of all stakeholders
3. The information in the report includes all significant influences of the company during the reporting period
4. The report contains an appropriate degree of assessment of the future significant impacts of the company on all stakeholders
5. The report enables informative assessments and objective decisions of all stakeholders
6. The report does not omit relevant information that reflects significant economic, environmental and social impacts on all stakeholders

7. The report realistically reflects the positive and negative aspects of the impact of companies as a factor in a reasonable assessment of the impact of companies on the community
8. The impact of a company on the community is measurable and can be compared through appropriate assessment tools
9. The report uses generally accepted protocols to collect, measure and display information, including information contained in the GRI Standards (Global Sustainability Reporting Initiative)
10. The reports state what data were estimated, as well as the basic assumptions and techniques used for the assessment
11. The report clearly shows the applicable standards, certificates held as well as fines or violations for deviations from legal regulations
12. The information in the report is current for the reporting period (information is not outdated)

Figure 2. The level of corporate reporting on corporate social responsibility using GRI standards



The graph above shows that the reporting of Croatian companies on corporate social responsibility is at a satisfactory level, while the regression model IREPORT and VA shown below shows the connection between integrated reporting and the creation of added value of companies. A Cronbach's alpha coefficient of 0.965 shows the reliability of the measuring instrument for the independent variable IREPORT.

Table 10. Regression model IREPORT and VA – model summary

Model Summary[b]					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,119[a]	,014	,012	8,40529	,898

a. Predictors: (Constant), IREPORT
b. Dependent Variable: VA

The correlation coefficient (R = 0.119) from the regression model IREPORT and VA from the previous table shows the relationship between the independent variable reporting on sustainability (IREPORT) and the dependent variable value added (VA) positive correlation exists but is weak. As the coefficient of determination is closer to zero than to one, the model is not well representative, i.e., the variations of the dependent variable VA are not a significant result of the variations of the independent variable. Durbin-Watson 1,898 means that no autocorrelation of relation errors was found in the sample.

Table 11. Regression model IREPORT and VA – ANOVA

ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	442,269	1	442,269	6,260	,013[a]
	Residual	30590,956	433	70,649		
	Total	31033,225	434			

a. Predictors: (Constant), IREPORT
b. Dependent Variable: VA

Indicator of independent variations with the number of degrees of freedom with a significance level of 0.05 it is concluded that the independent variable IREPORT statistically significantly predicts variations of the dependent variable VA (F1, 433 = 6.260; Sig. = 0.001). By analyzing the constant of the regression model in the following table (a = -1,062; IZDOP = 0; p = 0,001), it is evident that the lack of reporting on sustainability leads to the lack of value added of companies.

Table 12. Regression model IREPORT and VA – coefficients

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1,062	1,903		-,558	,577
	IREPORT	1,218	,487	,119	2,502	,013

a. Dependent Variable: VA

Due to the different measuring instruments of the variables, a standardized coefficient (β = 0.119) was analyzed, from which a positive but weak direction of the regression line was observed. A statistically significant contribution to the regression model is visible for the independent variable IREPORT, and it is concluded that the regression model as a whole statistically significantly predicts value added, i.e., although there is a weak statistical correlation between sustainability reporting (IREPORT) and value added (VA). With a significance level of 0.05 and given the representativeness of the model (n = 435), hypothesis H4 was confirmed, the level of development of sustainability reporting of Croatian companies is at a satisfactory level and is a positive factor in creating value added of companies.

CORPORATE INTEGRATED REPORTING AS A BASIS FOR COMMUNICATION BETWEEN COMPANIES AND USERS

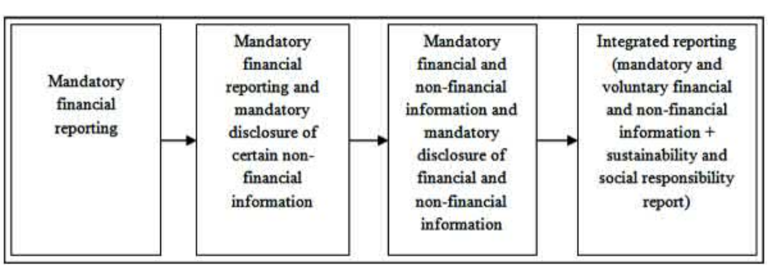
The purpose of corporate reporting is to provide information about the company and strengthen communication between the company and interested users (Ajmal, Rafay & Ajmal, 2020). Until recently, corporate reporting was limited to the disclosure of financial information in annual financial statements and referred to the publication of statements of financial position (balance sheet), income statement (statement of comprehensive income), statement of cash flows, statement of changes in equity and notes in addition to the financial statements. All of these financial statements present information that represents the effects of past management decisions and past business events (Rafay, Yasser & Khalid, 2019). However, various stakeholders are also interested in a number of other information about the company in addition to financial information.

Consumers' awareness of the environment, economy and society as a whole is becoming more pronounced, so their main question is whether a company generates value and wealth only for owners, or its business generates added value for society, environment and economy in which it operates. In addition to truthful and reliable information about past business events that have occurred as a result of past business decisions and that are disclosed in the financial statements, transparency should include a clear presentation of the strategy and future business initiatives of the company. Trends in reporting necessarily adapt to IT trends and opportunities and require the publication of information on a daily basis, instead of publishing information only when the accounting (reporting) period to which the information relates expires. The information must be immediately available to users in order to have added value for business decision makers and to be immediately implemented in the decision-making process.

The focus of reporting and publishing has changed significantly in recent decades, with increasing emphasis on critical global issues such as climate change, the contribution of business activities to improving the quality of life and ecosystems, and business performance across the entire supply chain (GRI, 2016). Also, the development of information technology plays a key role in data reporting and analysis (Rafay, 2019). Users want information immediately and without delay, in real time.

Financial markets rely on relevant information that is clearly and accurately presented, so that the comprehensibility and usefulness of corporate reports play a key role in ensuring the efficient functioning and support of a healthy economy (KPMG, 2015). Therefore, it can be concluded that to obtain a complete picture of the company's operations, not only financial information is sufficient, but also the publication of non-financial information to assess the company's potential for growth, long-term sustainability and earnings and cash flow generation in future periods. As the information needs of users and the environment in which companies operate have changed, corporate reporting has changed and developed, and its development is shown in next Figure.

Figure 3. Development of corporate reporting



Awareness of environmental, social, societal and economic issues has increased rapidly over the last thirty years or so. As a result, an innovative approach to corporate reporting has been developed that introduces an integrated reporting model. Through this novel approach to corporate reporting, companies should publish non-financial information in their reports, in addition to financial information, which would contribute to integrated thinking and improving the management process and corporate responsibility. Users are becoming more and more interested in information that provides a broader picture of the company's business, primarily information about the company's strategy and vision, the impact of the company's activities on society, the environment and the economy as a whole, how the company creates added value and the like. Such trends and changes in reporting and information needs require managers to understand and appreciate them in order to successfully integrate them into business strategy and the business decision-making process.

Stakeholders rightly expect that today's companies will protect all forms of capital - financial, natural, human, intellectual and social, which have never been more important in the context of corporate governance. Only by adopting such an approach, public confidence and reliability may be enhanced, which are very important for the health of the global economy (ACCA, 2017). The emphasis is increasingly on two-way communication between companies and information users, which means that companies and their management should "listen" to users and their information needs and provide them with such information publicly. In order to fulfill this communication, a transition from a periodic static report (annual financial statements) to ongoing reporting on financial and non-financial success and opportunities, as well as potential problems, risks and omissions, is required. The aim of the changes in corporate reporting is to introduce the obligation to compile an integrated report in which financial and non-financial information (information on the environmental, social and management performance of the company) will be published. In other words, the goal of corporate reporting is the integration of financial and non-financial information. Based on previous research and experience, it is concluded that the purpose of the integrated report is to replace the annual report.

Implementing an integrated reporting process and compiling an integrated report as the output of that process puts integrated thinking in focus. Understanding the integrated report requires a higher level of thinking, business decision-making and reporting process as opposed to "superficial" compliance with regulatory requirements for the preparation of the current corporate report (Stent & Dowler, 2015).

CONCLUSION

Integrated reporting is a new practice in corporate reporting that is still in the phase of intensive development and implementation at the international level. The integrated report provides information on how the company realizes its vision and strategy from the aspect of past events, but also the perspective in the future, indicates the social responsibility of the company and the perspective of sustainability of the company.

Disclosure of non-financial information either in the form of stand-alone reports or as part of an integrated report significantly contributes to transparency, strengthening the company's reputation and increasing confidence in the company's operations. Non-financial reporting, and especially its publication within the integrated report, significantly raises the quality of corporate reporting. The added value of non-financial reporting is the quantification of the effects of the company's operations on society, the environment and the economy as a whole, and consequently the impact of the company's operations on sustainable development.

Recently, there is a growing trend in non-financial reporting, mostly in the form of stand-alone reports, while there is still a lack of representation and preparation of integrated reports, except in South Africa where the law prescribes the obligation to compile integrated reports for listed companies. Companies that have introduced non-financial reporting as a component of corporate reporting have been found to include economic, environmental and social aspects of their business strategy and to quantify the effects of their business decisions and activities on the overall economy, society and environment in non-financial reports.

In order for integrated reports to be useful and understandable to different stakeholders, it is desirable that they be concise and concise with a focus on key financial and non-financial indicators that indicate the performance, social responsibility and sustainability of the company. It is reasonable to expect that the establishment and implementation of an effective integrated reporting system will require some time for companies to tackle the challenges and changes in the reporting system and reporting culture by applying the GRI Standard. It is undeniable that national legislation and regulations governing corporate reporting, as well as the requirements of stock exchanges for the reporting of listed companies, will play a key role in this entire process. In addition, prescribing the obligation to compile an integrated report and the development of integrated thinking in order to achieve better corporate communication between companies and all interested stakeholders requires the cooperation not only of companies and stakeholders, but also regulators, standard setters, auditors, accountants, civil society and all other business process participants interested in corporate reporting.

Finally, in addition to the fact that companies at the global level have begun to publish more and more non-financial information, it is necessary to develop integrated thinking, which means that management must begin to use such information in making strategic decisions. In future research, different ways of publishing non-financial reports should be analyzed in more detail, and as a measure of the scope of non-financial reports and their informative power for users, the number and type of published non-financial information should be investigated, as well as other indicators. Also, future research should investigate whether the increase in corporate transparency in the form of publication of integrated reports or separate non-financial and financial reports has a significant impact on the profitability of listed companies because a significant link between integrated reporting and the creation of added value of companies is visible.

DISCLAIMER

The contents and views of this chapter are expressed by the author in her personal capacity. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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Chapter 8
Renewable Energy:
An Overview for International Legislation

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ABSTRACT

Legislation regarding renewable energy became significant during the last few years. For this purpose, several international regulations have been adopted to regulate the environmental and energy policies of countries. These regulations are formulated in a wide range of binding instruments and soft laws. However, the proliferation of international instruments coupled with the uncertainty of the principles/rules of international law regarding the development of renewable energy sources necessitates the consideration of an international law approach. In this chapter, the author intends to examine the principles and rules of international law considering the importance of the development of renewable energy as an issue with global dimensions.

INTRODUCTION

Historically, the states worldwide used various energy sources related to their socio-economic potentials for their demand and development. For example, PR China utilized coal as an energy fuel for its thermal demand since the second millennia BC and natural gas since 200 BC (Spataru, 2017). Since the late nineteenth century, the global society relied economically on conventional fossil energy, e.g., coal, oil, natural gas, etc., providing around 75% of the energy demand portfolio. However, these fuels have some unavoidable challenges and problems. Research have shown that with known exploration and extraction technologies, conventional and unconventional oil and gas resources could last for another few decades (may be an average of five decades for oil and fifteen decades for natural gas) (Ottinger, 2005).

Additionally, based on the uneven geographical distribution of fossil fuel carriers, more than 90% of the proven oil reserves are available in only 15 countries (Ruta & Venables, 2012). Based on the famous economic system of supply-demand, while mentioned countries with oil reserves should theoretically be able to use the fruits of modern scientific developments and innovations, such a situation creates a seri-

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ous barrier for sustainable and inclusive development in other parts of the world. Furthermore, around 1.2 billion people, i.e., 16% of the global population, mostly from sub-Saharan Africa and developing Asia, do not have access to electricity (IEA, 2013). since those people cannot pay the energy price, these countries with fossil fuel reserves are blessed as finite sources, whereas new energies are theoretically infinite. Therefore, switching the focus from non-renewable fossil fuels to renewables to keep the stream of overall sustainable and clean development activities is known as a better and viable alternative, even though there are some inherent initial concerns, which are not unique to renewable energy generation rather present whenever any new technological innovations are introduced.

Climate change is a 'shared concern of humanity' (UN, 1998) and a threat to sustainable and equal development goals. Fossil fuel sources are responsible for 60% or almost two-thirds of the world's greenhouse-gas emissions, which account for the global warming leading to climate change (McCollum *et al*., 2017; IEA, 2015). Therefore, it is advised that 75% of all fossil fuels, i.e., 35% of petroleum, 52% of natural gas, and 88% of coal reserves worldwide, must be maintained unused till 2050 to keep the temperature variation compared to 1900s below 2°C (McGlade & Ekins, 2015; IEA, 2014). Additionally, in the world energy industry, it is advised to change these sources or at least increase the share of greener energy that can be produced by exploiting the new, alternative, and renewable energy carriers, e.g., solar, wind, hydropower, ocean, biomass, and Hydrogen, etc. (Adib *et al*., 2015). It is a matter of great hope that despite the significant decline in fossil fuel prices in the last decade, clean energy produced an estimated 23.7% of the global electricity, of which 70%, 15%, 8%, 5%, and 1% of the electricity came from hydropower, wind, bioenergy, solar, and geothermal respectively and the rest came from marine energy (IRENA, 2017).

After successful cooperation on the Millennium Development Goals, the United Nations members conducted the 2030 Agenda for Sustainable Development and the Sustainable Development Goals in 2015 to end poverty, protect the plant, and develop sustainable development. However, it cannot be defined precisely (Holden *et al*., 2014), requires energy savings on the demand side, efficient improvement in energy production, continuous flow of clean and secure energy with less environmental impacts (Lund, 2007), and demands the amount of renewable energy to be more than 27% (IRENA, 2017).

Based on the nature and global effects of climate change, anyone should expect the active role of the 'hard' international law provisions. However, the reality is that there is no direct and specific binding or 'hard' international instrument on the promotion of renewables. It may be relevant to share here that some of the International environmental law instruments, e.g., the Convention on Biological Diversity, 1993, the Convention on the Conservation of Migratory Species of Wild Animals, 1983 and the Ramsar Convention on Wetlands of International Importance, 1975, etc. contain some isolated provisions that should be considered before taking any wind energy projects. However, the paucity of international legal provisions addressing renewables does not undermine the growing importance of its implication to face climate change. Hence, the normative international law and the positive initiatives of the global actors, regional players, and international trade investment system may play an instrumental role in promoting renewables.

Without any hard international instruments, some scholars have already attended to consider the position of renewables under international law (Omorogbe, 2008; Bruce, 2013; Drake, 2016; Mulyana, 2016). However, there were some changes in the international legal order after their attempts. The historic Paris Agreement under the United Nations Framework Convention on Climate Change entered into force on 4 November 2016. This is considered the most significant move from the global community as 197 countries to the United Nations Framework Convention on Climate Change (UNFCCC) have signed the agreement, whereas 178 countries have already ratified this agreement to save the human world from the side-effects of climate change. Through this agreement, these countries pledged to keep global temperature rise below 2 °C in this century and to adopt initiatives to limit the temperature increase to 1.5 °C above pre-industrial levels. Efficient exploitation of renewables will be instrumental to this end as these member countries to the Paris Agreement can consider harnessing renewables, being clean and green energy, which will assist them in fulfilling their national commitments made under the agreement. Hence, it will be very timely to discuss renewables under international law in such a changing circumstance. Examining the current international law approach on renewable energy paints a clear picture for decision-makers in this regard. In the present article, the authors intend to examine the commitments of governments to develop the use of renewable energy by examining international documents and procedures. To this end, renewable energy sources are described first, then the principle of state sovereignty over natural resources and the challenges to international commitments on renewable energy development are discussed. Finally, the existing international rules and regulations in this field have been carefully considered. In this way, first, the binding documents of international law are explained, then the public international law will be examined, and finally, the development of renewable energies from the perspective of soft law will be mentioned (Warschauer, 2010).

LITERATURE REVIEW

From various events in the past few decades, the international movement can transfer traditional energy to renewable energy. In the legal field and under the auspices of the United Nations, the use and promotion of renewable energy can be indirectly mentioned in the 1972 Stockholm Declaration on the Human Environment, 1972 and the risk of erosion of non-renewable land resources has been verified (UN, 1972). Subsequently, the 1987 report of the World Commission on Environment and Development emphasized that renewable energy should be used to lay the foundation for the global energy structure in the 21st century. Next, the "Nairobi Action Plan for the Development and Use of New Energy and Renewable Energy" emphasizes the importance of developing new and renewable energy sources to help meet sustained economic and economic needs, especially in developing countries (Borowy, 2013). Even if these measures have no direct and significant impact on promoting renewable energy, it should be understood that since the importance of environmental protection as a global concern in the 1960s, the international community has regarded it as a reality almost immediately (Biswas, 1981).

In international law, the establishment of scientific institutions such as the Intergovernmental Panel on Climate Change (IPCC) by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 may be a turning point. Forget it. Designed to reduce the impact of climate change. Then, at the Rio Earth Summit in June 1992, an international agreement was approved is the UNFCCC. However, the UNFCCC does not explicitly mention renewable energy. Finally, the Third Conference of the Parties (COP3), held in December 1997, approved the "Kyoto Protocol" of the "United Nations Framework Convention on Climate Change." The "Kyoto Protocol" introduced some innovative mechanisms to reduce greenhouse gas emissions, and these mechanisms have an indirect impact on the promotion of global renewable energy (UN, 1988).

In 2011, the UN Secretary-General launched the "Sustainable Energy for All Initiative" (SE4ALL) to achieve 30% of the global renewable energy target by 2030 and emphasized that these targets should be achieved mainly through internal actions and specific targets. Resolution 151/65 of the United Nations

General Assembly (UNGA) declared 2012 as the "International Year of Sustainable Energy for All" and subsequently declared 20-20-2014 as the "Decade of Sustainable Energy for All" (UN, 2012). In 2015, the Sustainable Development Goals were adopted through Resolution A/RES/7-7 on 25 September 2015, including 17 global and 169 regional goals. The goal is to realize the transformation of a sustainable planet by 2030. Of all the goals set, goals 7 and 13 are particularly important for the discussion in this article. Goal 7 points out that to ensure affordable, reliable, sustainable, and modern energy sources for all and indicates that large amounts of renewable energy and fossil fuels are needed. By 2030, the share of renewable energy in the global energy structure will increase significantly (UN, 2015a). In addition, Goal 13 calls on the international community to take immediate action to address climate change and its impact. Understandably, as renewable promised, green, pollution-free energy can be used as a tool to combat climate change. Nevertheless, despite the ambitions of these SDGs, the survey of the SDG progress report shows that this progress is not satisfactory, and most of the activities related to renewable energy are electricity, not the final achievement. Agreement. Paris was ratified in 2016. The United Nations Framework Convention on Climate Change (UNFCCC) is not legally binding on materials but is binding on reports.

Regarding whether to adopt binding or non-binding legal documents, the international community is divided into different platforms. It is important to decide on this issue because the provisions of the legal documents necessary to reduce greenhouse gas emissions are used indirectly to promote renewable energy development. Developing countries are more willing to seek legal instruments because they have the largest greenhouse gas emissions, imposing a more pronounced burden on developing countries' climate change. In addition, because national legal systems have different effects on the signing and ratifying of international instruments at the municipal level, some countries may prefer to adopt them. Therefore, these countries tend to be flexible in this regard. However, the international community has already faced it. In this regard, the "Paris Agreement" seems to mix the needs of the two countries. Even though not all terms of the agreement are binding on the signatory, it does include some terms that can ensure transparency, accountability, and accuracy, and these terms should be finally considered when assessing the long-term importance of the agreement.

RENEWABLE ENERGY LAW

International law mainly concerns the rights and responsibilities of more than one country, while energy issues are more regarded as municipal issues(UN, 2016). As a result, energy law and energy law issues are being developed as international disciplines (Omorogbe, 2008; Bradbrook, 1996). However, a comprehensive set of laws, norms, and norms on energy and supply systems is difficult within international law and regulations. Although some attempts have been made to define the scope of energy law, these disciplines are considered underdeveloped (Gunningham, 2012) and maybe one of the most complex areas of law due to their conflict with many other laws (Heffron, 2016). The Energy Law stipulates rules and regulations related to the exploration, exploitation, distribution, exploitation, development, and supply of coal, oil, and natural gas reserves and nuclear energy to a certain extent. In the case of transportation, supply, and sale of energy, this situation considers that the role of international energy law and renewable energy very fragmented and largely incompatible (Bradbrook, 2008; Cottier, 2009) and complex (Cherp, 2011).

The Renewable Energy Law is a part of the Energy Law, which solves various issues related to the development, implementation, and commercialization of energy generated by renewable energy. Furthermore, since this type of law encourages renewable energy development in renewable energy development, land use, housing, and financial issues faced by entrepreneurs, projects such as food tariffs (FiTs), etc., other economic law incentives are also carried out following context. Due to these factors, at the international level, renewable legal issues have become a major challenge in public international law and may be used as case studies in legal "divisions" (Leal-Arcas, 2016).

It is important to discuss renewable energy from the perspective of international law. As an important tool for mitigating the impact of climate change, international law helps regulate the government's normative behavior; However, energy is mainly regarded as an internal issue, cooperation between countries and a compilation of technology transfer commitments are vital in energy security and stability of the states (Cherp, 2011). In the absence of any specific and direct international instruments on renewable energy, the existing literature in this field discusses international environmental law, especially sustainable international development law, and international economics (trade and investment), environment (climate, water, and biodiversity), and social rights (human rights and social development) are considered important components of the International Sustainable Development Law. Based on this concept, renewable energy law can be derived that from all aspects, the right to development will be regarded as human rights, climate change, trade, economics, and investment law.

Necessity to Develop and Use Renewable Energy

As mentioned, in recent years, special attention has been paid to the development of the use of renewable energy sources. Now the question that needs to be answered is why this is the case. Of course, since this issue itself requires a detailed discussion, a detailed description of it is not included in this space and will be provided only for the sake of a brief overview of the need to use renewable sources. Over the years, the most important reason for the increase in the average temperature on the ground has been the increase in greenhouse gas emissions (IPCC, 2007). Fossil fuels have played the most important role in greenhouse gas emissions. At the same time, climate change has been described as the most serious and long-term environmental challenge that can potentially affect all vital aspects of the planet. "*Scientists believe that to reduce the harmful effects of global warming, and the average temperature should not exceed 2 degrees Celsius by 2050*" (Watkins *et al*., 2007).

This has led to the adoption and implementation of several international instruments to reduce greenhouse gas emissions. Although applicable international instruments do not make direct reference to renewable energy substitution in this area, at present, the reduction of greenhouse gas emissions is largely achieved by the replacement of renewable energy sources. Therefore, the first reason raised in this context is the destructive effects of fossil fuels in increasing greenhouse gas emissions.

In this regard, it should be said that Iran currently has a significant share in the emission of greenhouse gases in the region and the world with a growing trend (Moradi & Aminian, 2010). In particular, as the most important source of greenhouse gas production, the energy sector has a major share in greenhouse gas emissions.

The second proposition that justifies the need to accelerate the use of renewable energy is the issue of limited fossil energy resources. Global energy consumption has increased by 45% over the past 25 years and will increase by 39% over the next 20 years.

The amount of natural gas consumption in 2000 was equal to 11724Bcm (BP, 2001) which reached 31690Bcm in 2010" (BP, 2011). Crude oil consumption is also on a completely upward trend, albeit with a lower slope than natural gas. Crude oil consumption in 2000 was 606000 barrels per day. This amount reached 873000 in 2010. Of course, the number of resources discovered and the amount of fossil energy production are also rising. But for now, it is predicted that with the same energy consumption, fossil energy sources can be exploited for the next 50 years, after which it is in a state of ambiguity. Of course, the predictions made in this regard are not definitive; "Because several factors, such as the discovery of new resources, the exploitation of unconventional resources, the increasing rate of exploitation of new reservoirs, the environmental costs and the high costs of exploiting unconventional resources, will be exacerbated by the current fossil fuels (Richter, 2010).

The third issue that needs to be addressed is the issue of energy supply. This issue can be examined nationally and internationally. In general, fossil energy sources are widely distributed around the world. The geography of resource distribution has led to many costs being incurred to transfer fossil fuels and some of the events that occur during the transfer. Also, significant costs are usually imposed due to the waste of resources along the transmission route.

These factors, along with other energy supply factors that are beyond the scope of this discussion, have led to the "decentralization" of "energy sources" to the attention of national and international actors (Smith & Taylor, 2008).

STATE SOVEREIGNTY AND REGULATIONS ON RENEWABLE ENERGY

With a brief description of renewable energy globally, the main topic can be dealt with, studying international law and renewable energy principles and rules. First, one of the most important challenges is addressed: governments' sovereignty over their natural resources. If there be no legislation on renewable energy in national regulations, international regulations will face certain difficulties.

The sovereignty of states over natural resources has been accepted as one of the principles of international law. The principle of sovereignty over natural resources means that states can regulate energy resources within their territory. Except in cases prohibited by international law. This principle has not only been emphasized in the declarations of the UN General Assembly but has been widely recognized in the "practice of states" (Schrijver, 1997). Therefore, there is no doubt that this principle is respected in international law, to the extent that some authors believe that this principle is now considered part of "public international law." As Shamsaii (2006) points out, this principle entered the field of international law from the 1960s onwards, following the independence-seeking approach of formerly colonized countries. This principle was primarily based on the human rights instruments (Lewis, 2020; Alston, 2020) and the recognition of the right to self-determination for nations, especially the newly independent states. This principle is also explicitly mentioned in the Stockholm Declarations. Thus, the Stockholm Declaration limited state sovereignty over natural resources to environmentally friendly use. Following the Stockholm Declaration, the focus on environmental protection in the exploitation of natural resources accelerated. To the extent that the concept of sustainable development was explicitly mentioned in the Rio Declaration (Mohseni, 2013). According to the principle of the Rio Declaration, first, the sovereignty of governments over their resources, concerning environmental policies and national development, and second, the responsibility of governments to control the actual activities in their territories are referred to as the concept of "preventing environmental damage." Thus, the emphasis on the sovereignty of states over their resources has, of course, been considered in the context of national environmental regulations (Najafifard, 2014).

But the question that comes to mind here is whether this principle is considered as one of the rules of international law or not? The need to answer this question arises from the fact that if that principle of the rule of thumb is considered, its observance will bind all subjects of international law. Therefore, this principle will prevail over other principles of international law. As a result, all international treaties and instruments in conflict will be considered null and void. As a result, it will be difficult to impose restrictions on governments' domestic policies and laws by creating international obligations to require the development and use of renewable resources(Wilkins, 2010).

On the other hand, if this principle is not considered a rule of thumb, it does not take precedence over other principles of international law and can even be modified in the shadow of other international rules. In answer to this question, Schrijver argues that contrary to the strong position of this principle in international law, it cannot be considered part of the rules of jurisprudence. The most important part of Eschzaifer's argument is based on the fact that if this principle is taken from the rules of *jus cogens*, all international treaties contrary to it will automatically be annulled. At the same time, many international treaties use the usual contractual terms, such as stability, international arbitration, etc., limiting the principle of state sovereignty over resources (Spataru, 2017). Governments also have freedom of action in negotiating and concluding international agreements. Therefore, it is very difficult to take this principle into account as a rule of thumb; Because the current practice of international law shows the opposite.

This view is endorsed by the growing trend of global economic development through foreign investment and international regulations approved and implemented by international organizations in this field; Because governments have in many cases been required to enforce international law instead of their domestic law. Besides, in many cases, governments are required to cooperate to protect the common environment. Thus, in practice, governments' principle of sovereignty of natural resources is significantly limited and applicable in the light of other international regulations. For example, Article 18 of the Energy Charter Treaty refers to the sovereignty of states over energy sources. In this article, the sovereignty of states over resources is recognized if it is exercised following international law. Moreover, in this article, the exercise of sovereignty over resources should also not affect the treaty's purpose to develop access to various types of energy (Leal-Arcas, 2016).

INTERNATIONAL LAW AND RENEWABLE ENERGY

Given the transboundary effects of climate change, the need for energy supply, and ultimately sustainable development, international law, albeit scattered, has addressed the use of alternative energy sources. Of course, in this context, our aim is not to examine in detail the existing provisions but merely to reach a general conclusion on the status of renewable energy in the light of international law is sufficient for the present article. In this section, the existing international documents and the principles of international law will be examined, respectively. The legal hierarchy will first examine the applicable documents, public international law, and the existing soft law in this field.

Renewables and Hard Law

Two binding instruments have regulations in renewable energy at the international level: the Energy Charter Treaty and the Kyoto Protocol. The Energy Charter Treaty is the first and only international treaty on international cooperation exclusively in energy. The main purpose of drafting the Energy Charter Treaty is to facilitate investment in the energy sector by defining the necessary provisions to reduce the non-commercial investment risks, removing trade and transit barriers. It is worth mentioning that Iran joined the Energy Charter Treaty in 2002 as a supervisory member. Therefore, because the authorities are considering accession to the Energy Charter Treaty, it will be important to pay attention to the Energy Charter Treaty provisions on renewable energy development. Article 1 (5) refers to the definition of economic activity in the energy sector. According to this article, electricity generators' production and operation are considered one form of economic activity in the contract. However, according to the final law of the European Energy Charter Conference, there is no reference in this article to the production of electricity through renewable energy sources, which serves as an interpreter of the Energy Charter Treaty, which includes electricity from renewable energy sources. Therefore, the production of energy from renewable sources falls within the scope of the Energy Charter Treaty.

According to Article 19 (D) of this Treaty, which deals with environmental aspects, States Parties shall pay particular attention to the development and use of renewable energy sources. However, as authors such as Bruce and Bradbrook have pointed out, the wording of this article does not reflect the binding commitment of member states to develop and strengthen the use of renewable energy sources (Bradbrook, 2013; Bruce, 2013). However, there is no denying that governments are explicitly obliged to develop renewable energy in the Energy Charter Treaty. But, of course, since no specific quantitative goals have been mentioned in the development of renewable energy sources, the guarantee of the implementation of this article will remain in an aura of ambiguity.

Climate change and its effects on the environment led to drafting the United Nations Convention on Climate Change in 1992. This internationally binding document is very much related to renewable energy. In this document, member states agreed to reduce greenhouse gas concentrations in the atmosphere to some extent possible environmental hazards. However, this document does not mention any specific commitment to developing the use of renewable energy sources to reduce greenhouse gas emissions. Therefore, governments are free to determine the methods needed to reduce greenhouse gas emissions "through human activities." In this regard, according to the Kyoto Protocol, which was drafted within the framework of the Convention, governments were divided into two general categories, and different obligations were set for each of these two categories (Telesetsky, 1999).

Under the protocol, developed countries (Annex A countries) must reduce greenhouse gas emissions individually or in partnership by at least 5% lower than in 1990 emissions by 2008 and 2012. Of course, some members, such as the European Union (15 members at the time), set higher targets (8%) for reducing their greenhouse gas emissions. On the other hand, developing countries (non-annexed countries "A") must also develop a program to reduce greenhouse gas emissions. Of course, the text of the Kyoto Protocol does not include any binding commitment to determine the types of tools to reduce greenhouse gas emissions, and governments are fully free to determine the mechanisms to meet their obligations. Nevertheless, Article 2 (1) obliges developed countries (Appendix (a) to develop and use renewable energy sources following their internal conditions, which is not in fact of a binding nature. However, one of the most important mechanisms implemented to achieve the set goals has been using renewable resources in practice. For example, in the European Union(EU), in addition to the economic crisis that led to a decrease in energy demand, the use of renewable energy has played a significant role in reducing greenhouse gas emissions in the realization of the ceiling of reducing greenhouse gas emissions. In addition to the above, Article 12 of the Kyoto Protocol refers to the Clean Development Mechanism (CDM). Following paragraph 2 of the said article, the purpose of this mechanism is to assist on the one hand the non-annexed countries "A" to achieve sustainable development and ultimately to achieve a reduction in greenhouse gas emissions and, on the other hand, to "help the countries." Their commitment is to reduce greenhouse gas emissions. One of the most important projects that have been considered and implemented under CDM is renewable energy projects.

In another study examining the effects of the Kyoto Protocol on reducing global emissions, the authors concluded that the adoption and implementation of the Kyoto Protocol would increase the use of renewable energy sources by up to 3% (Aichele & Felbermayr, 2013). Therefore, what is clear is the importance of implementing the Kyoto Protocol in increasing the rate of development and utilization of renewable energy. However, because of the issues raised, it can be stated that in the applicable documents, while the capacity for the development of renewable energy has been considered, no obligation has been assumed to consider the sources.

Renewables and Soft Law

Apart from the issues that may arise about the nature and guarantee of soft law enforcement, international instruments have already been developed in the form of soft law in many areas, especially in the environment. Thus, as one author defines, soft law refers to those rules that do not guarantee legal enforcement but have enforcement effects (Yanfang, 2011). Of course, as another author points out, soft law, although not inherently binding, in practice guarantees political performance that may lead to legal effects (Omorogbe, 2008). The authors have expressed various views on nature and guarantee the implementation of soft rights beyond this study's scope. However, given the growing importance of soft law in the development of international law, it will not be useless to review soft law documents on renewable energy.

The first international document to be adopted on renewable energy sources is the United Nations Conference on New and Renewable Energy. The most important outcome of this international conference is the need to develop the use of renewable energy, and secondly, the formation of a committee to develop and use renewable energy sources. Of course, this conference does not include implementing executive policies on renewable energy development, and even the committee was eventually merged into the UN Commission on Sustainable Development. In principle, the development of renewable energy sources was pursued within the framework of sustainable development, until in 1997, the General Assembly of the United Nations adopted a plan to implement Agenda 21 further. Article 45 of the resolution emphasizes the need for international participation to promote the use of renewable energy. In paragraph 46, the need to transfer technical knowledge from developed countries to developing countries is considered to such an extent that it will enable developing countries to increase energy production from renewable sources. The need for developing countries to systematize the use of renewable energy was also emphasized. However, there is no obligation on the part of the states to comply with the provisions of the said resolution, which in principle is not binding (Ruta, 2012).

International efforts to reduce greenhouse gas emissions and explain sustainable development in 2002 adopted the Johannesburg Executive Plan. As mentioned, this document is one of the most comprehensive international instruments ever adopted on renewable energy. Chapter 3 of the Johannesburg

Executive Plan is devoted to changing unsustainable patterns of production and consumption. Clause 20 (c) of the plan encourages governments and other international actors to use other types of energy to increase the share of renewable energy. Section 20(e) emphasizes the diversification of various energy sources, including fossil fuels, hydroelectric sources, and renewable energy sources. Besides, increasing the global share of renewable energy in total global energy production is emphasized. The importance of investing in renewable energy development by developed countries and international financial organizations in developing countries has also been emphasized on several other occasions.

Therefore, in the Johannesburg Executive Plan, paying attention to the development of renewable energy in the energy portfolio of countries is more explicitly emphasized. To the extent that the need to increase the share of these energies in total global energy production is also mentioned.

In 2005, the UN resolution on the World Summit outcome emphasized the need to take more effective steps to develop and support renewable energy. Finally, in 2011, the UN General Assembly adopted a resolution on sustainable development (Spataru, 2017).

The resolution designated 2012 as the "Year of Sustainable Energy for All." Of course, this document does not directly reference governments' commitments to developing the use of renewable energy sources. However, the document calls on the UN Secretary-General to report on implementing the resolution, in particular, to develop and promote the use of renewable energy. The report, entitled "Promoting New and Renewable Energy Sources," seeks to diversify programs at the national and international levels to promote sustainable development by considering different policies for developing and developing countries. The most recent document adopted on renewable energy development is the 2013 UN General Assembly Resolution on the "Promotion of New and Renewable Energy Sources."

Examining the existing soft law documents on renewable energy, it can be concluded that the emphasis on the use and development of renewable energy has grown exponentially in recent years and has been emphasized in many international instruments. Contrary to these emphases, however, no specific goals have been set for increasing the global share of renewable energy in the global portfolio. There can be several reasons for this; According to the authors, the most important factor is the difference in energy supply sources in different countries and technological and economic capacities for the development of this group of energy sources (McCollum *et al*., 2020); This is because these distinctions, especially considering the very high costs (at least in the short term) for the operation of such projects, have led to the difficulty of regulating comprehensive global regulations in this field. At the same time, the effects of non-binding documents in supporting the development of renewable energy sources cannot be ignored. For example, as mentioned at the end of the Rio + 20 conference, the document "The Future We Want" specifically mentions the need to develop renewable energy. In this regard, we can mention the steps taken by UNESCO to implement the "Renewable Energy for Us" program. The program will use renewable energy sources to expand renewable energy sources to reduce greenhouse gas emissions to provide energy in biosphere reserves and World Heritage Sources to renewable energy sources(Najafifard, 2014).

Public International Law

As one of the main sources of international law, public international law plays an important role in regulating international relations between states. The rules of public international law become enforceable once States have recognized them in practice. The authors have expressed different views on how to form and the elements that constitute the rules of international custom (Lepard, 2010). However, this chapter examines those rules of international custom that are recognized in international law. Although the rules on the development of renewable energy are not currently explicitly accepted within the framework of international custom, some of the accepted rules can be referred to as public international law. For example, the two non-damage and sustainable development principles are among the most relevant principles regarding renewable energy development. The principle of non-damages, which is now an integral part of public international law, first appeared in the arbitration of The Trail Smelter Case in 1941 in British Columbia, Canada, and then in the case of the Carrefour Canal in The International Court of Justice has been emphasized (Barboza, 2010). This principle is also recognized in the draft of the United Nations Commission on International Law on the Prevention of Cross-Border Damage Caused by Dangerous Activities in 2001.

Furthermore, this principle has been used in several cases in the International Court of Justice. However, numerous opinions have been expressed about the definition and limits of this principle. For example, Article 3 of the draft law of the United Nations Commission on the Prevention of Cross-Border Damage resulting from Dangerous Activities defines: Significant cross-border damage or in the event of an accident to reduce the risks.

On the other hand, Article 21 of the Stockholm Declaration states: "*States, following the Charter of the United Nations and the principles of international law, have the right to use their resources under their respective environmental policies*." Activities carried out within their sovereignty or control shall not damage the environment of other countries or regions outside the national sovereignty. With a slight change, the original Rio Declaration provides the same definition as the Stockholm Declaration of this principle. In its Advisory on Nuclear Weapons, the International Court of Justice defines these principles and the obligations of States about the prevention of transboundary damage as follows: The environment of other countries or the sphere of the sovereignty of countries is now part of the body of international law.

Examining the rulings of the International Court of Justice and the rulings of the International Court of Justice in this regard, it can be concluded that the principle of non-damage is currently one of the main principles of international environmental law. And governments are now obliged to comply with it. The question that comes to mind now is the relation of this principle to renewable energies. For example, some authors argue that the principle of non-harm includes protecting the earth's atmosphere; they state that the earth's atmosphere, like the oceans and seas, is part of its common heritage (Birnie & Boyle, 2002). Therefore, the same protection of the oceans in international law should apply to the atmosphere. According to the principles of customary international law, governments have international responsibility for greenhouse gas emissions.

However, as some authors have pointed out, there is no standard for determining the due diligence of states in this area (Lyster & Bradbrook, 2006); Because the standards set out in the Long-Range Transboundary Air Pollution Convention or the Ozone Layer Convention are not analogous to determining the appropriate effort to emit greenhouse gases. The standards contained in the Kyoto Protocol are also not like international custom; Because they are not subject to universal consensus. Some authors also argue that the principle of non-damage can be applied if the error or intention of governments to cause cross-border damage is established. Otherwise, the damage cannot be considered a violation of international law and responsible for governments (Brownlie, 2008). However, as another author acknowledges, the principle of non-damage does not necessarily imply governments' intent or error; this principle applies to non-prohibited acts and is common in international law (Borowy, 2013). In this regard, numerous lawsuits have been filed nationally and internationally against countries and companies that emit greenhouse gases (Gunningham, 2012).

Many authors also emphasize the international responsibility of states for damages that have been introduced in terms of greenhouse gas emissions (Cherp, 2011; Cottier, 2011). But so far, no lawsuit has been filed that has resulted in a ruling on reducing pollutants or compensation. Therefore, although it can be argued that governments are obliged to prevent damage to the earth's atmosphere and thus reduce greenhouse gases in the main shadow of no damage, the limits of damage and the commitment of governments to prevent it have not been determined. At the same time, For governments to be held accountable in this regard, there are numerous problems, such as standard, appropriate efforts, proving the causal relationship, the competent authority, etc., that have a long way to go to solve them, therefore, in the light of this principle, governments cannot be expected to develop renewable energy, which will reduce greenhouse gas emissions.

Renewable Energy and International Institutions

The role of international organizations in shaping various fields of international law is well known. Different international organizations are working hard to establish an appropriate legal framework for energy and energy governance systems.

United Nations agencies are actively working to promote renewable energy worldwide. UNEP is the leading United Nations organization supporting renewable energy advertising. UNEP's major contribution to the Renewable Energy Law is the publication of the "Handbook" (2007) and "Guide" (2016) to assist designers in developing countries, and the annual report "Global Renewable Energy Investment Trends," which involves various themes of renewable energy investment cases. UNDP has been active in transforming the global energy system for more than two decades by improving energy efficiency and using renewable energy systems. Recently, UNDP released the "Sustainable Energy Strategy Note 2017-2020: Sustainable Energy Supply in Climate Change", the first UNDP program, mission, method, guidance, principle, and focus on sustainable energy. To this end, it puts renewable energy in its vision and mission (UN, 2016). This is an important initiative of the UNDP program because the organization has played an effective role in development activities mainly from countries in Asia and sub-Saharan Africa, where disadvantaged and marginalized people cannot afford electricity.

The fact is that despite the active participation of United Nations agencies in global development activities, their energy activities are relatively ambiguous (Gunningham, 2012). There is a lack of coordination and trust among these organizations; that is, "the regime's system is ineffective for renewable energy to achieve sustainable energy" (Heffron, 2016). Therefore, the United Nations Department of Energy, composed of 21 member organizations, was established in 2004 to respond to energy Challenges; the United Nations system has established institutional mechanisms to promote coordination and coherence (UN, 2015b) The International Energy Agency (IEA) was established in 1974 after the oil crisis of 1973-79. It aims to coordinate the response of oil-importing countries to major oil supply disruptions. It is the most famous international organization dedicated to energy security, environmental awareness, and economic development. IEA was established following the decision of the OECD Council and is an autonomous organization within the framework of the OECD (International Energy Planning Agreement). But this is separate from the OECD and has been recognized by the "United Nations Framework Convention on Climate Change." Historically, the main focus of the IEA is neither renewable energy nor conventional fuels. The Renewable Energy Working Group (REWP) was recently established. Its task is to provide renewable-relevant technology and policy recommendations and projects to various IEA organizations. A very authoritative global energy outlook is published every year, which is the main reference for energy-related stakeholders by IEA. Founded in 2011, International Renewable Energy Agency (IRENA) is a leading international organization focusing on renewable energy. As of September 2017, it has 152 members and 28 future members. Through the 2009 IRENA Charter, the parties expressed their willingness to promote the recognition of renewable energy in terms of sustainable development and firmly believe that renewable energy provides a huge opportunity to solve and gradually reduce energy security issues and unsustainable energy prices. Therefore, IRENA enjoys the same privileges and immunities as the United Nations (Gielen, 2019), although IRENA has no explicit or implicit authority to set binding RE targets.

At the International Renewable Energy Conference held in Bonn in 2004, the International Geothermal Association, International Hydropower Association, International Solar Energy Association, World Biotechnology Association, and World Wind Energy Association formed an international alliance called Renewable Energy Alliance. It was later renamed to the 21st Century Renewable Energy Policy Network or REN21. The network connects a wide range of stakeholders and provides international leadership in promoting renewable, focusing on the annual "Report on the Global State of Renewable." In addition, various development banks such as the World Bank, Asian Development Bank, African Development Bank, Inter-American Development Bank, and New Development Bank play an important role in promoting renewable energy through financing projects. However, these banks did not have a comprehensive strategy to incorporate renewable energy into their overall loan plans (Wilkins, 2010). Therefore, it is clear that many non-governmental actors have been involved in promoting and developing renewable energy; although their activities do not overlap in some cases, IRENA is in a leading position.

SOLUTIONS AND RECOMMENDATIONS

Besides, although policies such as the transfer of energy production technology through renewable energy sources or the creation of financial incentives for investment in this sector have been proposed in the international instruments, it still seems relevant. And it is certainly easier to formulate and implement these policies in international law than to create international obligations for renewable energy development.

FUTURE RESEARCH DIRECTIONS

Nowadays, more researchers study the renewable energy industry, market, etc., and there is a significant interest and attraction to increasing the share of renewables in national energy portfolios. This global convergent ambient for renewable energy development owes much to international conventions, legal principles, and public international laws. This chapter suggests that the current successful trend continues, and a deep energy transition occurs in the decades to come.

CONCLUSION

The need to develop these sources of energy production is undeniable by examining the documents and principles of international law on renewable energy. This can be achieved by examining existing international instruments and in the light of the principles of international law, such as the principle of non-damage and the principle of sustainable development. China, which is not primarily responsible for reducing greenhouse gas emissions under the Kyoto Protocol, is currently one of the largest energy-producing countries through renewable sources. On the other hand, the right to a healthy environment has been mentioned as one example of the third generation of human rights in several international documents, and renewable energy is one of the most important sources of energy production. They reduce environmental pollution, especially air pollution. The authors believe that international law does not currently impose a specific obligation on governments to develop renewable energy for sustainable development and reduce the effects of greenhouse gases. At the same time, establishing such obligations is possible through international treaties and is not considered contrary to the sovereignty of states over their resources. For example, we can refer to EU laws in this regard. EU countries agreed in 2009 to supply 20% of total energy production through renewable energy sources by 2020, which has largely achieved this goal.

It is important to note that energy governance is a complex issue, and there is no suitable "best model" for renewable energy governance. At the national level, there is a gap between what is needed and what the government is doing, while at the regional and global levels, collective action challenges often create insurmountable obstacles. Several bills can be considered, including the promulgation and promulgation of special renewable energy laws, including a series of policies that support the introduction of renewable energy power generation prices. Providing incentives and subsidies can help bring about positive changes in Europe. International investment treaties and binding legal instruments can guarantee universal access to energy for all, although such plans require political commitment and excessive cross-border tendencies. Regional and institutional frameworks indicate that renewable energy has become an important issue for further developing cross-border countries. From Africa, South America to Asia, and other regions in developed countries, indirect measures (if not direct measures) taken in most parts of the world should be attributed to using and promoting renewable energy for sustainable change. Global and regional institutions are also actively promoting renewable energy and its potential contribution to sustainable development for all. Therefore, the use and consumption of renewable energy have promoted sustainable development in many ways. The United Nations has approved the Sustainable Development Goals and recognizes the importance of renewable energy in providing clean and cost-effective energy for all. Generally, in the context of the 21st century, the preference and dependence on rare piles of the earth is an internal, regional, and global reality, which cannot be denied or denied in any country.

DISCLAIMER

The contents and views of this chapter are expressed by the author in his personal capacity. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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KEY TERMS AND DEFINITIONS

Energy Charter Conference: Article 33 of the ETC establishes the Energy Charter Conference, which is the governing and decision-making body of the Organisation and has United Nations General Assembly observers' status in the resolution 62/75 adopted by the General Assembly on 6 December 2007. Members consist of Countries, and Regional Economic Integration Organisations signed or acceded to the treaty and represented in the conference and its subsidiary bodies. The conference meets regularly to discuss issues affecting energy cooperation among Members, review the implementation of the treaty and PEEREA provisions, and consider new activities within the Energy Charter framework.

Energy Charter Treaty: The Energy Charter Treaty (ECT) is an international agreement that establishes a multilateral framework for cross-border cooperation in the energy industry. The treaty covers commercial energy activities, including trade, transit, investments, and energy efficiency. In addition, the treaty contains dispute resolution procedures both for States Parties to the treaty (vis-a-vis other States) and between States and the investors of other States, who have made investments in the former territory.

Energy Community: The Energy Community, also referred to as the Energy Community of southeast Europe, is an international organization established between the European Union (EU) and several third countries to extend the EU internal energy market to Southeast Europe and beyond. With their signatures, the Contracting Parties commit themselves to implement the relevant EU energy acquis communautaire, develop an adequate regulatory framework, and liberalize their energy markets in line with the acquis's acquis under the treaty.

EurObserv'ER: EurObserv'ER is a consortium dedicated to monitoring the development of the various sectors of renewable energies in the European Union. Created in 1999 by Observ'ER, the Observatory of renewable energies in France, it is composed of five other partners: ECN (The Energy research Centre of the Netherlands), IEO (EC BREC Institute of Renewable Energetic Ltd), RENAC (Renewables Academy AG), FS (Frankfurt School of finance and management) and IJS (Institut *Jozef Stefan*).

European Integrated Hydrogen Project: The European integrated Hydrogen Project (EIHP) was a European Union project to integrate United Nations Economic Commission for Europe (UNECE or ECE) guidelines and create a basis for ECE regulation of hydrogen vehicles the necessary infrastructure replacing national legislation and regulations. This project aimed to enhance the safety of hydrogen vehicles and harmonize their licensing and approval process.

International Energy Charter: The International Energy Charter is a non-binding political declaration underpinning key principles for international energy cooperation. The declaration attempts to reflect the changes in the energy world that have emerged since the development of the original Energy Charter Treaty in the early 1990s. The International Energy Charter was signed on 20 May 2015 by 72 Countries plus the EU, Euratom, and ECOWAS at a Ministerial conference hosted by the government of the Netherlands.

Jus Cogens: Jus cogens, also known as the peremptory norm, is a fundamental and overriding principle of international law. It is a Latin phrase that translates to 'compelling law.' It is absolute, which means that there can be no defense for the commission of any act prohibited by jus cogens.

Chapter 9
FDI and the Gap of Clean Power Finance:
The Case of Africa

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ABSTRACT

Twin deficits in energy and financing are extensively detrimental in Africa which in turn entails foreign direct investment (FDI) to be effectively promoted. This study intends to examine the determinants of FDI in the clean power industry in Africa over the period 2003-2019. By using a robust model of FDI panel gravity fixed effects Poisson pseudo-maximum likelihood, a range of encouraging and reassuring results are found. Importantly, enhancing the awareness of the importance of renewable energy robustly attracts FDI in Africa. Moreover, as anticipated, geographical distance is not the main factor in influencing the decision made by foreign investors. Moving forward, improving renewable energy education with the timely availability of data promotes awareness in society and thus may facilitate the development of the clean power industry in Africa in the near future.

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INTRODUCTION

The power security issue is a precondition for economic development. Concurrently with announcements of reaching the electricity universal access and achieving electricity surplus by different countries worldwide, Africa is still incapable of meeting its people's power needs. Africa is an influential continent globally; the second-largest and fastest-growing population continent inhabited by a fifth of the world's people in 54 countries that is distributed into two central regions: North Africa (NA) and Sub-Saharan Africa (SSA). This labor and geographical wealth inadequately contribute to power security; almost 600 million Africans lived without power access and 900 million had no modern and clean cooking facilities in 2019 (IEA, 2019). Another example of an electricity insecurity issue is highly highlighted during combating coronavirus pandemic in which thousands of African hospitals were without power, leading to impeding social distancing (IEA, 2020). In other words, electricity frequent outages negatively affect the required environment for social distancing adoption in Africa, e.g., Africans could not stay connected at homes and continue to communicate with public services remotely; a situation that could force them to gather and communicate face to face. Generally, Africa forms only 4% of the global power utilization, achieving just 45% of the global access to power in SSA comparing with 98.5% in NA in 2019 (ADB, 2018; IEA, 2019; Pappis *et al*., 2019). NA is wholly electrified; however, this region struggles to meet its growing energy needs.

Readers immediately may infer that electricity insecurity is detrimental to Africa. Since 2010, the continent's gross domestic product (GDP) constituted limited growth of 3.1% comparing with 3.5% globally. The acute shortage of power aggravates the situation. Thus, Africa loses about 2%-4% of its GDP per annum; which disrupts doing businesses in many African countries (IEA, 2019). Energy poverty, therefore, is harmful to Africa. So, what do African policymakers do now? Is a fossil fuel-based power expansion relevant? It is an unwise option of which it would contribute towards global warming.

Global warming is an international threat ascribed to fossil fuel burning. Africa is the most vulnerable to this phenomenon's effects as it highly depends on agricultural activities, enacts weak adaptation policies, has food insecurity problems, and faces rising poverty rates (Acheampong *et al*., 2019). Thus, it is unwise that Africa treats its power deficit by fossil fuel burning. Put differently, in Africa's attempts to mitigate its electricity insecurity challenges with considering the Paris Agreement [limiting global average temperature to below 2 degrees Celsius and improving renewable energy technologies use] and the UN Sustainable Development Goals [specifically goal 7 of reaching affordable and reliable energy for all, as well as goal 13 of combat climate change]; it should harness its renewable energy [RE] resources (Garcia, 2022). It is believed that managing African power insecurity by RE can put the continent on the right track. The International Energy Agency (IEA) cited that Africa can me*et al*most a quarter of its energy demand by 2030 if it harnesses its RE effectively (Aliyu *et al*., 2018; IEA, 2019).

Here, the public may wonder, why is Africa still lagging in energy issues? The simple answer is because the RE financing gap, which renders a substantial part of clean power [CP] resources[1] untapped. Readers, thus, can easily understand that this gap is at the core of electricity insecurity issues in Africa. Additionally, for the information of the readers, African RE development is mainly funded by global financial assistance resources, which are basically insufficient. As a result, further RE financial needs are growing which entails inbound green foreign direct investment [FDI] to be promoted (Adesola et al., 2018; IEA, 2019; Bunyaminu & Yakubu, 2022).

Against this backdrop, this study intends to propose insights and recommendations to accelerate and stimulate the FDI into the clean power industry [CPI]. Put differently, this chapter empirically examines potential determinants of FDI in the CPI over 2003-2019 in 33 African countries. It is believed that the results could be important in formulating coherent CP policies by African policymakers and informative for *green progression* proponents.

The chapter addresses the financing gap and FDI inflows in the clean power industry in Africa. The literature review is also presented. Then, methodology, results, and discussion are introduced. The chapter concludes with a conclusion and policy implications.

THE CLEAN ENERGY FINANCING GAP IN AFRICA

Clean power challenges are multifarious in Africa. However, the RE financing gap is the essence. It is believed that this funding gap is at the main challenge that contributes towards power insecurity issues in Africa. Here, the conveyed message to the audience is that a sufficiency of RE financial resources could positively affect RE resources harness, RE infrastructure setting up, RE regulatory and financial/fiscal policies improving, modern cook facilitations availability, RE public awareness enhancement, and RE education, experience, and skills. However, achieving these targets requires substantial financial resources [demand side], whereas these resources availability [supply side] is largely insufficient. That variation between the demand and supply sides is known as a financing gap [financial resources supply - financial resources demand = ± financing gap]. If the CP financing gap is negative, it implies that Africa is stricken by a severe deficit in its RE financial capabilities.

Determinants of the Clean Energy Financing Gap

This financing gap is a complex issue having diverse interlinked drivers. The African energy's financing needs are about USD43 billion yearly. However, the current expenditure is approximately USD11.6 billion per annum, suggesting that the financing gap is about USD 31.4 billion a year (Schwerhoff & Sy, 2017). In the literature, this gap is attributed to several direct and indirect determinants [reasons], which are discussed as follows;

Firstly, RE reform policies are somewhat lagging and underdeveloped in Africa (Hafner *et al*., 2018). For instance, RE policies are remarkably inactive in countries of Niger, Sierra Leone, Somalia, and Zimbabwe, as well as carbon price policy was absent in Africa till 2019 [this policy was only implemented in South Africa by 2019]. Also, Eritrea and Libya did not ratify the Paris Agreement to date [until 2021]. Furthermore, wrong approaches are employed in addressing the African energy problems (Chirambo, 2016). Secondly, private investment as a funding supply source is still rare in the African power industry (Duarte *et al*., 2010). Schwerhoff and Sy (2017) cited that the RE projects absorb less than 1% of private equity, therefore, the African power industry's investment is less than USD5 billion a year (Amir & Khan, 2021).

Thirdly, African financial development matters. RE bankable projects are limited; as domestic RE experiences and skills are impoverished. Noticeably, there is a shortage of educated, trained, and professional personnel for RE development in Africa (Bishoge *et al*., 2020). As such, readers could infer that banks are always reluctant to provide RE financing, and its price [interest rate] is often costly. Further, the financial systems and markets, including bond markets, are underdeveloped and small in many African countries, a situation that could negatively affect the supply-side of the RE financial resources (Schwerhoff & Sy, 2017; Butu *et al*., 2021). The readers can find the same negative impact on this supply-side emanating from the lowest sovereign credit ratings in most African economies (Schwerhoff & Sy, 2017). Global factors also play a role in limiting the financial resources for RE development, the financial crisis of 2008 is an example (Elie *et al*., 2021). Fourthly, robust and accurate economic and RE information contribute positively to the correct financing gap determining. Readers may be surprised to realize that Africa is stricken by the absence of frequent accurate economic data records. Here, according to the World Bank, meticulous, regular, and reliable GDP and census data are absent in Africa (Beegle *et al*., 2016). In addition, there is a shortage of RE data, surveys, and studies on SSA (Bishoge *et al*., 2020).

Fifthly, growing poverty in Africa renders domestic accessible financial resources to be finite. The general public may be unaware that 34 African countries are categorized as the least developed countries. Africa itself encompasses 49 economies that having genuine negative savings, which constitute an essential part of the supply of financial resources (Aust *et al*., 2020). That is largely ascribed to poverty, civil wars, political instability, and corruption. In addition, most African utilities have unqualified billing and power payment collection approaches (Duarte *et al*., 2010). Sixth, investment inflows play a small role in the African RE industry and necessarily need to be accelerated and stimulated. As such, RE expansions are mainly financed by international development finance institutions (Kiranmai *et al.*, 2022).

Seventhly, the net average total costs of RE projects are exceptionally high compared with conventional energy investment. RE resources are almost free of cost, but the initially required finance for RE setting up, infrastructure, and technologies are expensive and illiquid. However, the running and operational costs are lower afterward (Duarte *et al*., 2010; Schwerhoff & Sy, 2017). Consequently, CP projects in SSA are classified as risky investments having a lower profitability level, thus, more than 80% of these projects are sorted as high risk or substantial risk (Schwerhoff & Sy, 2017; Butu *et al*., 2021; Elie *et al*., 2021). Lastly, corruption and inefficiencies in the RE industry, including transmission and distribution losses, electricity theft, bureaucracy, etc., could highly limit the supply of financial resources and increase the demand side.

Against this backdrop, if the readers combine all the above challenges together, they could effortlessly grasp the essence of the RE financing gap in Africa, as shown in

Figure 1. The clean energy financing gap determinants in Africa
Source; Authors' preparation

The Financing Resources to the Clean Energy in Africa

Most African RE projects are Greenfield donor-dependent investments. Those projects are mainly developed by global financial assistance resources. The African governments, development finance institutions [DFIs], climate funds [CFs], and global donors are the main investors/financiers/sponsors. Typically, the African utilities finance their power industry (Schwerhoff & Sy, 2017). For example, these domestic utilities invested more than 50% of the power industry's obtained finance over 1990-2013 in SSA except South Africa (Klagge & Nweke-Eze, 2020). Besides, Schwerhoff and Sy (2017) showed 95% of the RE projects financed by CFs' grants and only 3% by loans, and private equity constituted less than 1%. Also, 90% of the power infrastructure in SSA was financed by the African governments' budgets and the global donors in 2017 (IEA, 2019). Noticeably, the World Bank is the main player under DFIs since the 1950s. Yearly, it pours almost USD2 billion into the African RE industry (Schwerhoff & Sy, 2017).

In addition, readers who follow African affairs may know that the African Development Bank (AfDB) positively contributes [direct and indirect] to energy industry development. AfDB supports RE by about USD2 billion yearly. In addition, in 2010, the AfDB commenced green bonds issuing, as a clean energy financial instrument, to fund climate change alleviation activities, and collected USD30 billion in 2014 (Schwerhoff & Sy, 2017). Besides, China plays a key role in RE development in Africa. The Chinese financial assistance increased from about USD313 million in 2000 to more than USD4.4 billion in 2012. Further, China installed 30% of the power capacity in SSA over 2010-2015 (Sy & Copley, 2017).

The readers may be astonished when they know the above-mentioned assistant financial resources are deficient in meeting the African energy needs (IEA, 2019). It is also important to mention that the climate funds' financial resources are not orientated towards CP generation, as these resources are exclusively poured into capacity setting up and pilot projects (Schwerhoff & Sy, 2017). As a result, several solutions have been cited in the literature to alleviate the RE financing gap in Africa. For instance, this gap could be reduced by USD3.3 billion a year in the case of effective handling of the inefficiencies in the power utilities (Duarte *et al*., 2010). Another proposed solution is suggested by the IEA in 2019 in which the FDI should be stimulated and accelerated to complement the above-mentioned funds in Africa, which is consistent with the objectives of that the present chapter.

THE OUTLOOK FOR FDI IN THE CLEAN POWER INDUSTRY IN AFRICA

Readers may be interested in exploring the FDI's *status quo* in the CP industry in Africa. Over the past two decades, FDI in this industry has been growing, but remarkably fluctuated and unevenly flowed among the CP sub-industries across African countries. For instance, the solar electric industry was the most attractive for FDI in which this sub-industry witnessed an FDI peak in 2015. Dissimilarly, hydropower and geothermal electric industries came as the lowest puller destinations for FDI over 2003-2019. Further, the largest FDI inflows were poured in Cameroon, Egypt, Ghana, Kenya, Morocco, Mozambique, Nigeria, South Africa, and Tunisia. In the same vein, the European economies, China, Canada, India, the UAE, and the USA have been predominant investors in the CP industry (FDI Markets, 2020). Readers can visibly find the FDI development in the African CP industry over 2003-2019 in

Figure 2. FDI in the clean power industry in Africa over 2003-2019
Source: FDI Markets, 2020

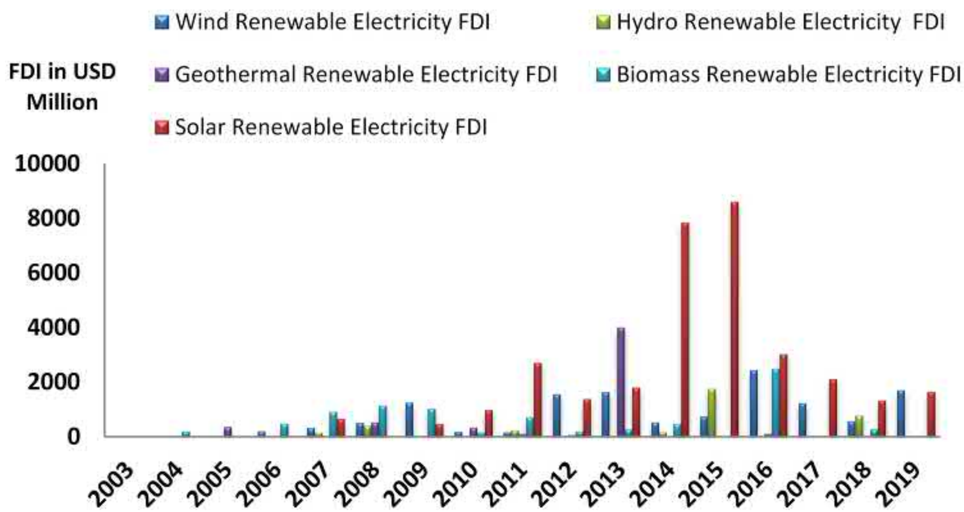
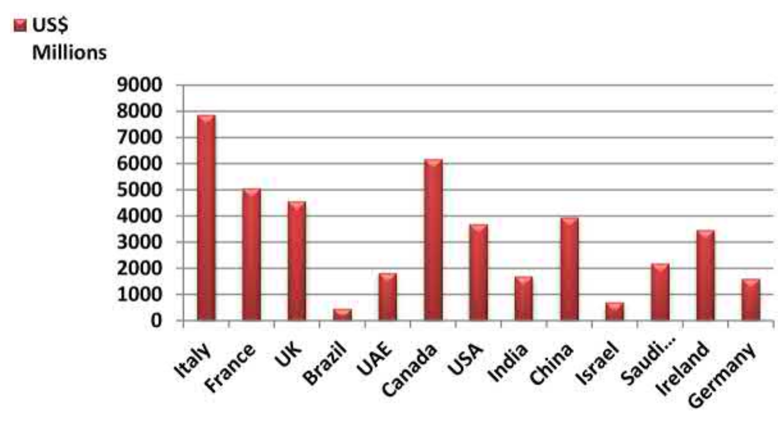


Figure 3. Value of investments by the most invested countries in the clean power industry in Africa between 2003 and 2019
Source: FDI Markets, 2020



LITERATURE REVIEW

Theoretically, FDI theories are various, aiming to explain and justify the global investment movement. The eclectic paradigm of Dunning (1977-2001) is considered the most comprehensive and holistic FDI theory in the literature (Aziz, 2015; Kathuria *et al*., 2015; Yong *et al*., 2016; Tampakoudis *et al*., 2017; Asiamah *et al*., 2018; Mahbub & Jongwanich 2019). The paradigm is also known as the OLI framework as Dunning builds his explanation of FDI movement depending on ownership [O], location [L], and Internalization [I] advantages. Simply, the ownership merits refer to different effective qualifications that enable foreign companies to invest abroad, whereas the location advantage means host countries' pulling factors that could attract and persuade foreign investors to pour investments. The most profitable modes for foreign investors to enter host markets are depicted in the internalization advantage. As such, combining these three pillars together could constitute successful FDI (Dunning, 2001; Faeth, 2009).

In the empirical literature, on the other hand, RE FDI determinants have been remarkably examined responding to climate change and energy insecurity issues. The literature has investigated RE policies, traditional determinants [macroeconomic indicators], and global financing assistance as potential RE FDI drivers. However, the reported results are mixed and inconclusive as a reaction to different employed methodological frameworks.

In their attempts to suggest a definition of RE investment as a necessary investment for greenhouse gas and harmful emissions reduction, Eyraud *et al*. (2013) found that low interest rates, a growing economic growth, high fossil fuel prices, and feed-in tariffs (FiT) bolstered RE investment in 35 advanced and emerging countries. The FiT was documented as the most important policy for RE development. This result is substantiated by Kathuria *et al*. (2015) in which FiT, per capita income, banking facilities, and low energy transmitting costs attracted FDI in the wind energy industry [the industry that got the lion's share of FDI] in 8 Indian states over 2004-2010. Both fixed effects and random effects models were used to explore the uneven FDI distribution issue among Indian states. The conclusion stated that the institutional factors improved FDI in the respective industry. Besides, the extreme growth in China's economy renders the energy security issue to become China's top priority; pushing China to provide a substantial amount of RE finance inside and outside; leading the country to be the most important RE investor worldwide. Consequently, the attractiveness of the European countries' location advantages in influencing Chinese FDI in the RE sector is analyzed by Lv and Spigarelli (2016). To do so, a fixed-effects logit model is used. The results showed that political stability, large market size, market affluence, ownership merits, and controlled corruption enhanced Chinese FDI inflows in the European RE industry. The limited rule of law, interestingly, positively associated with outward Chinese FDI in the concerned industry. The paper considered its novelty and originality emanate from its focusing on industrial analysis/sectorial insights [the novelty of the present chapter depends on the industrial/sectorial analysis as well].

For reference to developing countries, Keeley and Ikeda (2017) revealed that RE economic and regulatory policies, trade openness, and access to finance facilitated FDI movements in the wind energy industry during 2008-2014. This study also confirmed that the traditional determinants and RE policies have almost the same impact on wind investment. These results are corroborated by Sirin (2017) in which stable macroeconomic indicators, CP fiscal incentives, institutional reforms, enabling business environment policies, real exchange rate, and privatization robustly improved FDI in the power industry in 12 economies, focusing on Turkey as a special case study. A 10-year paper by Romano *et al*. (2017) covered 56 developed and developing economies, proved that the effectiveness of CP policies in affecting FDI varied among those countries due to variation in their economic and social development stages. Given the data's nature, the paper used the panel corrected standard errors model. Zeng *et al*. (2017) reviewed the RE history in BRICS and revealed that the most of green resources are underdeveloped because of the financing gap and enacted imperfect policies. Thus, developing capital markets, build-own-operate, and build-operate-transfer systems, as well as expanding the financing leasing service are the main suggestions for further improvements by this study.

A global sample study of 137 countries over 2005-2014, by employing fixed-effects estimation, found that RE net metering and financial support policies did not persuade foreign investors to pour RE investment. However, FiT, tax incentives, and renewable portfolio standards robustly absorbed FDI in the RE sector globally (Wall *et al*., 2019). More RE qualitative studies were suggested for future research by the paper. These results are consistent with findings by Polzin *et al*. (2019) who pointed out that FiT, renewable portfolio standards, and auctions are effective RE instruments for CP projects. The study further ensured that the most successful RE policies are the policies that intend to increase investment returns and alleviate risks simultaneously. Again, these results are supported by Ragosa and Warren (2019) as they reaffirmed that FiT, political stability, regulatory policies, and global assistant financing were central FDI determinants in CP generation in 62 developing economies within 2008-2014.

Overall, the paper chronologically synthesizes the seminal related literature to introduce compelling arguments to the readers. Most of the preceding papers focus on macroeconomic/aggregate analysis whereas sectoral/industrial analysis is infinitesimal. One proposed reason behind that is the difficulty of collecting industrial data (Keeley & Ikeda, 2017). However, sectoral and industrial studies could provide more focused and deepest results. Moreover, addressing the FDI determinants issue in the African clean power industry is neglected in the literature. Hence, to the best of our knowledge, no study has explicitly examined potential FDI determinants in the clean power industry in Africa. This chapter, thus, is going to fill these gaps.

METHODOLOGY

In what follows, the research design is introduced.

Theoretical Framework

As cleared its importance earlier, Dunning's Eclectic Paradigm (1977-2001) is considered as a theoretical framework for FDI in the CP industry in Africa.

Variables Description, Hypotheses, and Data Description

This study employed variables which can be categorized into gravity variables (the gravity model is used in analysis), variables of interest, RE variables (regulatory and financial/fiscal policies), and control variables. As it is widely known, the basic form of the gravity model is used in non-linear form for international trade analysis. As s result, all the gravity variables are used in natural logarithmic to fit the data into a linear functional form.

Variables of Interest

- **FDI** is the dependent variable. It presents foreign investment inflows in the renewable electricity industry in 33 African countries over 2003-2019. FDI is measured in current USD millions. FDI data is deliberately obtained from the Financial Times' FDI Markets Database. It is neither public secondary nor readily available data. It is a novel dataset. Further, the Financial Times' FDI Market is a specialist department in tracking FDI worldwide since 2003. Markets' data is used in UNCTAD's world investment reports (Falk, 2016; United Nations Conference on Trade and Development [UNCTAD], 2019; UNCTAD, 2020).
- The Paris Agreement **(Paris Agree**) is an international treaty that aims to combat climate change through greenhouse gas emissions (GHG) reduction by limiting global average temperature to below 2 degrees Celsius. The Paris Agreement was adopted in Paris by the end of 2015 under

the United Nations Framework Convention on Climate Change. For achieving the announced objectives, the treaty entails developed countries to financially support developing countries, encourages effective utilization of CP technologies, and necessitates signatory countries to report their progress plan towards reducing GHG every five years. The Paris Agreement is employed as a variable of interest as this treaty could encourage African signatory countries to enhance their RE industry, the situation that could accelerate FDI into their RE industries. Furthermore, to the best knowledge of the authors, the Paris Agreement's impact on FDI in African RE has not been empirically discovered yet. Based on the literature, the effect of international climate agreements on investment flows is inconclusive, and the inclusion of the Paris Agreement is limited in preceding studies. As such, a positive significant impact is hypothesized. The result could be important to African policymakers for considering the upcoming environment and RE agreements, and particularly, to policymakers in Eritrea and Libya in which both countries did not ratify the Paris Agreement. Besides, data is collected from the United Nations Treaty Collection Website[2], in which a dummy variable with a value of (1) is used in a ratification year onward and a value of (0) otherwise.

- RE public awareness **(REAware)** is focused on in the analysis; as the literature frequently cites that the limited knowledge, cultural challenges, and insufficient skills and experiences towards RE impede its investment and development in Africa (Aliyu *et al*., 2018; Kuamoah, 2020). As such, enhancing the African awareness of RE is necessarily required. This study thus intends to empirically measure the impact of the RE public awareness in Africans on FDI in the CP industry. REAware is a broad concept and many proxies can be employed for econometrics purposes. This study follows the work by Caruso *et al*. (2020) in using Carbon dioxide emissions (CO_2) [metric tons per capita] as a proxy for public awareness of CP utilization. It is supposed that in a country with a growing recognition of RE importance, benefits, etc., the effective demand of CP applications could be increased and by extension, CO_2 could be decreased (as a result of a growing REAware) -a situation that may encourage more FDI inflows in the CP industry. Thus, it is to examine the impact of CO_2 on FDI in the CP industry in Africa. CO_2 data is sourced from the World Bank's World Development Indicators (WDI). For CO_2's missing data; the linear interpolation method (Hassaballa, 2014; and Ankrah & Lin, 2020) is used.

The Gravity Variables

- The gross domestic product in a logarithmic form **(LGDPhome)** is used as a proxy for the host country's market size. In the literature, GDP is cited, to a great extent, as the most important attractive FDI determinant (Faeth, 2009; Keeley & Ikeda, 2017). A growing GDP could be considered as a location advantage and a good indicator of a present and future RE effective demand in Africa which could encourage FDI inflows. Further, high GDP could mean adopting expansionary RE financial/fiscal policies and research & development activities. Thus, a positive and statistically significant relationship between FDI and LGDPhome is hypothesized. The data is in current USD pooled from WDI.
- The GDP of exporter countries for FDI **(LGDPsource)** is included to refer to those countries' wealth. It is presumed that a high LGDPsource is attributed to remarkable affluence in a country that may expand opportunities for its national companies for investing overseas. Countries having

a growing LGDPsource intensively invest in Africa's clean power industry, this is the hypothesis. GDPsource is in current USD and collected from WDI.

- Geographical distance in a logarithmic form **(LDistance)** depicts the span in Kilometers between Capitals of the host African countries and FDI source countries. This study considers distance as a proxy for transportation cost and cultural divergence among countries. In light of the globalization era and reasonable profits; this study hypothesizes that LDistance has an insignificant impact on FDI in the African CP industry. Distance data is sourced from CEPII database.

Renewable Energy Variables

- RE targets **(RETs)** present ambitious plans to develop RE in the future. RETs are perceived as a political will to RE expansion and development. Based on reviewing the literature, a positive association between RETs and FDI in the CP industry is hypothesized. RETs are employed as a dummy variable with value (1) once they are in place onward and (0) otherwise. The data is derived from REN21 reports, IEA, and IRENA Joint Policies & Measures database.
- RE financial and fiscal variables/policies **(REFs)** are also added. These policies include green loans, import duty tax exemption, grants, subsidies, tax exemption, rebate, tax credits, tax reduction, decreasing VAT, etc. Depending on preceding studies, a positive and statistically significant relationship is anticipated. REFs are presented as a dummy variable with a value of (1) when any of these policies is implemented and (0) otherwise. The REF data is pooled from IEA and IRENA Joint Policies & Measures database and REN21 reports.
- Feed-in tariffs **(FinT)** depict RE regulatory policy. FinT is designed to determine the price of one unit produced of CP. The impact of FinT on FDI is inconclusive in past published papers. However, the present chapter hypothesizes that the implementation of FinT, as an organized and regulatory policy, accelerates FDI in the African CP industry. The data is employed as a dummy variable, like RETS and REFS variables, and is collected from IEA and IRENA Joint Policies & Measures database and REN21 reports.

Control Variables

- The effectiveness index of African governments **(GovEfftiV)**, which reflects qualities of civil/public services, policies formulation soundness, and the role of those governments in commitment to such policies, is included. These conditions could be important to foreign investors. Therefore, it is believed that good GovEfftiV facilitates FDI in the CP industry in Africa. GovEfftiV index is pooled from the World Bank's World Governance Indicators (WGI).
- Political stability and the absence of violence **(PoS)** are widely, and intuitively, accepted as FDI influential factors in the literature. A growing inbound FDI into any African country that witnesses PoS is hypothesized. The PoS index is derived from WGI.
- Gross fixed capital formation **(Infrastructure)** refers to infrastructure. Infrastructure could matter to investors. As such, a positive and statistically significant coefficient is expected. This study treats the limited missing data by the mean imputation method. Data is in current $U.S. collected from WDI.

The Gravity Model

A micro-balanced annual panel data for 33 African countries over 2003-2019 is employed. The merits of panel data analysis are confirmed in the literature. These advantages include containing a large number of observations of different units over years, the ability to explicitly control the heterogeneity aspect which naturally resulted from panel data mechanism, etc. Using the GM is justified that it is deemed a workhorse framework in international economics analyses and commonly employed in the literature for its reliable and powerful notion (Yotov *et al*., 2016). Further, it should be noted that the idea behind the GM was cited from Newton's law of universal gravitation (1687) and was applied for the first time on social science in 1858 and on international economics in the 1960s by studies of Tinbergen (1962), Linemann (1963), Poyhonen (1963), and Pullainen (1963). Tinbergen thus is known as the discoverer of the GM in the literature. This idea of the GM is based on the prediction that global flows of trade, FDI, tourism, immigration, or remittance are positively associated with countries' economic scale (GDP/GDP per capita/population/national income) and inversely linked with the distance between them (World Trade Organization, 2012). As such, the basic presentation of the trade GM can be shown as follows;

$$X_{ijt} = c\left(Y_{it}^{\alpha} Y_{jt}^{\beta}\right) / \left(D_{ij}^{\lambda}\right) \tag{1}$$

For econometrics analysis purposes, the natural logarithm is used to transform the model [1] to a log-linear regression in the model [2]. The log is taken only for the regressors without the regressed as explained in the next subsection.

$$FDI_{ijt} = \beta_0 + \beta_1 LGDP_{it} + \beta_2 LGDP_{jt} + \beta_3 LDistance_{ij} + \varepsilon_{ijt} \tag{2}$$

The Gravity Model Specification and the Estimation Method

The collected variables across 33 African nations over 2003-2019 could be modeled in the following GM specification:

$$\begin{aligned} FDI_{ijt} &= \beta_0 + \beta_1 LGDPsource_{it} + \beta_2 LGDPhome_{it} + \beta_3 LDistance_{ij} + \beta_4 RETs_{jt} \\ &+ \beta_5 REFs_{jt} + \beta_6 FinT_{jt} + \beta_7 ParisAgree_{jt} + \beta_8 REAware_{jt} + \beta_9 GovEfftiV_{jt} \\ &+ \beta_{10} PoS_{jt} + \beta_{11} Infrastructure_{jt} + \gamma_t + \alpha_{ij} + \varepsilon_{ijt} \end{aligned} \tag{3}$$

Where β represents parameters to be estimated, *i* indicates source countries, *j* means host countries, *t* represents years, *α* shows country-pair fixed effects and *Υ* depicts time dummy variable [including *α* and *Υ* to control heterogeneity], *ε* is the remainder error term, and *L* refers to the natural logarithm.

For the estimation approach, many FDI zero observations are explored. This challenge is common when considering FDI at industrial/sectorial levels comparing with aggregate/ macroeconomic/countries levels. That issue may be attributed to incorrectly recorded zeros, rounding errors, or foreign investors' inability or unwillingness to invest in a given country at a specific time. This study is facing the latter case.

This case is called true zeros, real zeros, and actual zeros. Real FDI zero observations are informative; needed to be analyzed, estimated, and discussed (WTO, 2012). Herein, taking the natural logarithm for FDI is not defined and not feasible in the presence of zero observations. Zeros FDI thus is a challenge that necessitates a robust estimator.

Zeros FDI is a controversial estimation issue. This study reviews the literature and finds several employed estimation methods. Notwithstanding, the consensus is absent. For example, for handling zeros FDI; the Truncating method is proposed. This method depends on dropping zeros observations. However, those observations are informative; needed to be explained. Another technique is constructed on adding a small value/constant, say $1, to the zero observations. This way is known as the Censoring method and Tobit estimator. Nonetheless, these above-mentioned estimation techniques could produce unreliable results and inconsistent estimates; as they depend on whether dropping observations or distorting them, which leads to sampling selection bias. Furthermore, there are no strong theoretical and empirical foundations and justifications for adopting these methods (WTO, 2012; IMF, 2010).

Poisson pseudo-maximum likelihood (PPML) estimator is the most commonly employed in the literature instead of the above-mentioned methods. PPML estimator is robust in controlling heteroskedasticity and handling zeros observations. Also, this estimator is reliable and straightforward in use. PPML estimator was introduced by a pioneer study of Silva and Tenreyro in 2006 (Silva & Tenreyro, 2006; WTO, 2012). As such, FDI zeros are kept in the presence of ppml employing. Thus, there is no need to take the natural log of FDI. Further, unlike the Tobit estimator, ppml allows including fixed effects (Chaisse & Gugler, 2009; Welfens & Baier, 2018; Motta, 2019).

This study uses the robust ppml estimator as proposed by Chaisse and Gugler (2009), Welfens and Baier (2018), Motta (2019), and IMF (2010) [the last study by the IMF (2010) proposed a semi-log functional form to manage zero observations]. Put differently, the FDI panel gravity fixed effects PPML model is employed. However, in the literature, all gravity estimators have their advantages and disadvantages, as a perfect estimator is absent.

Table 1. Descriptive statistics

Variable	Obs[3]	Mean	Std.Dev.	Min	Max
FDI	647	96.129	329.179	0	5000
LGDPhome	647	23.895	1.646	20.004	27.066
LGDPsource	646	8.856	12.987	0	30.56
LDistance	647	7.435	119.204	0	3033.126
RETs	647	.748	.434	0	1
REFs	647	.563	.496	0	1
FinT	647	.402	.491	0	1
ParisAgree	647	.21	.408	0	1
REAware	647	1.845	2.737	.021	9.998
GovEfftiV	647	-.567	.566	-1.892	1.057
PoS	647	-.564	.717	-2.524	1.2
Infrastructure	647	1.61e+10	2.24e+10	4.89e+07	8.57e+10

RESULTS AND DISCUSSION

Initially, descriptive statistics for the employed variables are introduced. **Table 1** shows the number of observations, variables' mean, standard deviations, minimum and maximum values of regressed and regressors. Next, the collinearity issue is detected. **Table 2** presents the matrix of correlations in which it appears that the values of correlations among the independent variables are not high. As a result, it is suggested that collinearity is absent between the variables. Then, the FDI panel gravity fixed effects PPML regression is run. **Table 3** reports the results by using Stata 14.0 statistical software package.

Table 2. Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) FDI	1.000											
(2) LGDPhome	0.300	1.000										
(3) LGDPsource	0.414	0.510	1.000									
(4) LDistance	0.092	0.025	0.083	1.000								
(5) RETs	0.127	0.316	0.225	0.031	1.000							
(6) REFs	0.188	0.454	0.338	0.046	0.486	1.000						
(7) FinT	0.209	0.486	0.411	-0.018	0.410	0.570	1.000					
(8) ParisAgree	-0.007	0.068	0.163	-0.015	0.299	0.285	0.217	1.000				
(9) REAware	0.171	0.604	0.351	-0.008	0.080	0.193	0.300	0.057	1.000			
(10) GovEfftiV	0.112	0.360	0.316	0.003	0.080	0.253	0.361	0.065	0.445	1.000		
(11) PoS	-0.073	-0.181	-0.015	-0.015	-0.024	-0.160	-0.148	-0.034	0.128	0.390	1.000	
(12) Infrastructure	0.354	0.832	0.496	-0.000	0.198	0.351	0.437	-0.008	0.686	0.345	-0.152	1.000

Table 3. Conditional fixed-effects poisson regression results

FDI	Coef.	Robust St. Err.	t- Value	p-Value	[95% Conf	Interval]	Sig
LGDPhome	1.556	0.689	2.26	0.024	0.206	2.907	**
LGDPsource	0.149	0.026	5.72	0.000	0.098	0.200	***
LDistance	0.001	0.000	9.26	0.000	0.001	0.001	***
RETs	0.642	0.355	1.81	0.071	-0.054	1.338	*
REFs	0.811	0.435	1.87	0.062	-0.041	1.664	*
FinT	1.103	0.330	3.34	0.001	0.456	1.750	***
ParisAgree	0.447	0.235	1.90	0.058	-0.015	0.908	*
REAware	-0.158	0.054	-2.92	0.003	-0.264	-0.052	***
GovEfftiV	-4.164	1.130	-3.68	0.000	-6.379	-1.949	***
PoS	1.848	0.440	4.20	0.000	0.984	2.711	***
Infrastructure	-1.381	0.000	-0.67	0.500	0.000	0.000	
Mean dependent var			95.989	SD dependent var			329.415
Number of obs			646.000	Chi-square			390658.793
Prob > chi2			0.000	Akaike crit. (AIC)			47309.695

*** p<0.01, ** p<0.05, * p<0.1

The Results of the Gravity Variables

Over 2003-2019, LGDPhome has attracted FDI in the African CP industry. A 1% expansion in African markets size encourages FDI into the industry by 1.5%, holding all other variables constant. It seems that the RE development remarkably depends on the power of African markets. The hypothesis, as such, is true, confirms that a growing/sizable GDP revitalizes the CP market through, for example, African effective demand and RE fiscal/financial policies development; a situation that could pull FDI. Consequently, it could be inferred that the RE FDI inflows have been market-seeking in nature during the period 2003-2019. This result is corroborated by Eyraud *et al*. (2013) and Lv and Spigarelli (2016) who reported that the European GDP was a catalytic factor for the Chinese FDI in the RE sector in Europe from 2004 to 2013. However, the result is inconsistent with Keeley and Ikeda (2017) who found that GDP played nothing in attracting FDI in the wind energy industry in developing countries.

Similarly, the reported results provide undeniable evidence that a powerful GDP in the source countries positively pushes their companies [outward FDI] to pour green investment overseas, especially in the African CP industry. Thus, the proposed hypothesis is approved. Here, it is supposed that in the presence of African attractive location advantages and RE merits; wealthier countries promote their green outflow FDI into the RE sector in Africa. The notion and result are supported by Falk (2016) and Lv and Spigarelli (2016).

Contradictorily to the suggested hypothesis, geographical distance positively, but limitedly, associated with clean FDI in Africa. That is, the distance coefficient's magnitude is weak [=0.001] with a positive and significant sign. Thus, the strength of this relationship is powerless. These statistics suggest that, in real life, there is no nexus between FDI and distance as long as there are a foreign investor-friendly environment and satisfactory future profits. Again, everything is easy with globalization and suitable returns which both could make the distance among countries unimportant. Further, inbound FDI in African CP markets is categorized as a horizontal investment in nature, so foreign companies serve African domestic markets and households with CP. As such, foreign investors could be indifferent to the distance between countries. The literature also substantiates the result where Falk (2016) and Keeley and Matsumoto (2018) found the distance did not affect FDI in the hospitality, solar, and wind energy industries, respectively.

The Results of the Variables of Interest

Based on the findings, and as hypothesized by the authors, African countries that ratified the Paris agreement conveyed a serious message to green investors that those countries are keen to develop their RE industries, which highly reflected in enhancing FDI inflows toward those countries. Also, it appears that the Paris agreement ratification in Africa stimulates existent and new RE foreign investors to expand and pour their investment into the CP industry. Therefore, it is not surprising to find that the Paris agreement's coefficient is positive and statistically significant. Further justification is built on that the ratified African countries' adherence to the Paris treaty's articles, targets, requirements, and duties [which are known as the Intended Nationally Determined Contributions (INDCs)], entails them to cut their GHG, adopt RE technologies, receive green financing, and report their progress report every five years. As such, African political will on RE development could be enhanced, and by extension, more RE FDI inflows could be increased. The result is consistent with Aguirre and Ibikunle (2014) who cited that the Kyoto Protocol is an important RE growth determinant globally. Similarly, a recent paper by Pillot *et al*. (2019) concluded that the ratification Kyoto Protocol is shaping the global sustainable development framework and supporting the CP industry (Rafay, 2022).

Interestingly, the results provide compelling evidence that a growing RE awareness in Africa is influential behavior in attracting RE investment. As expected, the amount of CO_2 emissions, which highly reflect the public awareness levels of RE in population, impact clean FDI in Africa. CO_2 has a negative and statistically significant effect on FDI at a 1% significance level. Here, the escalation in CO_2 figures in a country could indicate a lower public's perception of importance, benefits, and usage of the RE applications; a situation that could mean powerless RE demand and development in the country which in turn could limit green FDI inflows, and vice versa. The bottom line is that green FDI is highly a function of people's awareness of RE, and the latter is a powerful determinant of CO_2 emissions. This result agrees with Aliyu *et al*. (2018); Caruso *et al*. (2020); and Kuamoah (2020) who confirmed that a lack of RE public awareness impedes RE progression.

The Results of Renewable Energy Variables

All employed RE policies in the analysis facilitated FDI in the CP industry during 2003-2019, as their coefficients are positive and statistically significant. Thus, the proposed hypotheses are verified. This could imply that well-prepared RE targets, FinT, and RE financial/fiscal policies develop the CP markets, resulting in the acceleration of green FDI. Another explanation refers to that the implementation of these green policies could assure investors that some RE rules will be fixed and steady over the years; causing an increase in their investment in the CP industry. These results are in line with evidence provided by Eyraud *et al*. (2013), Kathuria *et al*. (2015), Keeley and Ikeda (2017), Polzin *et al*. (2019), and Ragosa and Warren (2019) who found that FinT played an effective role in attracting FDI in RE markets. On the contrary, Romano *et al*. (2017) showed that FinT and RE fiscal/financial incentives were unimportant in pulling green investment into developing countries over 2004-2011. Conversely, RE fiscal/financial policies stimulated FDI in the Turkish and Bangladeshi power sectors according to Sirin (2017) and Mahbub and Jongwanich (2019), in respective order.

The Results of Control Variables

As hypothesized, and intuitively to a great extent, most politically stable African countries robustly attract FDI in the CP industry. The political stability variable has a positive and statistically significant impact on FDI with a strong coefficient's magnitude [a powerful association]. The political instability & corruption, and violence indeed lead to an unfriendly and discouraging investment climate for both domestic and foreign investors; a situation that could highly cause disinvestment. Further, political stability is regarded as a precondition for investment, as it assures investors that the current rules, policies, and regulations could be actively continued, avoiding any changes or cancellations, and by extension, the expected future returns could be achieved. This result underpins the proposed hypothesis, the theory, and past studies' findings by Lv and Spigarelli (2016), Mahbub and Jongwanich (2019), and Ragosa and Warren (2019). Another supportive evidence provided by Komendantova *et al*. (2014) where stakeholders of solar energy in North Africa decided not to increase their investment due to political instability and governance impediments issues (Rafay, 2021).

Surprisingly, the results show that the coefficients of government effectiveness index and infrastructure are negative and statistically significant for the former and insignificant for the latter. The probable explanation is that, to a great extent, the RE policies framework is lagging and underdeveloped in Africa (Hafner *et al*., 2019). Also, infrastructure is aging, and the unfriendly bureaucracy issue is pervasive in Africa. Moreover, improving the RE industry has not been taken as a priority on policymakers' agenda in many African countries (Ankrah & Lin, 2020; Opoku & Boachie, 2020). Further, the largest financing is provided to fossil fuel projects rather than RE investment in Africa (Baldwin *et al*., 2017). Here, if the readers combine and consider all these challenges together, they can infer that the governmental practices and aging infrastructure in Africa can limit FDI in the CP industry. This result is further substantiated by recent evidence by Zheng *et al*. (2019) who found that the relationship between the ASEAN governments' effectiveness and the Chinese FDI is negative and statistically significant.

Robustness Tests

Attaining regression assumptions is essential for robust estimation and inference. For the homoskedasticity issue, the baseline panel regression is run with the inclusion of the "vce (robust)" option for controlling heteroskedasticity. As a result, this study employs robust standard errors to report heteroskedasticity-robust estimates. Regarding autocorrelation issue [serial correlation] detection; the Wooldridge test for serial correlation in panel data is used. **Table 4** reports the result that implies the residuals are independent, i.e., this study failed to reject the null hypothesis of no first-order autocorrelation. Concerning check collinearity, further robustness assessment [addition to Matrix of correlations] is introduced. Thus, the variance inflation factor (VIF) method is employed. **Table 5** reaffirms the absence of collinearity issue among used variables; as the VIF (β_i) < 5 (Studenmund, 2017). As such, it can be concluded that the reported estimation is robust to heteroskedasticity, autocorrelation, and collinearity.

Sensitivity analysis is further conducted to reinforce the robustness of the results. The sensitivity analysis aims to explore the sensitivity of reported results to replacing, dropping, or adding some regressors to the analysis. Here, the sensitivity analysis is presented by comparing results of seven models. Model 1 is the baseline regression. In model 2, only the variables of interest are included. In model 3, the variables that are found with results that contradict the theory [based on model 1 results] are dropped [GovEfftiV and Infrastructure]. Similarly, all RE and gravity variables are declined in models 4 and 5, respectively. Model 6 includes new regressors: inflation and corruption. Lastly, in model 7, variables of interest are excluded. The results of the sensitivity analysis are reported in **Table 6**. Based on these results, it can be concluded that REAware, LGDPhome, LGDPsource, LDistance, FinT, and Pos robustly attracted FDI in the CP industry in Africa over 2003-2019; as these variables coefficients' magnitude, signs, and significance do not change through the sensitivity analysis.

Table 4. Wooldridge test for autocorrelation in panel data

H0: no first-order autocorrelation
F(1, 32) = 2.720
Prob > F = 0.1089

Table 5. Variance inflation factor

	VIF	1/VIF
Infrastructure	4.266	.234
LGDPhome	3.981	.251
REAware	2.281	.438
FinT	1.902	.526
REFs	1.847	.541
GovEfftiV	1.813	.552
PoS	1.584	.632
LGDPsource	1.519	.658
RETs	1.515	.66
ParisAgree	1.199	.834
LDistance	1.018	.982
Mean VIF	**2.084**	.

FUTURE RESEARCH DIRECTIONS

The ongoing energy insecurity issue, particularly in SSA, entails more rigorous and deliberate research. The deepest analyses of the most effective RE policies and enhancing RE financing can be focused on as the future RE research. Further, concentrated studies on raising African awareness of the environment and RE are necessarily needed. In addition, semi-structured interviews with RE investors are an important method for RE development. Besides, conducting this chapter's research issue on the Arab economies is suggested future RE research.

CONCLUSION AND POLICY IMPLICATION

Clean power [CP] insecurity and financing gap are two faces for the same coin in Africa; the issue that entails enhancing foreign direct investment [FDI]. This study thus has examined determinants of FDI in the CP industry over 2003-2019 in Africa. The FDI panel gravity fixed effects PPML model is employed, followed by diagnostic and robustness tests.

The results are a range of supportive findings for African CP industry development. The most encouraging results indicate that raising African clean energy awareness and developing renewable energy policies have a positive and considerable influence on FDI in the CP industry. Another reassuring result is that the geographical distance could be unimportant in FDI making decisions. Despite these interesting results, the incompleteness of data of some variables constitutes the limitation of this chapter, which is highly resulted from the little attention given to African renewable energy. However, the good news is that several proxies can be used and reliable methods can treat the issue as widely employed in the literature.

Future work will entail conducting this chapter's research issue exclusively on some of Arab countries. Besides, based on the findings, African policymakers should effectively collect, or even prepare, accurate renewable energy data and studies for investors. Clean energy education and awareness in Africans should be developed through, for instance, establishing specific renewable energy campaigns and school and university courses. Also, CP regulatory and financial measures should not be neglected. It is believed that effectively implementing these recommendations could help in CP development in Africa.

Table 6. Sensitivity analysis results

	Model						
	1	**2**	**3**	**4**	**5**	**6**	**7**
LGDPhome	1.556*		1.025**	1.608*		1.991**	1.452*
	(2.26)		(2.70)	(2.20)		(2.70)	(2.13)
LGDPsource	0.149***		0.151***	0.147***		0.149***	0.151***
	(5.72)		(5.41)	(6.19)		(5.70)	(5.77)
LDistance	0.00105***		0.00109***	0.00108***		0.000979***	0.00101***
	(9.26)		(8.82)	(9.66)		(9.88)	(9.21)
RETs	0.642*		0.587		0.633	0.752*	0.622*
	(1.81)		(1.49)		(1.19)	(2.21)	(1.66)
REFs	0.811*		0.559		0.916*	0.776*	0.831*
	(1.87)		(1.20)		(1.69)	(2.13)	(1.79)
FinT	1.103***		1.393**		1.389**	1.149**	0.949**
	(3.34)		(3.15)		(3.07)	(3.24)	(3.01)
ParisAgree	0.447*	0.104	0.433*	0.112	0.0289	0.432*	
	(1.90)	(0.49)	(1.82)	(0.46)	(0.07)	(2.14)	
REAware	-0.158**	-0.222**	-0.256***	-0.113*	-0.301**	-0.152**	
	(-2.92)	(-3.04)	(-4.27)	(-1.72)	(-3.23)	(-3.03)	
GovEfftiV	-4.164***		-4.335**	-2.897	-4.195***	-4.593***	
	(-3.68)		(-3.20)	(-1.63)	(-3.71)	(-4.19)	
PoS	1.848***		1.008*	1.861**	1.669*	1.949***	1.851***
	(4.20)		(2.17)	(3.28)	(2.47)	(4.03)	(3.79)
Infrastructure	-1.38e-11		-3.20e-12	1.00e-11	-1.54e-11	-1.03e-11	
	(-0.67)		(-0.14)	(0.39)	(-0.70)	(-0.54)	
Inflation				0.00918			
				(0.57)			
Corruption				-0.0382*			
				(-1.79)			
N	646	647	646	646	647	646	646

t statistics in parentheses. All models are estimated with the "vce(robust)" option for controlling heteroskedasticity to obtain robust Standard errors [heteroskedasticity-robust estimates], * p<0.05, ** p<0.01, *** p<0.00

DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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KEY TERMS AND DEFINITIONS

Clean Power: Produced electricity from renewable energy resources.

Clean Power Financing Gap: Supply of renewable energy financial resources – demand for renewable energy financial resources = ± financing gap.

Financial Deficit: A negative gap between supply and demand for financial resources.

Green Investment: Investment poured in renewable energy industry.

Renewable Energy Measures: Policies to organize and govern the renewable energy industry regulatorily and financially.

Renewable Energy Public Awareness: General awareness of all aspects of renewable energy resources.

Renewable Energy Resources: Sustainable and limitless resources to yield clean energy.

ENDNOTES

1 Clean power and renewable electricity are used interchangeably.

2 Source: https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter =27&clang =_en [accessed on 1 April 2021].

3 This chapter's empirical analysis includes 33 African economies over 17 years, and 86 observations in which some of those African countries received FDI from different source countries in the same year. Therefore, n=33*17+86=647 Obs.

APPENDIX

Country List

Those countries included in the analysis as a result of data availability: Algeria- Angola- Benin- Burkina Faso- Burundi- Cameroon- Cote d' Ivoire- Democratic Republic of Congo- Djibouti- Egypt- Ethiopia- Gabon- Ghana- The Gambia- Kenya- Liberia- Libya- Mali- Mauritius- Morocco- Mozambique-Namibia- Nigeria- Rwanda- Senegal- Sierra Leone- South Africa- Tanzania- Togo- Tunisia- Uganda-Zambia- Zimbabwe.

Chapter 10
Economic Growth, Energy Consumption, and Carbon Emissions:
The Case of Nigeria

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ABSTRACT

This chapter examines the interactions among energy consumption, economic growth, and carbon emissions in Nigeria for the period 1971-2018. The study adopts time-varying parameter vector auto regression (TVP-VAR) to explore the dynamic effects among the variables of interest. After analyzing the statistical properties of the data with Markov chain Monte Carlo (MCMC), a causal relationship between energy consumption and economic growth was found. It is also found that the environmental Kuznets curve (EKC) hypothesis is valid for Nigeria. It implies that as the economy of Nigeria grew, emissions were reduced. It is recommended that the Nigerian government should continue pursuing emissions reduction policies, such as the nationally determined contributions (NDCs), and should also ensure the appropriate energy mix to enhance industrialization drive and improve environmental quality.

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INTRODUCTION

Environmental and energy economics have gained a lot of attention due to climate change from equivalent carbon emissions. Energy use is essential for growth; however, there is a dire consequence of the resultant emissions of greenhouse gases (GHGs), which are detrimental to the environment and human health (Appiah, 2018). Nigeria is the largest producer of crude oil in Africa (ECP, 2021). The country consumes 428,000 barrels of oil daily with a teeming population of over 200 million people. Nigeria is the world's 17th highest emitter of greenhouse gases and second to South Africa in the African continent (EIA, 2019). The critical issue is that Nigeria, with the largest population in Africa, is an emerging economy that needs more energy consumption for its industrialization drive. Thus, expectedly, there could be emissions in an energy-driven economy, implying either a cost or benefit. When emissions impose costs on the environment and the society, it connotes a negative environmental externality (Faiyetole, 2015). Emissions stem heavily from energy use and could impose unintended economic costs in pollution and consequential environmental hazards.

Most studies on CO_2 emissions and economic growth relationships aim to verify and estimate the existence or not of the environmental Kuznets curve hypothesis or describe the short-run and long-run equilibrium relationships among emissions, economic growth, energy consumption, population growth, and others (Kaika & Zervas, 2013; Dinda, 2004; Dritsaki, & Dritsaki, 2014; Grossman & Kruger, 1995).

Based on those as mentioned earlier, the purpose of this study is to evaluate for the validity or otherwise of the EKC hypothesis in Nigeria, being an emerging economy, producer and consumers of fossil fuels, such as oil, coal, and gas, which have a very high propensity for carbon emission. Thus, this study is relevant at this present time because of the global shift from fossil fuel to renewable energy use. Secondly, the Paris Agreement (2015) of the United Nations framework convention on climate change (UNFCCC) has committed the industrialized countries and oil-producing countries and, in fact, nations worldwide through the NDCs, to limit the emissions target from 2°C to 1.5°C warming above the pre-industrial level. The study adopts the Bayesian time-varying VAR method developed by Kim & Nelson (1999), Primiceri (2005), and Nakajima (2011) as opposed to previous studies, such as Alkhathlan *et al.* (2012), Aiyetan & Olomola (2017), Işık *et al.* (2019) and Khan *et al.* (2020) that have used the traditional VAR.

LITERATURE REVIEW

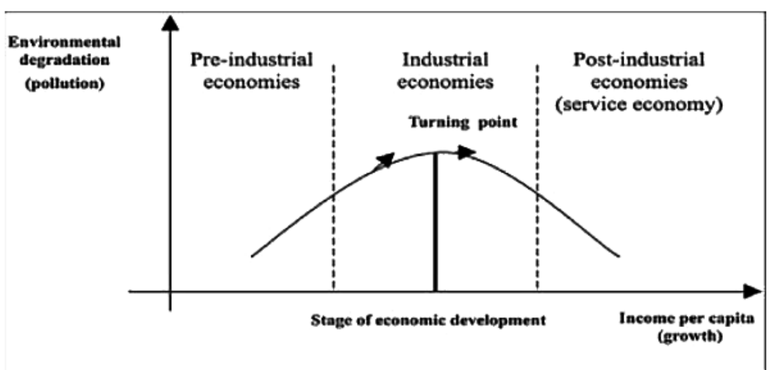
The controversial EKC is a hypothesized relationship between various indicators of environmental degradation and income per capita. Typical EKC shows that environmental degradation increases in the early stages of economic growth, but beyond some levels of income per capita of economic growth, the trend reverses, leading to an environmental improvement (Stern, 2004; Cole *et al*., 1997; Grossman & Kruger, 1995). At these points, societies are environmentally aware, and countries can implement costly mitigative strategies, such as acquiring expensive technology for emission mitigation (Faiyetole, 2018; Faiyetole & Adesina, 2017; Kaika & Zervas, 2013; Dinda, 2004; Dritsaki & Dritsaki, 2014; Grossman & Kruger, 1995). The EKC is based on the hypothesis of a U-inverted relationship between emissions and income levels (Kuznets, 1955). It implies that plotting an environmental impact indicator (CO_2 per capita) against a function of income (GDP per capita) should follow an inverted-U or N-shaped curve (Panayotou, 2003, 1997; Moomaw & Unruh, 1997).

However, there have been arguments and counter-arguments on the existence of EKC. For instance, from an econometric and diagnostic statistic point of view, Perman & Stern (2003) have shown that EKC is non-existent. Other studies that found an absence of EKC hypothesis include Perman & Stern (2004), Xue *et al.* (2012), Gorus & Aydin (2018), and Khan *et al.* (2019), among others. However, the strong proponents of EKC have continued to argue that various other underlying variables or policy considerations buttress the existence and viability of EKC (Panayotou, 1997, 2003). Amongst such variables or policies could include – scale, changes in economic structure or product mix, changes in technology, and changes in input mix, as well as others, such as environmental regulation, education, and awareness – these variables, are what Stern (2004), refers to as proximate variables. Panayotou (1997) had identified three distinct structural forces that affect the environment, namely: i) the scale of economic activity, ii) the composition or structure of economic activity, and iii) the effect of income on the demand and supply of emission mitigative efforts. Thus, according to Panayotou (2003),

[APL] = [GPA] x [SCG] x [PME] (A)

Where, APL = ambient pollution level; GPA = GDP per unit area; SCG = structural composition of GDP; and PME = pollution abatement efforts.

Figure 1. The environmental Kuznets curve: a development-environment relationship
Sources: Panayotou (2003) and Zoundi (2017).



Source: Panayotou [46]

Environmental Kuznets Curve

Panayotou (2003) and Sachs *et al.* (1999) opined that theories and experience have shown that economic growth involves systemic structural change. Depending on the stage of economic growth, the environment is markedly impacted. "As the output continues to rise in the course of the industrialization process, the share of employment and output in industry reaches a peak and begin to decline, as the economy shifts to services." As such, the carbon emissions intensity of agricultural-led economies, industry, and service-dominant economies differ distinctively. For instance, emissions from industry (Raheem & Ogebe, 2017; Attari *et al.*, 2016) are higher than agriculture, and agriculture is higher than for services. Hence, the inverted-U in *Figure 1*. Thus, as GDP increases, irrespective of the sector of the economy leading the increase, the rise in carbon emissions doesn't vary directly in the same proportion with the GDP, even if the relative price of energy is constant (Panayotou, 2003; Zoundi, 2017).

In their investigation for Turkey, Yavuz (2013) used the Johansen cointegration test to determine a long-run relationship among CO_2 emissions per capita, income per capita, and energy consumption per capita and found the validation of the environmental Kuznets curve. While Esso & Keho (2016), considering selected African countries, reported that in the long-run, energy consumption and economic growth are associated with an increase in atmospheric pollution in most African countries. Their results from the Granger causality test further show evidence of economic growth causing CO_2 emissions in the short-run in a few African countries, including Nigeria, which implies that economic expansion cannot be achieved without affecting the environment. Expectedly, Esso & Keho (2016) also found that energy use and economic growth cause emissions in Nigeria and South Africa and more African countries in the long-run. There is evidence of reverse causality from CO_2 emissions to economic growth in Nigeria, indicating emissions mitigated policies may adversely affect economic growth.

In another study, Alkhathlan *et al.* (2012) examined the dynamic relationship among economic growth, CO_2 emissions, energy consumption, and employment in Saudi Arabia from 1980 to 2008. The study found a long-run relationship among economic growth, energy consumption, and employment ratio with the autoregressive distributed lag (ARDL) model and error correction model (ECM) analysis techniques. Mohiuddin, Sarkodie & Obaidullah (2016) investigated the relationship between carbon emissions, electricity consumption, electricity production, oil production, and GDP for Pakistan from 1971 to 2013. The study shows long-run cointegration among the variables. The causal relationship revealed causality from electricity consumption to carbon emissions while weak uni-directional ran from emissions to electricity production.

For Nigeria, Aiyetan & Olomola (2017) explored the relationship among CO_2 emissions, energy consumption, population growth, and the environment in Nigeria from 1980 to 2012. The study found the inverted U-shaped in Nigeria using ARDL bound testing, structural breaks, and the Toda Yomamoto non-Granger causality test. It suggested an increase in environmental tax to reduce CO_2 emissions in the country. Gorus & Aydin (2018) investigated the causal relationship between energy consumption, economic growth, and CO_2 emissions using panel frequency and time domain Granger causality tests for the Middle East and North Africa (MENA) countries from 1975 to 2014. The result found no panel causality between energy use, economic growth, and CO_2 emissions. Isik *et al.* (2019) determined the effects of GDP, population, renewable energy, and fossil fuel energy use on CO_2 emissions for ten states in the United States between 1980 and 2015. The study found fossil fuel energy use impacts CO_2 emissions negatively in Texas and positively in Florida. The EKC hypothesis was valid only in Florida, Illinois, Michigan, and New York. In recent studies, Shaari *et al.* (2020) investigated the effects of oil and gas consumption on CO_2 emissions in 20 organizations of Islamic cooperation (OIC) countries from 1990 to 2017 with panel ARDL analysis. The panel result showed that national output significantly increased CO_2 emissions in the short-run for Algeria, Tajikistan, and Malaysia while reducing emissions in the short-run for Nigeria and Turkey. Khan *et al.* (2019) investigated energy consumption and economic growth on Pakistan's carbon emissions using ARDL from 1965 to 2015. The result showed that energy consumption and economic growth positively impacted the environment in the short- and long-run. The EKC hypothesis did not hold, just as we had in another study on Pakistan by Khan *et al.* (2020), which examined the nexus between energy, economic growth, and CO_2 emissions using ARDL. The result showed energy consumption and economic growth increase CO_2 emissions in both the short- and long-run.

DATA SOURCES AND METHODOLOGY

The study spans from 1971 to 2018, and the data were sourced from World Development Indicator, 2020. The energy consumption is measured in kilogram (Kg) of oil equivalent consumed in Nigeria. It is the consumption of fuel, firewood, gas, diesel, and energy-related commodities. The emission used is CO_2 measured in metric tons and expressed as greenhouse gas emitted from the burning of fossil fuels, automobile and natural gases during industrial and consumption activities of solid, liquid gas fuel, gas flaring, and those generated during cement production. At the same time, economic growth is defined as the growth rate of the output of goods and services produced in the country's currency and per capita terms. This study uses Bayesian time-varying VAR to capture the dynamic effects of energy consumption mediating through economic growth on emission in Nigeria for the period of study. The methodology helps to elicit information on the viability of the EKC hypothesis in Nigeria.

The choice of the TVP-VAR is informed by the different international climate change-related negotiations by the United Nations over time, from the Montreal Protocol (Fahey, 2013; Velders *et al*., 2007) to the Kyoto Protocol (UNFCCC, 1997), the Marrakesh Accords in 2001, the Copenhagen Accord in 2009, the Cancun Agreement in 2010, the 21st Conference of the Parties (COP21), the so-called Paris Agreement in 2015, and up to Katowice Decision (COP24) in 2018. These negotiations have influenced the different regimes of implemented climate change policies. For example, in Nigeria, the Department of Climate Change (DCC) in the Federal Ministry of Environment was created to implement the Kyoto Protocol activities by formulating and implementing climate change policies (NPCC, 2013). The Bayesian TVP-VAR model starts from the structural vector autoregression (SVAR) to the TVP-VAR model and finally to the Bayesian method of estimation using MCMC to generate posterior distribution and the impulse responses.

The SVAR Model

The SVAR model, according to Sims (1981,1986), Bernanke (1986), and Shapiro & Watson (1988), was proposed to account for structural identification of economic models which the normal VAR is incapable of. The SVAR model can be represented in general form as:

$$Ay_t = A_1^* y_{t-1} + \ldots\ldots + A_\rho^* y_{t-\rho} + B\epsilon_t \tag{1}$$

Where A_i^*'s (i=1,…,ρ) are (k×k) structural matrices, matrix A specifies the instantaneous relations between the variables of interest and ϵ_t is a vector of length k. The reduced form of the SVAR can be obtained by pre-multiplying with A^{-1} as:

$$y_t = \pi_1 y_{t-1} + \ldots\ldots \pi_\rho y_{t-\rho} + u_t \tag{2}$$

Where $\pi_1 = A_1 A^{-1}$, $\pi_\rho = A_\rho A^{-1}$ and $u_t = A^{-1} B\epsilon_t$, an unobserved structural innovation.

The TVP-VAR Model

The SVAR model is also extended to the TVP-VAR to account for the structural changes in an economic model. The basic structural TVP-VAR can be written as:

$$Ay_t = F_O + F_{1,t}y_{t-1} + F_{2,t}y_{t-2} + \ldots + F_{\rho,t}y_{t-\rho} + u_t \text{ Where t=1,2,…,T} \quad (3)$$

The disturbance u_t is a k×1 structural shock, equals to $A_t^{-1}\Sigma\epsilon_t$, assumed to be u_t~(0,ΣΣ) and time-varying where A is a lower triangular matrix with ones on the main diagonal and with Σ a diagonal matrix, where:

$$\Sigma = \begin{pmatrix} \sigma_{1,t} & 0 & \ldots & 0 \\ 0 & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \ldots & 0 & \sigma_{1,t} \end{pmatrix} \text{ and } A = \begin{pmatrix} 1 & 0 & \ldots & 0 \\ a_{21,t} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ a_{k1,t} & \ldots & a_{k,k-1,t} & 1 \end{pmatrix}$$

Equation (10) can further be expressed as:

$$y_t = B_O + B_{1,t}y_{t-1} + B_{2,t}y_{t-2} + \ldots + B_{\rho,t}y_{t-\rho} + A_t^{-1}\Sigma\epsilon_t \text{ Where } B_{\rho,t}=A^{-1}F_{\rho,t} \quad (4)$$

In reduced forms, the equation. (4) can be written as equations (4) and (5):

$$y_t = B_O + (B_{1,t}, \ldots, B_{\rho,t})\begin{pmatrix} y_{t-1} \\ \vdots \\ y_{t-\rho} \end{pmatrix} + A_t^{-1}\Sigma\epsilon_t \quad (4)$$

$$y_t = \beta_t X_t + A_t^{-1}\Sigma\epsilon_t \quad (5)$$

The coefficient β_t, the parameter a_t and Σ_t are all time-varying with stochastic volatility, $h_{jt}=\log\sigma_{jt}^2$. Following Primiceri (2005) and Nakajima (2011), the coefficients and the parameters follow a random walk process as:

$$\beta_t = \beta_{t-1} + u_{\beta t} \quad t=0,\ldots,T-1 \quad (6)$$

$$a_t = a_{t-1} + u_{at} \quad t=0,\ldots,T-1 \quad (7)$$

$$h_t = h_{t-1} + u_{ht} \quad t=0,\ldots,T-1 \tag{8}$$

Where $u_{\beta t}$, u_{at} and u_{ht} are i.i.d and jointly normally distributed with the variance and covariance matrix as:

$$\begin{pmatrix} \epsilon_t \\ u_{\beta t} \\ u_{at} \\ u_{ht} \end{pmatrix} \sim N \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_a & 0 \\ 0 & 0 & 0 & \Sigma_h \end{pmatrix} \tag{9}$$

From the model in eq. (5), all the three variables are treated as endogenous with the variable ordering as:

$$\ln y_t = (enc,\ gdp,\ ems) \tag{10}$$

Where *enc* implies energy consumption, *gdp* is the gross domestic product and *ems* is emission. The ordering of the variable conforms to economic reality. Theoretically, the expectation is that an increase in energy consumption leads to a rise in economic growth and emissions. It should be noted that Eq. (10) is a matrix of a 3×3 matrix expressed in a structural identification model as:

$$A_t = \begin{bmatrix} 1 & 0 & 0 \\ a_{21} & 1 & 0 \\ a_{31} & a_{32} & 1 \end{bmatrix} \begin{bmatrix} enc \\ gdp \\ ems \end{bmatrix} = \Sigma\varepsilon_t = \begin{bmatrix} \varepsilon_{1t}^{enc} \\ \varepsilon_{2t}^{gdp} \\ \varepsilon_{3t}^{ems} \end{bmatrix} \tag{11}$$

Where A_t is the identification matrix of lag variables and Cholesky decomposition? The first row denotes that past values of *gdp* and *ems* shocks have no effects on energy (*enc*), only the past values of enc. The second row means past values of *enc* and *gdp* shocks have effects on *gdp* while the past values of ems do not. Lastly, the third row implies that the past values of *enc*, *gdp*, and *ems* shock have effects on ems—the variable vector in Eq. (10) is used to estimate the Bayesian TVP-VAR model.

Bayesian Inference

The treatment of the hyper-parameters, i.e., the unobservable states, β_t, a_t and Σ_t, time-varying and random variables necessitate the Bayesian method of estimation (Koop, 2003; Geweke, 2005; Olayungbo & Akinlo, 2016). The need to account for the different climate change policies adopted by the sample country to mitigate emissions motivates a time-varying model. In Bayesian inference, the posterior distribution is proportional to the likelihood function multiplied by the prior distribution. The posterior distribution is computed by Baye's theorem in continuous form and stated as:

$$\pi(\theta \mid y) = \frac{f(y \mid \theta)\pi(\theta)}{\int f(y \mid \theta)\pi(\theta)d\theta} \tag{12}$$

The prior density $\pi(\theta)$, represents the beliefs about θ prior to having the data y. $f(y|\theta)$ denotes the likelihood function. The posterior distribution can further be stated in proportionality form as

$$\pi\left(\theta \mid y\right) \propto f\left(y \mid \theta\right)\pi\left(\theta\right) \tag{13}$$

Given the hyper-parameters to be estimated, the posterior distribution is:

$$\pi\left(\theta,\beta,a,h \mid y\right) \propto f\left(y \mid \theta,\beta,a,h\right)\pi\left(\theta\right) \tag{14}$$

Where $\theta=\Sigma_\beta,\Sigma_a,\Sigma_h$, and the likelihood is:

$$f\left(y \mid \theta,\beta,a,h\right) = \exp\left[-\frac{1}{2\sigma^2}\left(y-x\beta\right)'\left(\sigma^2 I_T\right)^{-1}\left(y-x\beta\right)\right] \tag{15}$$

$$\pi(\theta \mid \Sigma_\beta,\Sigma_a,\Sigma_h) = \exp[-\frac{k}{2\sigma^2}\left(\beta_{it}-\beta_{it-1}\right)'\Sigma_\beta^{-1}\left(\beta_{it}-\beta_{it-1}\right)] \tag{16}$$

$$\pi\left(\theta,\beta,a,h \mid y\right) \propto \exp\left[-\frac{1}{2\sigma^2}\left(y-x\beta\right)'\left(\sigma^2 I_T\right)^{-1}\left(y-x\beta\right)\right].\exp\left[-\frac{k}{2\sigma^2}(\beta_{it}-\beta_{it-1})'\Sigma_\beta^{-1}\left(\beta_{it}-\beta_{it-1}\right)\right] \tag{17}$$

The posterior distribution was estimated using the MCMC sampling methods given the likelihood function and the prior distributions. The MCMC allows the function of the parameters such as the impulse response function and posterior means to be estimated. Samples from the posterior distribution were drawn, $\pi(\theta,\beta,a,h,|y)$ given $f(y|\theta,\beta,a,h)$ and $\pi(\theta|\Sigma_\beta,\Sigma_a,\Sigma_h)$ by using the MCMC algorithm presented in Appendix 1.

Choice of Priors and Calibrations

Nakajima (2011) and Olayungbo & Akinlo (2016) procedures were followed in choosing the priors. Flat priors were set for the initial state because there was no information about the initial state a priori. The inverse gamma distributions, a family of two parameters, are used as priors alongside the normal distribution variance to ensure precision. In Bayesian statistics, the inverse gamma distribution serves as the conjugate prior to the variance of a normal distribution (Nakajima, 2011). The prior choices are summarised as follows: $(\Sigma_\beta)_i^{-2} \sim$ Gamma (40, 0.02), $(\Sigma_a)_i^{-2} \sim$ Gamma (4, 0.02) and $(\Sigma_h)_i^{-2} \sim$ Gamma (4, 0.02).

For the initial state of the time-varying parameters, flat priors are set; $\beta_0=a_0=h_0=0$ and $\Sigma_{\beta_0} = \Sigma_{a_0} = \Sigma_{h_0} = 10 \times I$, Nakajima (2011) and Olayungbo & Akinlo (2016).

EMPIRICAL ANALYSIS

This section contains the description of data, presentation, and discussion of results. Descriptive statistics is necessary to analyze the statistical distribution in terms of the average and extreme values of the data employed in the study.

Descriptive Statistics

The descriptive statistics of the variables of interest are presented in Table 1. It shows that the average value of energy consumption, GDP, and carbon emissions for the period of study is almost 83 billion kilograms, N23 trillion (equivalent to US$313billion with an exchange rate of N410 to US$1) and 68814 metric tonnes, respectively. The maximum and minimum values of the variable of interest suggest that GDP and carbon emission increase with energy consumption. The positive value of standard deviation and kurtosis implies that the data are not normally distributed. However, the closer the value of the skewness of energy consumption and emission to zero suggests normal distribution. Finally, the null hypothesis of the normal distribution is rejected with the Jarque Bera value of 4.05, 24.6, and 4.40 greater than 0,05%.

Table 1. Descriptive statistics

	Energy Consumption	GDP	Emission
Mean	82,698,502,771	22,129,785,031,252	68814
Median	73,606,284,000	2,434,515,000,000	68890
Maximum	166,708,000,000	129,113,000,000,000	106067
Minimum	33,179,448,000	10,375,400,000	32280.6
Std. Dev	37,183,696,108	35,684,427,225,374	23805
Skewness	0.66	1,62	0.06
Kurtosis	2.47	4.36	1.52
Jarque Bera	4.05	24.6	4.40
Observations	48	48	48

DISCUSSION OF RESULTS AND FINDINGS

After analyzing the statistical properties of the data, it proceeded to the presentation and implementation of the TVP-VAR model. In analyzing Bayesian TVP-VAR results, it generated M=10,000 draws from the posterior using the MCMC simulation with one optimal lag length selection (see Table 3 in Appendix). The initial 1,000 samples were discarded as burn-in. In addition, the Bayesian and the convergence diagnostics performed well with low autocorrelations of estimates and suggested independence of the parameter estimate with high efficiency. Table 2 shows the posterior mean, posterior standard deviation, 95 percent interval, and the Geweke (1992) convergence diagnostic of the diagonal elements such as $\Sigma\beta_1$, $\Sigma\beta_2$, Σa_1, Σa_2, Σh_1 and Σh_2. In the results, the Geweke convergence values of 0.03 percent, 0.05 percent, 0.06 percent, 0.37 percent, 0.40 percent, and 0.82 percent, respectively, meaning the acceptance of the null hypothesis of convergence to the posterior distribution for the first three parameters at 0.05% and 0.10%.

Similarly, the inefficient factors were reasonably low with 3.40 percent, 4.24 percent, 20.77 percent, 16.35 percent, 13.20 percent, and 11.61 percent, suggesting the number of efficient samples employed in the MCMC simulation was sufficient. The minimum sample number is M/10=1000 iteration. The evidence of convergence of all the parameters is further confirmed, as shown in Figure 2 with the convergence and stable movement of the sample autocorrelation, sample paths, and the sample parameters' posterior densities. The sample autocorrelation in the first row of Figure 2 (top) shows that the sample tends towards zero. It implies the absence of autocorrelation of the sample distribution. In addition, the consistent overlapping of the sample path in the second row of Figure 2 (middle) indicates the efficiency of the MCMC draws and proves that the model fits the observed data well. Finally, on the Bayesian diagnostics and visual inspection, there are relatively smooth changes of the histogram bars looking at the third row of Figure 2 (bottom), meaning that the posterior distribution is well represented.

The dynamic relationships among energy consumption, economic growth, and emission rate are explained using impulse response functions (IRFs) plotted for the 4, 8, and 12-period ahead in Figure 3. It comprises nine figures in all. The first impulse response shows a positive shock of energy consumption on itself ($\varepsilon_{enc} \rightarrow enc$). The second one to the right is a response of GDP to shocks from energy consumption ($\varepsilon_{enc} \rightarrow gdp$). The IRFs of GDP to energy consumption were positive and increased from 0.08 percent in 1981 to 0.10 percent in 2018 for the 4^{th}, 8^{th} and 12^{th} periods. This result indicates energy consumption promotes economic growth in Nigeria. The third impulse response also shows a positive response of CO_2 emission to energy consumption shock ($\varepsilon_{enc} \rightarrow ems$). The CO_2 impulse response initially increases to 0.005 percent and later tends towards zero by 2018. The second row of the impulse response shows that energy consumption responds positively to GDP shocks. However, we had a lower maximum value of 0.04 percent compared to the maximum value of 0.10 percent of GDP response to energy consumption shocks. These results imply a causal relationship and dependence between energy consumption and economic growth in Nigeria during the study period. This study contrasts Gorus & Aydin (2018), where no causal relationship was found for the MENA panel study. The GDP shock on itself is positive, as shown in the second row of the impulse response.

In addition, the responses of CO_2 emissions to GDP shocks ($\varepsilon_{gdp} \rightarrow ems$) are significantly positive with an initial value of 0.02 percent, increase to 0.03 percent, and fall to 0.01 percent at the end of the study period. This result indicates that emission initially rises, gets to the peak and falls. This result validates the hypothesis of EKC that emission increases initially but reduces as economic growth occurs and is consistent with studies including ones contemporaneously on Nigeria (Esso & Keho, 2016; Aiyetan & Olomola, 2017; Panayotou, 2003, 1997; Moomaw & Unruh, 1997).

Although the relationship between economic and socio-political development is essentially linear, the economic development and emissions relationship has been shown to follow an inverted U-shaped pattern in peripheral countries (Faiyetole, 2019; Dietz & Rosa, 1997; Grimes & Roberts, 1995; Roberts & Grimes, 1997). Notably, according to Panayotou (2003), in equation A, evidence of EKC on emissions and economic growth relationship is a function of the structural composition of the GDP and pollution mitigative efforts. For example, in 2014, Nigeria's economy was rebased, which essentially shows new sectors were factored in the sectoral composition of the GDP (NBS, 2014). The earlier understanding that the Nigerian economy is oil-and-gas-driven gave way to the service sector with a 240% increase from the 2010 base year, increasing the GDP from N34 trillion to N54.2 trillion. The implication of this to the existence of EKC found in this study is that economic growth leads to environmental improvement, hence the inverted U-shaped.

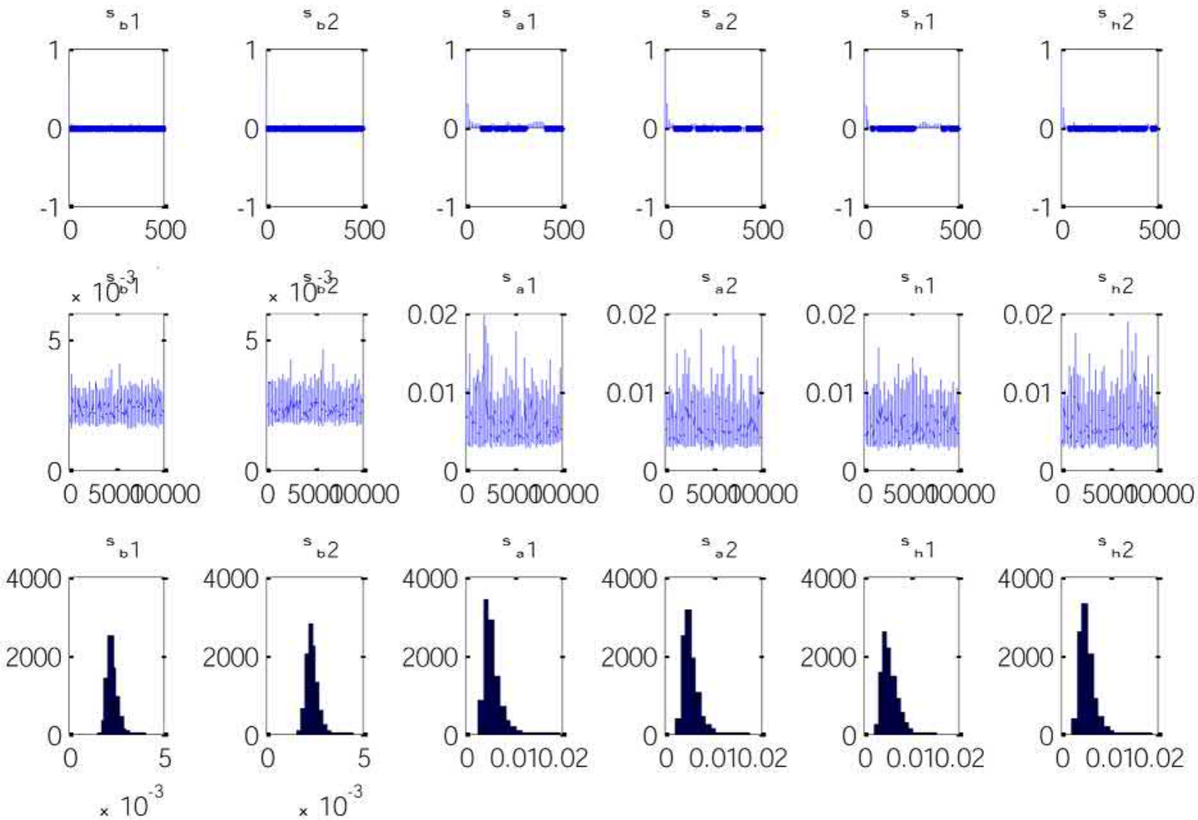
Lastly, the impulse responses of energy consumption to CO_2 emission shocks show a negative of -0.005 percent to -0.01 percent. It means that energy consumption reduces with an increase in emission. The impulse responses of GDP to emission shock are negative at -0.05 percent through the period of study ($\varepsilon_{ems} \rightarrow gdp$). The Paris Agreement's (of 2015) ambitious target of a 1.5^{o}C warming limit above pre-industrial levels aims at a net-zero emission in the second half of this century, requiring more stringent goals, which is hoped to be attained through the NDCs. According to UNFCCC (2018), Nigeria, a peripheral African country, in its NDC target, aims to achieve a 20% unconditional cut from its business-as-usual (BAU) level and a 45% conditional cut in the emission of CO_2 equivalents. Nigeria is comparably meeting the target better than the USA (Faiyetole, 2019), the largest economy in the world by any standard, which intends to reduce emissions by 28% below its 2005 level to stand at ~4,500 million metric tons of CO2 $_e$quivalents (UNFCCC, 2018).

These measures being implemented by Nigeria reflect on the sectors of the economy that contribute to its GDP, such as reducing emissions by ending gas flaring, generating 13 GW of off-grid solar power, and shifting transportation from cars to mass transit. Including improving the electricity grid, practicing climate-smart agriculture and reforestation, and using efficient gas generators (Faiyetole, 2019). By implication, the energy mix implementation by Nigeria has reduced the stocks of energy that lead to excessive emissions, hence a semblance of reduced energy consumption. However, the emission increases because the population of the country keeps rising. For example, the average annual rate of population change (AARPC) for sub-Saharan Africa is the highest of all the regions at 2.4%, with Nigeria at 2.8% (UNFPA, 2014), which is relatively the highest compared to most other countries. The emission in the stationary energy sector is predominantly high due to the extensive use of distributed diesel or petrol generators because of the inadequate supply of grid electricity to meet the growing demand due to the sharp rise in population. Thus, in addition to population increase and its overarching effects on emissions, for example, in Lagos (Nigeria), in 2013, there were 17,000 units such distributed diesel or petrol generators found in 13,000 households, industrial and commercial locations. Additional to transport emissions owing to diesel and petrol use in road vehicles. Also, despite the insufficient supply of grid electricity, it is a significant source of emissions due to its high share of gas and oil-based generation in the national energy mix (LSG, 2020). Hence, the reduced energy consumption with an increase in emissions has been evidenced in the findings of this study. On the other hand, the responses of emissions shocks on themselves are positive and varied over the study period.

Table 2. Estimation result of the parameters in the Bayesian TVP-VAR model

Parameters	Mean	St. Dev.	95% Upper	95% Lower	Geweke Diag.	Inefficiency
$\Sigma\beta 1$	0.0023	0.0003	0.0018	0.0029	0.037	3.40
$\Sigma\beta 2$	0.0024	0.0003	0.0019	0.0030	0.050	4.24
Σa_1	0.0056	0.0017	0.0034	0.0098	0.058	20.77
Σa_2	0.0055	0.0016	0.0033	0.0097	0.368	16.35
Σh_1	0.0056	0.0016	0.0033	0.0094	0.396	13.20
Σh_2	0.0055	0.0017	0.0034	0.0096	0.824	11.61

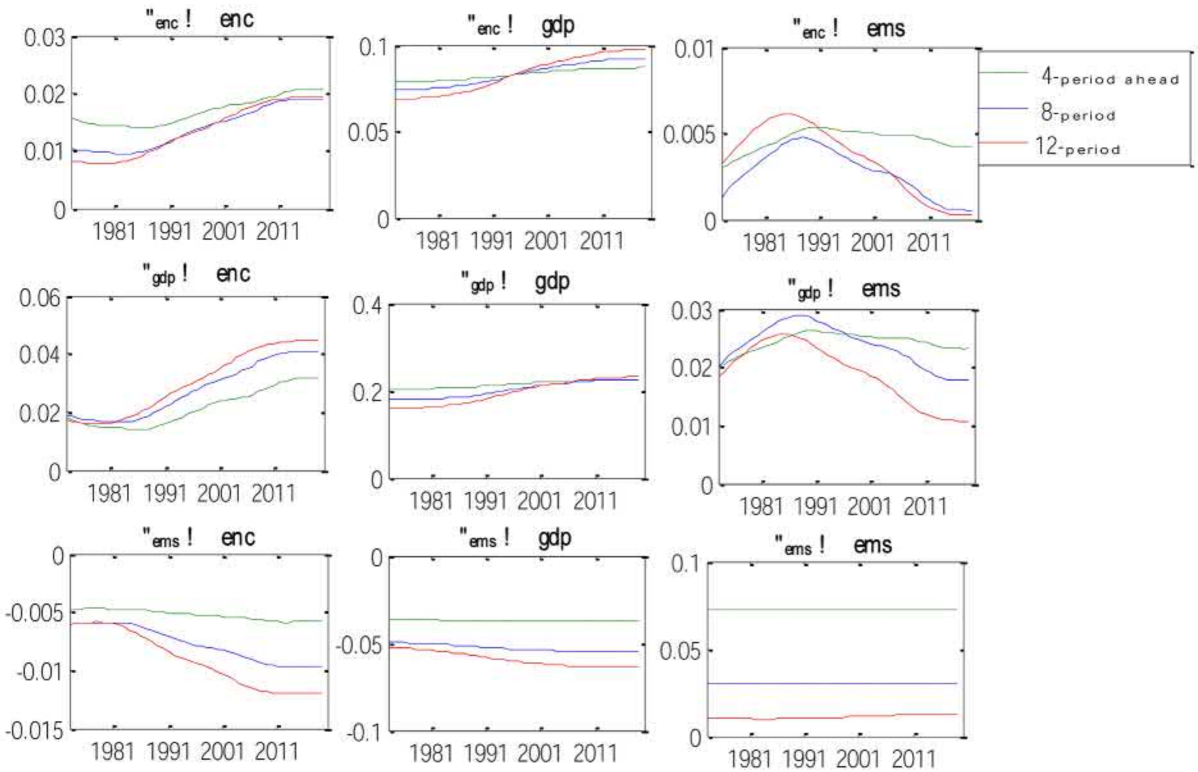
Figure 2. Sample autocorrelation (top), sample paths (middle), and posterior densities (bottom)



CONCLUSION AND RECOMMENDATIONS

This study examines the dynamic relationships among energy consumption, economic growth, and CO_2 emissions from 1971 to 2018. The study adopts the TVP-VAR to explore the dynamic effects among the variable of interest. After analyzing the statistical properties of the data with MCMC, a causal relationship between energy consumption and economic growth was found. It is further shown in this study that the EKC hypothesis is valid for Nigeria. It implies that as Nigeria's economy grew, emissions reduced. One of the reasons could be the commitment on the part of the government by supporting the shift to the use of renewable energy primarily informed by the country's NDC choices. Many households in the country are adopting the use of solar energy as against fossil fuel generators. The results, by implication, indicate that the government of Nigeria, as the largest oil producer in Africa, has been complying with the United Nations framework convention on climate change to reduce emissions and invariably committed to reducing the global greenhouse effects. Therefore, this study recommends that the Nigerian government continue pursuing emissions reduction policies, such as the NDCs, with an appropriate energy mix to ensure a quality environment in the face of reasonable industrialization drive and economic growth achievement.

Figure 3. Impulse responses of the TVP-VAR model for energy consumption, economic growth, and emission



DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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APPENDIX

Table 3. Lag length selection criteria for the TVP-VAR estimates

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-246.0505	NA	1908.760	16.06777	16.20655	16.11301
1	-165.5678	140.1956*	19.04298*	11.45599*	12.01108*	11.63694*
2	-158.8569	10.39109	22.50641	11.60367	12.57508	11.92033
3	-150.3072	11.58348	24.30684	11.63272	13.02045	12.08509
4	-143.4693	7.940788	30.68910	11.77221	13.57626	12.36029
5	-136.9111	6.346695	42.33580	11.92975	14.15011	12.65353

* indicates optimal lag order selected by the criterion. LogL-Log Likelihood, LR-Likelihood Ratio, FPE-Final Prediction Error, AIC-Akaike Information Criterion, SC-Schwarz Information Criterion, HQ-Hannan Quinn Information Criterion

1. Algorithm of the Markov Chain Monte Carlo (MCMC) Simulation

Given the likelihood and the prior distributions, the posterior distribution was estimated using the MCMC sampling method. Samples are drawn from the posterior distribution $\pi(\theta,\beta,\mathrm{a},\mathrm{h}|y)$, by the following MCMC algorithm recursively with 10,000 iterations:

1. initialize β,a,h and θ.
2. sample $\beta|a,h,\Sigma\beta,y$.
3. sample $\Sigma\beta|\beta$.
4. sample $a|\beta,h,\Sigma a,y$.
5. sample $\Sigma a|a$
6. sample $h|\beta,a,\Sigma h,y$.
7. sample $\Sigma h|h$.
8. go to ii.

Step i-viii were done recursively in 10,000 draws to generate estimates of β, a, h, Σ_β, Σ_a, Σ_h, and y (*see* Nakajima, 2011, Olayungbo & Akinlo, 2016).

Section 2
Environmental Finance

Chapter 11
Economic Valuation and Cost of Air Pollution

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ABSTRACT

Air pollution has huge economic consequences for society, including reduced work hours, increased healthcare costs, and lost household income. Quantifying the environmental and health costs of air pollution is conducive to improve the quality and efficiency of environmental regulations and understanding the real costs of economic development. This chapter provides an overview of all the costs associated with air pollution, the pros and cons of the traditional and new methods of air pollution cost accounting, and valuable insights into how future air pollution-related cost accounting should be. Another objective of this chapter is to carry out the economic valuation of air pollution. For this reason, environmental economic valuation and valuation methods are considered within the theoretical framework. It is proposed to carry out a public policy strategy to internalize the costs of pollution.

INTRODUCTION

Air pollution is, in the words of the World Health Organization (WHO), "*the world's largest single environmental health risk*". It is a major risk factor in several diseases leading to disabilities and deaths, including cancer, lower respiratory infections, and cardiovascular and cerebrovascular diseases – in short, heart disease and strokes – with the two last-named accounting for the greater share of the deaths attributable to air pollution (Lelieveld *et al*., 2020). Air pollution is especially severe in some of the world's fastest-growing urban regions, where greater economic activity is contributing to higher levels of pollution and to greater exposure. Environmental economists have performed numerous studies to

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quantify the impacts of air pollution on health and monetize these as social costs. In theory, air pollution can affect economic production through four channels (Dechezleprêtre *et al*., 2019):

1. Affecting the size of the workforce (through deaths and migration);
2. Reducing the number of hours worked per worker, if they are sick and cannot work (or have to take care of a sick family member);
3. Reducing the productivity of workers, and;
4. By affecting the quality of natural capital, which is an input to production, particularly in the agricultural sector.

This simple conceptual framework illustrates the mechanisms through which pollution can affect economic production. It is used to show how the impacts of pollution on total economic output can be measured. A synthetic review of the literature on these four channels previously identified is provided below.

1. **Pollution and population**: The burden that air pollution imposes on human health is well identified (Sohrabi *et al*., 2020; Rehman *et al*., 2022). Large epidemiological studies have provided evidence for at least 30 years that contamination by small particles in the air ($PM_{2.5}$) increases the death rate, especially through respiratory diseases and cancer (Zhu *et al*., 2019). Literature also finds evidence that pollution affects birth outcomes and infant mortality (Guo *et al*., 2019). Recent research also suggests that air pollution affects migration (Rafay, 2022). For example, Liu and Yu (2020) found a great movement between provinces in China to avoid air pollution. Taken together, these studies suggest that air pollution likely reduces the population in a region, by reducing live births, and increasing deaths and net emigration.
2. **Pollution and absenteeism**: In addition to its effect on the general population, pollution has been found to affect absenteeism as a result of increasing sickness. Aragón *et al*. (2017) found that a key factor to explain absenteeism, especially at moderate levels of pollution, is the presence of dependents in the home (for example, children). Therefore, there may be also a link between school and work absenteeism.
3. **Pollution and productivity**: In addition to causing significant health and mortality problems, air pollution also affects cognitive and physical function. Once again, $PM_{2.5}$ is of particular concern. When this pollutant is inhaled, the particles can enter deep into the lung and pass into the bloodstream, where they can affect brain and heart function (Boda *et al*., 2020). Since contamination influences physical and intellectual capacity, there is a clear way through which it can influence productivity in the working environment. Several investigations have shown that high contamination causes an abatement in productivity, focusing on workers for whom efficiency is straightforwardly measurable and for whom assignments cannot be effortlessly postponed or relocated. For instance, air contamination has been displayed to diminish the number of pieces gathered by laborers on a farm in California (Graff-Zivin and Neidell, 2012), the quantity of articles of clothing sewn each hour in a factory in India (Achyuta *et al*., 2014), or the quantity of boxes packaged in an indoor office (Chang *et al*., 2016). There is likewise proof that contamination influences productivity in high-expertise assignments, for example, understudy execution on normalized secondary school tests (Ebenstein *et al*., 2016). Recently, a large-scale study using data from manufacturing plants

in China evidenced that a 1μg/m[3] increase in average annual $PM_{2.5}$ concentration reduces a plant's productivity by 1.1% (Fan, 2020).

4. **Pollution and productivity of natural resources**: Notwithstanding effects of contamination that are interceded through the work market, air contamination may likewise straightforwardly affect yield, specifically in the forestry or agricultural sectors, where air contamination can possibly harm harvests or trees and subsequently cause decreases in yield. Many authors found evidence that agricultural production is affected by environmental pollution. Sun *et al*. (2017) show how air pollution can not only affect plant growth and animal health but also shift market equilibrium of both agro-inputs and outputs in the food supply chain and thereby affect food security indirectly. Even at relatively low levels, air pollutants may cause a range of physiological, chemical or anatomical changes which will lead to detectable yield reductions and may increase the crop's sensitivity to other stresses, thereby further contributing to significant yield losses (Marshall *et al*., 1997). Outside the agricultural sectors, Liyuan *et al*. (2019) found that $PM_{2.5}$ contamination in China causes huge losses in solar photovoltaic production (by 20% on an average yearly premise in eastern China) as it diminishes the direct radiation reaching the solar panels.

These recent results, based on study populations around the world, clearly confirm that air pollution affects health and population size, absenteeism, and productivity at work (of both high-skilled and low-skilled workers) and has direct impacts on production in the agricultural sector through reductions in crop yields. Having into consideration all of these effects, a recent study found that, on average every inhabitant of a European city suffers a welfare loss of over €1,250 a year owing to direct and indirect health losses associated with poor air quality. This is equivalent to 3.9% of income earned in cities (de Bruyn and Vries, 2020). If the expenses of the COVID-19 pandemic were fully included, the costs calculated in this study are expected to rise. In other parts of the world, the situation is similar, if not worse. The overall yearly cost of air pollution in China is projected to be $900 billion, while the cost in the United States is estimated to be $600 billion. Cities in India have received a poor rating in a recent study. Indian towns have scored adversely in air pollution indexes for years and the issue costs the country $150 billion per year on average. In 2018, the cost of polluted air equated to 6.6 percent of Chinese GDP, 5.4 percent of India's GDP and 3 percent of US GDP (Myllyvirta, 2020). Environmental costs are also important. Without a doubt, air pollution is closely associated with climate change, and the consequences can be severe for mankind. Climate change and the effects of global planetary warming have a significant impact on different ecosystems, resulting in difficulties such as food safety concerns, plant and animal extinction, and other consequences. Numerous studies have also been conducted in order to assess the environmental effects of air pollution and convert these into monetary costs under the principle of "willingness to pay" for clean air. This is one of the most important indicators of the public's acceptance of air pollution mitigation policies (Pu *et al*., 2019). These studies show how air pollution costs have grown since 1990, and also the willingness to pay (Sánchez-García *et al*., 2021). During this time, environmental losses nearly doubled and labor income losses increased by 40 percent (Lanzi *et al*., 2018). So greater action on air pollution is required despite countries having made great gains in economic development and health outcomes (WB & IHME, 2016).

BACKGROUND

Economic growth is represented through the volume or quantity that a country has managed to produce in terms of its Gross Domestic Product or GDP. Growth has been a goal pursued by economists since the 1960s of the previous century. This is why for several years they have focused their efforts on creating models that allow long-term growth (Joffe, 2021). However, economic growth is not necessarily a measure that reveals the well-being of a society. There are several cases, in which some countries, despite having positive economic figures, lack a good standard of living for society, that is, despite having growth, they have not achieved economic development (Olayungbo *et al.,* 2022).

Economic development is a term that goes far beyond the economic returns that a nation generates. According to Ray (2002, 2017), economic development is a multidimensional concept, which not only considers the income generated, but also the level of health, education, access to public services, and life expectancy, among others. It can be said that economic development is closely related to the well-being of human beings. Among the existing dilemma between growth and development, a new concept is generated "sustainable development", which has gained momentum today. According to the EC (2016), sustainable development stands for "*meeting the needs of present generations without jeopardizing the ability of futures generations to meet their own needs – in other words, a better quality of life for everyone, now and for generations to come*". That is, sustainable development includes the harmony between productive activities and the responsible use of natural resources. This vision is particularly important because it includes natural goods and services as part of the production process and therefore recognizes their importance and their care and conservation. In similar terms the US Environmental Protection Agency defines sustainability, as a "*state or condition that allows for the fulfillment of economic and social needs without compromising the natural resources and environmental quality that are the foundation of human health, safety, security, and economic well-being*". According to Landrigan *et al*. (2018), improvements in developed countries have not only decreased health issues but have also resulted in significant economic advantages. For every dollar invested in air pollution management in the US since 1970, an estimated $30 in benefits (range, $4–88) has been returned to the economy. As a consequence, sustainable development is both "a goal of achieving this state for the benefit of current and future generations, and a process whereby innovative tools, models, and approaches are adopted to advance economic prosperity while minimizing adverse global impacts" (USEPA, 2018). However, the vision of sustainable development is not the only one to incorporate natural resources into its premises. According to Samuelson and Nordhaus (2009) there are occasions when the government must intervene in the economy. One of these cases is the provision of public goods. These goods are those that cannot be acquired in the market, and adequate private production for them does not exist, since they have characteristics of non-exclusion and non-rivalry. For this reason, the State is obliged to provide this type of property to guarantee its existence. A peculiarity of pure public goods is that since they are non-exclusive, all agents can benefit from them. In addition, by not being able to establish a property figure, the use that is given to them is subjected to possible exploitation or deterioration. In the specific case of natural goods and services, such as air, all individuals can enjoy it. However, there are no autonomous incentives on the part of individuals to reduce air pollution levels. And here is where the market failures are revealed.

The market is the institution where supply and demand are combined, where the price mechanism agents make their purchase decision and maximize their utility. The market, according to economic theory, reaches efficiency when a correct allocation of resources is made. However, there are various situations where the market "fails" and is not efficient. In these situations, the intervention of the State as an economic regulator is required (Ziolo *et al*., 2019). According to Stiglitz and Rosengard (2015), externalities are the typical market failure associated to air pollution. Externalities are consumption or production decisions that affect third parties. They can be divided into positive and negative externalities. A positive externality (Marshall, 1890) is a situation in which the acts carried out by an economic agent benefit third parties without their having contributed thereby. On the other hand, a negative externality arises when the acts of an economic agent cause costs or damages to third parties. The problem with negative externalities is that the entire damage is not assumed by those who generated them. The State is obliged to intervene, to ensure the correct management of these failures. The classic example of negative externalities is pollution caused by economic activities (Pigou, 1920). In this case, economic theory indicates that a "contamination optimum" must be determined. In other words, a point must be reached where the contamination is not so high as to harm the agents, nor is it minimal to prevent the firms from producing. Once the social optimum is defined, it can be decided whether or not government intervention is desired. The justification for State intervention is based on the concept of efficiency in the Pareto sense, this is a situation in which an agent cannot maximize its welfare without worsening the welfare of another. Within economic theory, a scenario is known as socially optimal, since both parties have reached their maximum level of well-being (Stiglitz and Rosengard, 2015). On the other hand, if government intervention is not desired, the theory of Coase (1960) is applied. This author argues that the damages caused by externalities can be fixed through negotiation between the affected parties and the cause of the externality. However, Coase (1960) did not consider in this theory the transaction costs involved in negotiation, or a possible abuse of power by one of the parties.

In this scenario, the Environmental Economy arises to guarantee the optimal use of natural resources. This is a branch of microeconomics that deals with the analysis of the interactions between the economy and the environment. In this way, maximum air pollution levels can be established, and economic growth can be combined with the pollution generated. Environmental economics starts from the premise that future generations have the same rights over the biosphere as current and past generations (Ahlheim, 2018), similar statement that the supported by the sustainable development concept.

Environmental economic valuation is a very useful tool to monetize environmental impacts. The objective of this tool is to assign a monetary value to environmental goods and services in order to evaluate the real economic impact and the opportunity cost that losing natural capital would involve. The main purpose of this tool is to fully exploit the use of resources in a sustainable way. In addition, it supports regulatory institutions that are in charge of managing the protection of certain resources, designing policies and making decisions (Tinch *et al*., 2019). Of special interest when dealing with air pollution is the hedonic price method. This method is based on the theory of consumer demand that recognizes the utility is not provided by the goods themselves, but by the attributes they have. In such a way that consumers make their purchasing decisions based on the number of attractive features that the products have. Harrison and Rubinfeld (1978) presented for the first time the theory of hedonic prices related to air pollution arguing that the total price of the good, in this case the air, is equal to the sum of the value of each of the attributes that it possesses. The purpose of the method is to determine the valuation that consumers give to each characteristic in order to know which of them contributes a greater percentage to the total price (Mei *et al*., 2020). The hedonic price model is an alternative approach to value air quality and has also been widely applied in developed countries (Bajari *et al*., 2012; Chen *et al*., 2018; Freeman *et al*., 2019). It suggests that properties' price differentials resulting from local variations in air pollution can be used to estimate the benefits of air quality improvement or the costs of air quality deterioration. In other words, the benefits or costs associated with air pollution are able to be capitalized into, for example, the housing prices (Mei *et al*., 2020).

THE ECONOMIC COST OF AIR POLLUTION

Valuation of Air Pollution Externalities

As already introduced in the previous section, externalities are those costs (or benefits) generated by the behavior of a group of people that affects to another group and are not compensated by the first group. For example, traffic environmental external costs reflect the monetary value of the loss of social welfare from pollutant emissions and various environmental hazards that are not assumed by the user (EC, 2008; IMEP, 2021). One vehicle emitting hazardous pollutants causes air quality deterioration, and therefore depleting local inhabitant's health, leading into costs not assumed by the driver nor owner. Air pollution is caused by several pollutants, coming from different economic sectors and can occur in rural or urban areas with different population distribution, causing different impacts. For example, same number of different pollutants emitted in one zone, or the same mass of emissions of the same pollutant in different geographical areas have different impact in economy. Several studies have been carried out to quantify air pollution impacts on economy. The assessment of a refinery closure near Mexico City (Hanna and Oliva, 2015) estimated that individuals living within a 5 km radius would see a 1.3-hour per week increase (or 3.5 percent) in work on average in comparison to neighborhoods further away from the refinery. A study in California (Graff-Zivin and Neidell, 2012) concluded that a 10 ppb drop in ground-level ozone would boost agricultural worker productivity by 5.5%. To arise to these conclusions, the Institute of Medicine (IOM, 1981) created one of the first models in this field in the early 80s. The base of this model was estimating "fractional contribution" of pollution attributable to a concrete disease (Forouzanfar *et al*., 2016). The model enabled to correlate the effects of pollution and GDP. This fist approach properly worked in countries with robust data systems while failed in other with fewer resources. Other drawback of this model was that the model did not reflect intangible losses such as family disruption occurred by the dead of a progenitor. Finally, a model that only considers GDP is not suitable to address all pollution threats (Landrigan *et al*., 2018). To defeat these points there are currently several methodologies to estimate externalities:

- **Damage Cost Approach**: It is the preferred option by the economists. It is based on assessing the damage caused by an individual. Since there is often a lack of market damage information, this method typically makes use of the willingness to pay (WTP) of individuals. There are two types of approaches for calculating the WTP: (1) Stated preference methods that makes use of questionnaires, surveys, interviews and choice experiments; (2) Revealed preference methods, which evaluates economic impacts in other economic markets to calculate the monetary value of externalities (van Essen *et al*., 2019). One of the most advanced countries assessing damage cost is the UK. UK evaluates the damages costs produced by five pollutants: nitrogen oxides (NOx), particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), volatile organic compounds (VOCs) and ammonia (NH_3). Table 1 shows average 2020 cost of each pollutant in £/t (UKG, 2021a). Other confinable sources give similar information such as the Handbook on the external costs of transport published by the European Commission (van Essen *et al*., 2019).

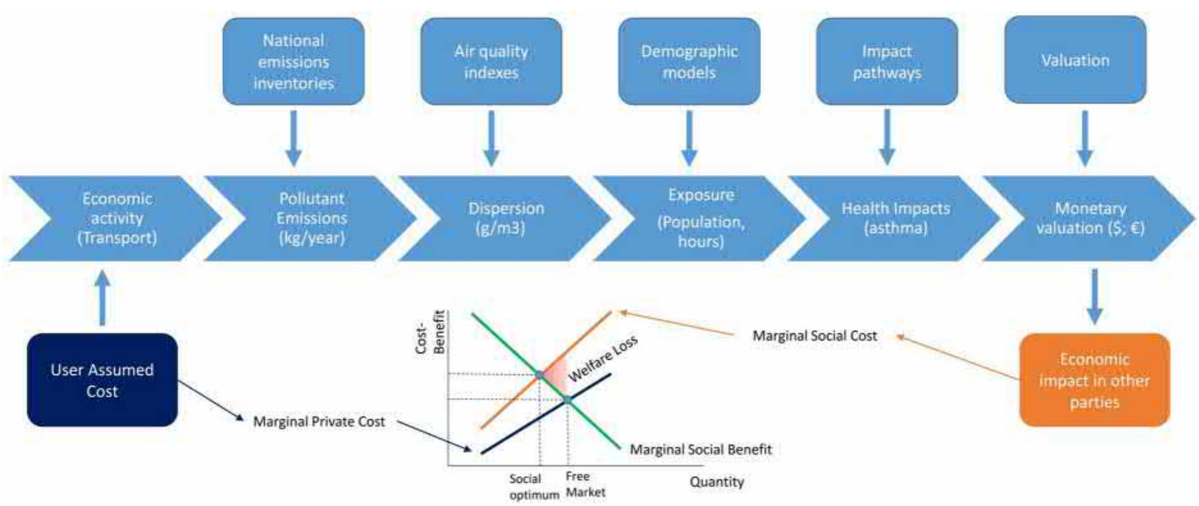
Table 1. Average pollution contribution cost per substance for 2020

Pollutant	Cost (£/t)
NOx	6,385
SO_2	13,206
NH_3	7,923
VOC	102
$PM_{2.5}$	73,403

(UKG, 2021a)

- **Impact Pathway Approach**: It is the method used by UK government for scenarios where costs are higher than 50M£. It is based on evaluate how a policy intervention affects to pollutant dispersion and therefore impacts on public health, mortality, morbidity, ecosystems and economy. Valuation considers chronic mortality, acute mortality, morbidity, hospital admissions, disease duration, productivity losses, damage caused by SO_2 to buildings (limestone, sandstone…), damage caused by ozone to materials, soiling of buildings due to PM, ecosystem damages and overlap of NOx and PM. The assessment of health impact and cost valuation is made with the advice of the Committee on the Medical Effects of Air Pollutants (COMEAP) and Public Health England (PHE) (UKG, 2021b). Figure 1 gives an overview of this method.

Figure 1. Impact pathway approach.
Adapted from van Essen et al. (2019) and UKG (2021b)



Other extended methodology is avoidance cost approach, especially useful when the externality's harms are unknown and/or difficult to quantify. It calculates the cost of introducing an additional level of environmental quality based on CO_2 price and avoidance costs functions. Finally, replacement cost approach estimates the cost accounted for reparation, refurbishment or replacing a good due to an externality, this methodology may undervalue actual costs, since not always a good can be replaceable or reparable (van Essen *et al*., 2019).

- **Value Transfer Approach**: Some studies are carried out into specific socioeconomic conditions. To appropriately transfer these approaches to different locations with other conditions, it is crucial to apply value transfer approach. This considers prices differences as well as income differences (van Essen *et al*., 2019). In addition, it is important to apply a correction factor to update costs from the year of the source to the year of the study, according to the GDP.

Health Costs Accounting on Air Pollution

It has been previously analyzed how exposure to air pollution is associated with premature mortality and loss of quality of life. This impact of environmental pollution on health can be evaluated from an economic point of view from two perspectives: 1. the market cost perspective, as a result of a decrease in productivity due to morbidity or an increase in health spending, among other causes; and 2. the perspective of the cost of well-being, translating premature mortality into monetary terms. The measurement of this welfare cost has acquired special relevance since it has been shown to have significant consequences for the economy (WHO & OECD, 2015). Methods to quantify mortality and morbidity effects are available, and they are based on air pollution concentrations, basic demographic and health data, and the relationship between the ambient concentrations and each specific health outcome. This can be translated into number of human lives lost or costs associated with mortality and morbidity (EEA, 2020).

Knowing the results obtained from both points of view is interesting when analyzing the benefit of intervening in reducing exposure to environmental pollution, although the use of one or the other depends largely on the context (OECD, 2020; WHO & OECD, 2015). From the point of view of health economics, the priority is to know the market cost of the risk factor considered, with the intention of maximizing the health budget assigned to it. On the other hand, environmental economics focuses on measuring the cost of well-being, for which indicators are used that measure how much a given society values the intervention in improving its quality of life, in this case, by reducing exposure to air pollution.

To measure the real economic incidence of environmental pollution, what is known as the "chrysohedonistic illusion" whereby wealth equals money, must be set aside and understand that the loss of wealth attributed to the risk factor considered, air pollution in this case, it is the welfare cost (EC, 2018; WHO and OECD, 2015). It is important to understand when measuring the economic impact of environmental pollution that the cost of a person's premature death from the perspective of GDP could even lead to a reduction in state spending, if, for example, this person was a beneficiary of a subsidy. However, in terms of the cost of well-being, the economic impact of a person's premature death is the value of his or her life itself (WHO and OECD, 2015). For this reason, the impact of environmental pollution on the economy is measured using the Value of Statistical Life (VSL), which incorporates the economic assessment of society to avoid the consequences associated with a specific risk factor.

The VSL is the standard method used in economics to measure people's preference in allocating resources to protect life. Specifically, this index is based on the idea that citizens have to weigh the allocation of their budget between consumption, leisure, health and life based on the value they place on each (EC, 2018; WHO and OECD, 2015). The VSL starts from the basis that if individuals want to allocate part of this budget to improving their health and preserving their lives, they have to sacrifice the acquisition of consumer and leisure goods. Therefore, it is necessary to know the willingness of individuals to pay (WTP) to ensure a marginal reduction in the risk of dying prematurely, in this case, due to exposure to air pollution.

First of all, it should be noted that when considering a risk factor such as exposure to air pollution, the burden of assuming the cost of solutions to minimize the impact of this threat falls on the states and it does not depend on individual decisions of people (de Bruyn and de Vries, 2020). This does not mean that environmental pollution is a national problem, but that, generally, the responsibility in making decisions in the allocation of the budget destined to reduce the incidence of air pollution in health rest, in the last instance, in governments at the national level. It is for this reason that, even being aware that within the same country there are considerable differences in the exposure to air pollution and in the WTP of its inhabitants, adding the value of the VSL at the state level is a representative index of the economic impact of environmental pollution (WHO and OEDC, 2015).

To determine the VSL of each country, it is assumed that each individual has an expected utility function $UE\ (y, r)$ that weights the utility of the consumption of goods $U\ (y)$ and the risk of premature mortality (r) in a given period of time (y) (EC, 2018; WHO and OECD, 2015). The expected utility of the individual will increase to a greater extent the lower their probability of dying in the period of time considered, as shown in Equation 1:

$$UE\ (y, r) = (1 - r)\ U\ (y) \qquad (1)$$

If the fact of how much the individuals in a society value life is considered, the individual's willingness to pay (WTP) for reducing the risk from r to r' must be included in the expected utility, as shown in Equation 2:

$$UE\ (y, r) = UE\ (y - WTP, r') \qquad (2)$$

Based on this idea, VSLs are defined as the marginal replacement rate of reallocation of the budget of goods to an improvement in health. That is, a VSL represents the value that individuals assign to greater longevity for each budget unit that they decide to allocate to r and not to y (Li et al., 2020), as shown in Equation 3:

$$VSL = \partial WTP / \partial r \qquad (3)$$

Through the VSL it is possible to assign a monetary value to a determined risk factor, in this case the air pollution, and to understand the true economic dimension of premature mortality that is attributed to it. To determine the welfare cost of premature mortality due to exposure to air pollution, the VSL is multiplied by the total number of premature deaths that have occurred in the country during the period of time considered (EC, 2018). However, it is necessary to bear in mind that VSL will only include the economic consequences of premature mortality and not morbidity, nor does it include all market costs. For these reasons, some studies suggest that the value of one year of life (VOLY) index is more representative of the welfare cost of environmental pollution since it also includes the incidence of morbidity. However, there is currently no standard index by which to measure the cost of morbidity, although it has been estimated that it represents approximately 9% to 10% of the economic cost of air pollution (WHO and OECD, 2015).

According to the analysis carried out by Iglesias (2021) about the impact of air pollution on the health of the European population, it was observed that those countries that reported lower VSL rates for 2017, showed that the welfare cost of premature mortality due to air pollution as a percentage of GDP was considerably higher than that of those countries with higher VSL rates. This reality is not surprising, since the incidence of this pollutant on health was higher. Indeed, in 2017, while in Finland and Sweden the welfare cost of premature mortality attributed to particles (PM2.5) presence in air was 1.6% and 1.8% of their GDP, in Bulgaria and Lithuania this figure reached 8.70% and 7%, respectively. On the other hand, in the context of the EU, it is striking that as premature mortality has decreased by 24.71% since 1990, the VSL has increased by 42.4% in all the countries. This can be interpreted as a greater concern of community citizens to improve their quality of life, sacrificing part of the budget allocated to consumer goods to guarantee a reduction in exposure to air pollution and improve their quality of life.

A recent OECD study on the impact of air pollution on the economic activity of the market in Europe (Dechezleprêtre et al., 2019) estimated that a decrease of 1 μg/m3 in the average annual concentration of PM2.5 would increase the Europe's GDP by 0.8%, which represents around 200 euros per capita per year. Of this increase in GDP, 95% is the result of increases in people´s health, translated into higher production per worker, through less absenteeism from work or higher labor productivity, due to less air pollution. This study concludes that stricter air quality regulations could be justified solely on economic grounds, as the direct economic benefits of air pollution control policies far outweigh the costs of abatement, even when the costs are ignored, great benefits in terms of avoided mortality. These authors also estimated that if all EU countries met their national targets for reducing exposure to PM2.5 in 2020, European GDP would grow by 1.28% between 2010 and 2020, representing reduction costs of around 0.01% of GDP. Poland, with the highest reduction target, would increase its GDP by up to 2.9% and Bulgaria by 1.7%. The impact is around 1.5% for Austria, Belgium, the Czech Republic, France and Italy; 1.2% for Germany and the United Kingdom, and even for countries with low concentrations of PM2.5, such as Ireland or Norway, GDP increases are still substantial at around 0.8%.

Impacts on Agricultural Systems

Air pollution is harming not only human health but also the agricultural systems. Air pollution has deleterious effects on both soil and water. Concerning particulate matter as an air pollutant, its impact on crop yield and food productivity has been previously reported (Manisalidis et al., 2020). Zhou et al. (2018) used an econometric model to assess the impact of PM2.5, the main indicator of haze, on the average yields of three main crops (wheat, rice and corn) in China between 2001 and 2010. The results indicated that the increased exposure to particulate matter was devastating to wheat and crop yields. In particular, PM2.5 can significantly reduce the average wheat yield by interacting with temperature and sunlight, two key elements of solar radiation. Similar to climatic factors, PM2.5 also has a non-linear quadratic effect on average wheat and corn yields. The quantification of the effects of air pollution on agricultural yield calls for the identification of the dose-response functions between pollutant concentration and agricultural losses (Wang et al., 2020). The negative effects of air pollution on agricultural production, especially those associated with ozone, have attracted attention from many researchers (Zhou et al., 2018). Studies have shown that ozone is detrimental to crop growth and can significantly reduce crop quality. For example, ozone concentrations between 31 and 50 ppb can reduce wheat yield by 9.7% (Feng and Kobayashi, 2009) and a 1% reduction in ozone could increase winter wheat yield by 0.68% (Yi et al., 2016). Ozone can destroy plant leaves and impede their metabolism by influencing respiration

(Young and Aidun, 1993) and affect the photosynthesis of plant leaves (Sirotenko et al., 1997), which would lead to lower crop yields. Van der Eerden et al. (1988) found that air pollution reduced crop yields in the Netherlands by 5%, where 3.4% was due to ozone, 1.2% was due to sulfur dioxide, and 0.4% was due to hydrogen fluoride. Using exposure–response functions (ERFs) for seven crop types, Vandyck et al. (2018) calculated the crop yield impact of climate policy-induced reductions in tropospheric ozone mixing ratios. By projecting future changes in crop yields on current values of agricultural production, these authors obtained the impacts shown in Figure 2, where monetary agricultural co-benefits are expressed in per capita terms. The results for this scenario highlight areas where ozone reductions overlap with high production values of ozone-sensitive crops, such as wheat, soybeans, and corn in the US, or soybeans and sugarcane in Brazil. While reducing ozone emissions would globally increase wheat, corn, soybean, rice and yields by 0 4% to 0.6%, 0.4% to 0.7, 0.8% to 1.1% and %, 0.1% to 0.3% in 2030, respectively, a more ambitious climate policy limiting warming to 2 °C would further increase the productivity of these crops by 0.9-1.7%, 0.8-1.5%, 1.8-2.7% and 0.2-0.8% according to these authors. Estimates of monetary agricultural co-benefits for yield impacts for 2050 exceed $10 per capita in some regions, when calculated using the current value of agricultural production. Wei et al. (2014) also noted that an agricultural loss of $1.43 billion was caused by industrial sulfur dioxide pollution in China, which accounted for about 0.66% of the total agricultural value of the considered area.

Furthermore, climate change, as a consequence of air pollution, is resulting into a very high rate of land degradation causing enhanced desertification and nutrient deficient soils. The menace of land degradation is increasing by the day and has been characterized as a major global threat (Arora, 2019).

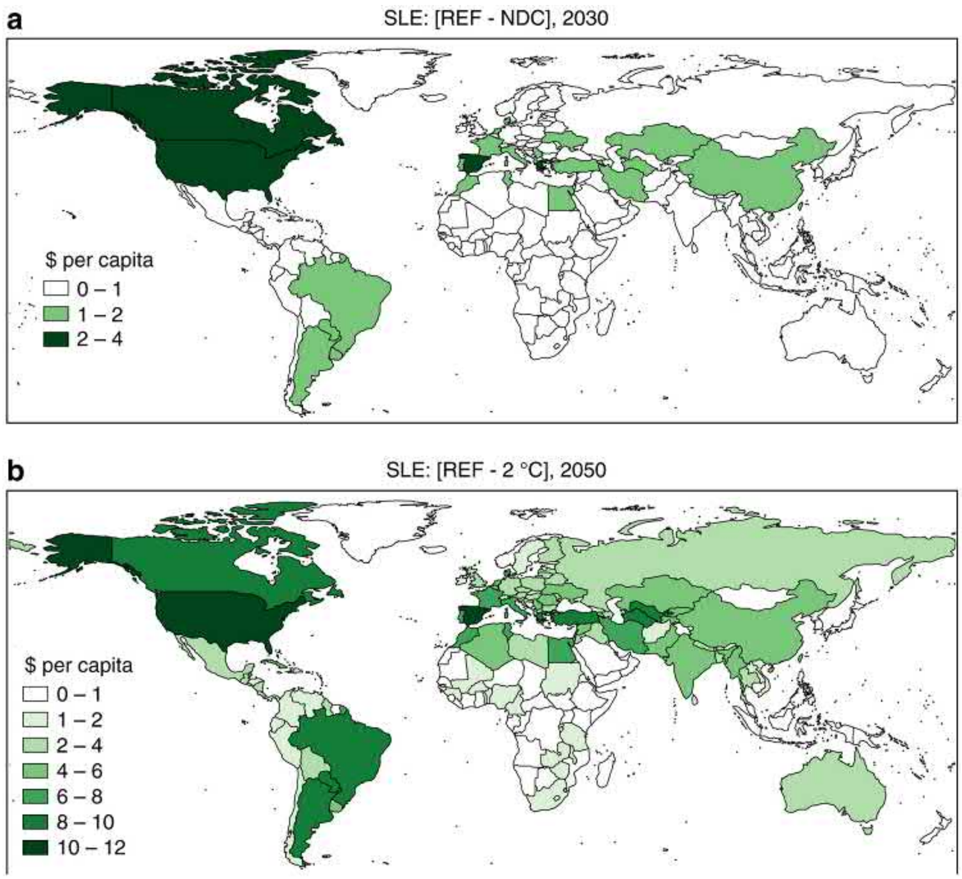
POLICIES AND TOOLS TO REDUCE AIR POLLUTION AND RELATED COSTS

The environmental policy has developed various methods and instruments to provide a solution to the problems of pollution and degradation of natural resources. Instruments can be classified into two large groups. On the one hand, there are the mandate and control measures, which are basically regulations through legal normative. On the other hand, there are market mechanisms, also known as economic instruments. The latter seek to correct the price of goods and services by incorporating the social cost (in addition to the private cost) that was incurred for the cleaning of these natural resources when they are polluted (Wang, et al., 2019).

The mandate and control measures are the most common form of regulation, they take the name of “mandate” because they are mandatory standards for polluters. For the design of these mechanisms, a monitoring system is implemented to verify possible non-compliance. According to Labandeira (2006) among the main command and control measures are:

- **Norms on Emission of Pollutants:** These norms are in charge of regulating the polluting gases emitted by a specific agent in a given time. They are also known as “operating standards”.
- **Norms on the Emission of Pollutants:** They are in charge of verifying that the emission of gases is within the permitted levels in a certain area at all times.
- **Technological Standards:** These regulations oblige companies to introduce new technologies that generate a lower level of contamination, or, failing that, to implement decontaminating technologies. These standards are also known as “design standards”

Figure 2. Agriculture benefits associated with ozone emissions reduction due to climate policy in dollars per capita. a) Difference between the current scenario and the scenario in 2030 based on nationally determined contributions (NDC) stipulated in the Paris Agreement on climate change; b) Difference between the current and the -2 °C scenario in 2050.
Source: Adapted from Vandyck et al. (2018).



- **Norms on Final Goods or Intermediaries:** These norms are in charge of regulating the levels of pollution or energy consumption produced by the goods that are offered to the public. An example of this is the regulations that are issued to control the gases emitted by motor vehicles.
- **Planning Rules:** As its name explains, these rules are responsible for the organization and projection of the territory by creating buildable conditions or noise levels.

Referring market mechanisms, these instruments are intended to modify the environmental behavior of agents through the application of economic incentives. Market mechanisms present some flexibility in the implementation of environmental policies because people react to the intervention according to their capacities. In this way, pollution is reduced at a minimum cost to society (Labandeira et al., 2006). Th*e mos*t common market mechanisms are taxes, emission rights markets and subsidies.

- **Taxes:** These are mandatory fees that must be paid by agents that carry out polluting activities. Taxes are said to be a "price instrument" since when they are levied on a polluting activity, they create an externality price. It should be considered that an environmental tax does not have the objective of collection. Its main objective is to encourage changes in the behavior of economic agents, as stipulated in the role of "penalization". Such a tax is considered successful when it achieves lower collection over time, which means that pollution levels have decreased. Only in this case, it can be said that the incentives applied were correct, and the environmental policy has achieved its ends.

The implementation of environmental taxes has several advantages, they are:

1. Static efficiency: Ability to achieve the same level of pollution reduction at a lower total cost since each agent can choose how much to reduce according to their particular marginal costs.
2. Dynamic efficiency: Environmental taxes encourage agents to adopt new, cleaner and more innovative technologies.
3. Generalized treatment: All agents face the same tax rate, which eliminates the need for the regulatory authority to individually negotiate the rate to be taxed.
4. Revenue potential: The objective is not to promote higher collection with these taxes; however, such collection should be channeled to financing environmental policy programs, prevention of natural damage, or remediation.

Similarly, environmental taxes also have several difficulties and disadvantages.

1. Sometimes they are not the most successful mechanism: In cases of health or life-threatening effects, the most appropriate instrument would be to implement command and control measures.
2. Reaction of economic agents: Adverse reactions can be generated in agents, if they assume that they have permission or right to pollute given the payment of the tax.
3. Adverse impact on equity: Households with fewer economic resources may be most affected since taxes are levied on goods such as energy and fuels at a uniform rate for society. In such a way that their relative spending on these goods has a greater proportional impact (Franco and Marin, 2017).

Emission rights markets: They are also known as quantity instruments. They propose the creation of a fictitious market in which, based on the amount of interchangeable rights allowed, the price per unit of issue is formed (Labandeira, 2006). There are some variations of emission rights markets, among them, according to the nature of the market, according to the definition of the permit, according to the static and dynamic exchange rules and according to the definition of property rights. It should be noted that these variations are not mutually exclusive.

Issuance by property rights is one of the most common, it is classified into two types, auctioned emission permits or permits distributed for free. This case arises from the definition that society has of who has the rights to the environment. If the State is the one who owns the property rights, the auctioned permits are applied. Otherwise, if it is considered that the companies are the ones who own the rights to the environment, free permits are granted.

Subsidies: Subsidies are the market mechanism that, unlike in the previous cases, does not comply with the principle of "whoever pollutes pays", in fact the application of subsidies fulfills the opposite premise: The State pays the agents causing the pollution in exchange for them reducing their level of emissions. Labandeira (2006) proposes two types of subsidies. The first are granted in order to make investments in decontamination technology. These types of subsidies are the most common because their application is simpler. The second type of subsidies is constituted by subsidies that the State grants for each unit of reduced emission. Its application is more complicated, because it requires constant monitoring and control of the contamination produced by each agent. On the other hand, subsidies for decontamination do not comply with efficiency parameters, although they encourage the reduction of emissions, they cease to be effective when the subsidy ceases to be profitable due to the increase in marginal costs of decontamination.

In conclusion, it can be said that air pollution can be analyzed from the economic point of view as a negative externality, so market failures and the need for intervention by the State should be under discussion in any scenario.

FUTURE DIRECTIONS

As it has been amply demonstrated in this chapter, emissions from anthropogenic activities seriously affect the global economy mainly due to their negative effects on health and ecosystems. The effectiveness, globally and in the 2050 horizon, of policies and measures to reduce air pollutant emissions and the cost derived from this pollution has been continuously evaluated by the International Energy Agency (IEA, 2016, 2017, 2018, 2019, 2020), considering, country by country and sector by sector, all the relevant policies and measures adopted or announced as imminently applicable worldwide to fight against air pollution and climate change.

One of the most striking conclusions pointed out by this organization is that despite the fact that in the reference scenarios based on the new policies implemented around the world, with the application of existing and planned sectoral policies at the international level, emissions would be significantly cut, the progress made would not be enough to improve air quality at a global level, which is why a more drastic and decisive international intervention is necessary.

According to the New Policies Scenario (IEA, 2016), the growing concern and attention given by the international community to the problem of air quality, together with the commitments acquired by the international community after the Paris summit in December 2015 (COP21) to accelerate the energy transition towards a more efficient and decarbonized model, will translate between now and 2040 in a slow but continuous decrease in the set of global emissions of air pollutants.

The aforementioned scenario contemplates an increase in the combustion of coal, oil, natural gas and biomass, in order to cover an increase of close to a third of the global energy demand. However, despite this, global emissions of PM are expected to fall by 7% by 2040, those of SO_2 by 20% and those of NOX by 10%. This decoupling between both trends reflects, in approximately equal parts, the application of pollution control technologies and the global movement towards the adoption of a cleaner energy model. Pollution controls have been applied more and more rigorously in areas of growth in energy demand, mainly in Asia, where air quality regulation has made considerable progress to adapt to the rapid growth rate of industrial and urban activity and demographic expansion. At the same time, the widespread transformation of the energy sector, catalyzed by the Paris agreement on climate change, could mean that more than a third of the expected growth in energy use is achieved from sources free of polluting emissions, such as wind, solar, hydro and nuclear. Another 30% would come from natural gas, the combustion of which emits fewer pollutants than the other two fossil fuels and biomass.

With an eye to the horizon of 2040, the New Policies Scenario set by the International Energy Agency in 2016 contemplates that the continued reduction of polluting emissions in the industrialized world, and the beginning of their decline in China, will be accompanied by a modest growth in India and Southeast Asia, as well as faster growth in some parts of Africa. Taken together, the International Energy Agency projections discussed in this section represent bad news for the health of millions of people around the world and the ecosystems, at the same time that higher costs associated with air pollution. Despite intensifying efforts to improve air quality, rising demographic trends, along with growth in urbanization and energy use, especially in developing Asian countries, suggest that the number of premature deaths attributable to air pollution outside homes will continue to rise.

What has been exposed so far goes to show that although the measures to be applied to improve air quality are known, the problem is far from being able to be satisfactorily solved on a global scale in the next two decades? It is clear that any significant progress requires more determined government bets, which drastically reinforce and accelerate current international commitments for the deployment of new energy and air quality policies. It is, therefore, necessary to implement stricter control and mitigation measures that really achieve an effective reduction of air pollution phenomenon in all the activities of humanity. In agreement with Amann *et al*. (2020), the future scenario deliberately requires a range of ambitious policy interventions that clearly deviate from current practices. Implementation will require clear political will and public support. For this reason, the International Energy Agency has developed a much more ambitious scenario than the one previously discussed, called the Clean Air Scenario (IEA, 2016). This includes a wide range of energy and air quality policies, very pragmatic, of proven efficacy and exclusively based on currently operating technologies, the implementation of which would ensure much cleaner air and better health for the citizens of the world. Thus, in the Clean Air Scenario, premature deaths caused by air pollution outside homes would fall to 2.8 million in 2040, while those attributable to air pollution inside homes they would stand at around 1.3 million on the same date (in the New Policies scenario, both figures were 4.5 and slightly less than 3.0 million, respectively). Obviously, the improvements obtained would be mostly concentrated in developing countries.

Achieving the anticipated progress in the Clean Air Scenario would depend on the global implementation of a range of policies, including others would include the following:

1. Ensure access for the entire population to clean stoves in order to reduce the use of inefficient biomass stoves and their $PM_{2.5}$ emissions.
2. Raise the requirement and strictly enforce emission standards in road transport, especially in cities, in order to reduce NOX pollution.
3. Control emissions and promote fuel switching in the heat and electricity generation sector (paying special attention to the substitution of coal) and increase efficiency in the industrial sector, in order to cut SO_2 emissions.

According to the International Energy Agency, the additional investments required to implement the measures contemplated in the Clean Air Scenario are not insurmountable. The cumulative investment required through 2040 would be 7% (or $ 4.8 trillion) higher than that forecast in more conservative scenarios, while the value of the resulting benefits would be much higher.

Along these lines, the rapid technological development in the field of sensors is opening the door to achieving real-time monitoring and control of emissions, under the premise that if something can be measured, it can be controlled and reduced. The development of harmonized measurement methodologies will increase the reliability of the data collected and the credibility of the consequent mitigation procedures implemented by the authorities through their policies. For example, the integration of measurement systems into the transportation infrastructure can help identify vehicles that do not meet prescribed limits and allow the operator and vehicle owner to be quickly informed of a vehicle's environmental deficiencies, or help to authorities to identify polluting vehicles, preventing their access to low emission zones, thus mitigating the effects of non-compliance with tolerance limits. On the other hand, the integration into the infrastructure of solutions with negative emissions (such as nature-based solutions) can also contribute to an effective reduction of the negative effects (including costs) of emissions. Technology is an important tool (Rafay, 2019) and is useful to support public policies to control air pollution.

CONCLUSION

The need to improve air quality stems from the public health problem caused by its effects on premature morbidity and mortality, as well as the impacts on the environment and the associated costs. Thus, this need, and compliance with the legislation derived from it, is not an environmentalist or ecologist option, but rather the obligation to respond to such a pressing problem.

Economic co-benefits related to air quality include reduced cost of air pollution control measures, health care expenses avoided, non-commercial value of reduced morbidity, fire reduction implications and, therefore, GHG emission and related air pollution reduction through a proper land use, good indoor air quality and the corresponding positive results on human health, the effects of acidification and eutrophication on ecosystems, and the impact of air pollution on human capital formation and job performance, among others.

At a time when COVID-19 has created extraordinary uncertainty, governments have unique capacities to act and guide the actions to be taken. They can lead the way by providing the strategic vision, the stimulus for innovation, the incentives for consumers, the policy signals, and the public finances that catalyze action by private actors. A zero-emission future is a choice: for consumers, investors and industries, but most of all, for governments.

DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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KEY TERMS AND DEFINITIONS

Externality: Cost or benefit caused by a producer that is not financially incurred or received by that producer.

Gross Domestic Product (GDP): Total monetary or market value of all the finished goods and services produced within a country's borders in a specific time period.

Hedonic Pricing: Model that identifies price factors according to the premise that price is determined both by internal characteristics of the good being sold and external factors affecting it.

Marginal Cost: Change in total production cost that comes from making or producing one additional unit.

Monetize: Process of turning a non-revenue-generating item into cash.

$PM_{2.5}$: Particulate matter less than 2.5 microns in diameter.

Public Goods: That good which belongs to or is provided by the State at any level through all those organizations that are part of the public sector.

Value of Statistical Life (VSL): Marginal rate of substitution between income (or wealth) and mortality risk.

Chapter 12
Carbon Financing and the Sustainable Development Mechanism:
The Case of China

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ABSTRACT

China has been one of the largest global emitters of carbon dioxide (CO2). As a result, the country is committing itself to implement the 2030 Agenda for Sustainable Development. The attention that is being paid to the serious problem of climate change has increased manifold. Corresponding policies are introduced in relation to the financing of carbon. In particular, in the wake of the announcement that China would be going carbon neutral before 2060, concrete efforts are being consistently made towards carbon emission reduction. Policies and measures related to carbon finance are being continuously promulgated, and a national carbon emission trading market too has been established on July 16, 2021. This chapter gives a brief overview of the carbon market, carbon finance, and its policies in the context of sustainable development. It also examines the approach towards the future development of the carbon finance market by discussing in detail the existing deficiencies and areas of improvement.

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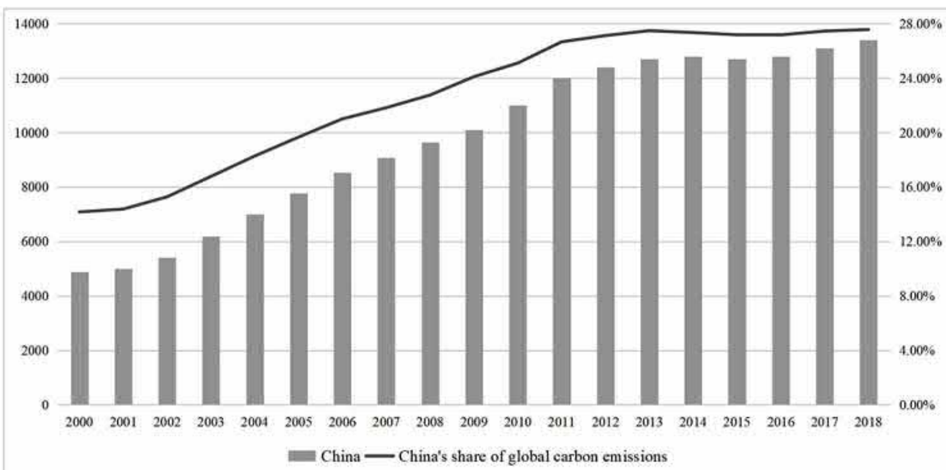
INTRODUCTION

People's Republic of China (PRC), a world-renowned producer of industrial goods, has today become the world's largest emitter of carbon (Dudley, 2019). Between 2000 and 2016, China's CO_2 emissions grew by an average of more than 11% on a yearly basis with CO_2 emissions almost tripling in a very short span of time (Figure 1). It has been reported that in the year 2016, nearly 30% of global CO_2 emissions came from China (The World Bank, 2021). Though, it is the manufacturing industry that is generally held liable for the majority of CO_2 emissions, but in recent years, the tertiary industry too is being recognized as the main source of CO_2 emission in China (Wang *et al.*, 2020).

Figure 1. China's carbon emissions and its share in the world total carbon emissions from 2000 to 2018 (Unit: $MtCO_2$)
Source: https://www.climatewatchdata.org/



Cities are mostly a hub for human activities and at the same time for the consumption of fossil fuels and emission of CO_2 as well (Chen *et al.*, 2020; Meng *et al.*, 2019). In order to tackle climate change and reduce emissions, China as a country will have to bear heavy responsibility for introducing significant changes in its economy for energy conservation (Chen & Zhu, 2019; Liu & Bae, 2018). Driven by a decline in overall carbon intensity and a rise in inter-city carbon inequality, 41.38% of provinces and 49.65% of cities are still under great pressure to reduce carbon emissions. These cities emit carbon dioxide at a higher than the average level than the most parts of the country (Cheng *et al.*, 2020).

Since the past decade, China's primary energy consumption has been rising. Even if the elasticity coefficient of China's energy consumption drops below 1, or even stabilizes below 0.6 for a long time, it can still be concluded that China's GDP growth is inseparable from a large amount of energy consumption. In addition, China's energy production is characterized by huge differences at the provincial level. All these factors have become roadblocks to China's efforts to reduce its overall percentage in carbon emissions (Figures 2 and 3).

It is widely accepted that CO_2 emissions are the macro determinants of environmental quality (Leal & Marques, 2020; Nidhaleddine *et al.*, 2021), and serious environmental problems have resulted into significant damage to the sustainable development of economy (Wang & Luo, 2020). Hence, it is urgently required that China comes up with innovative solutions and techniques at a breakneck speed along with implementing policies and measures that contribute to reduction of carbon emissions.

As China joins global response to combatting the looming threat of climate change by working on reducing carbon footprint; appropriate financial flows, new technology framework and enhanced capacity building are few areas that will require attention from the government on an immediate basis. A systematic yet long term shift to a sustainable economy characterized by promoting investments that accelerate decarbonization, sustainable solutions, creation of green jobs are few challenges that will have to be overcome to build back better from the current crisis of pandemic coupled with increasing carbon emissions.

Figure 2. Primary energy consumption and annual elasticity of energy consumption in China and the world from 2010 to 2020 (All GDP is calculated in 2010 constant dollars)
Sources: BP Statistical Review of World Energy 2021 (70th edition) and World Bank

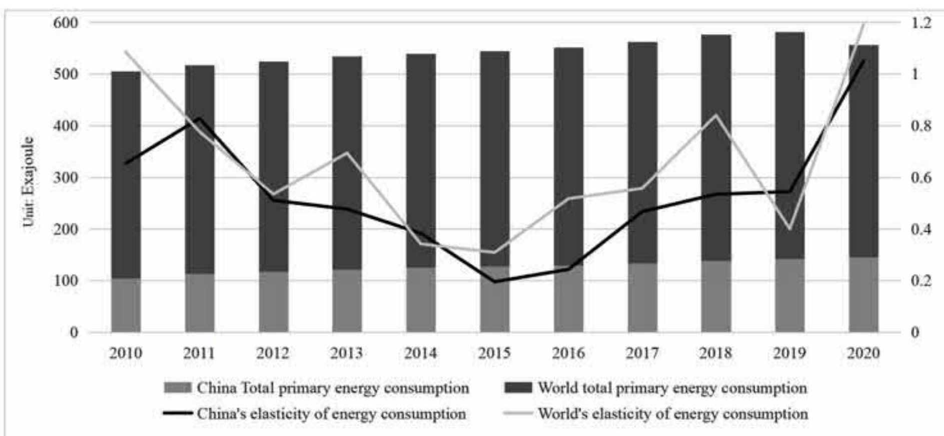
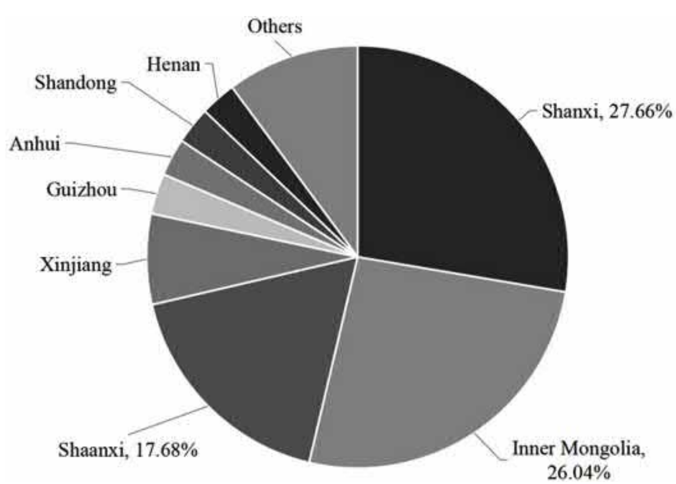


Figure 3. Share of coal production by region in 2020
Source: China Foresight Industry Research Institute

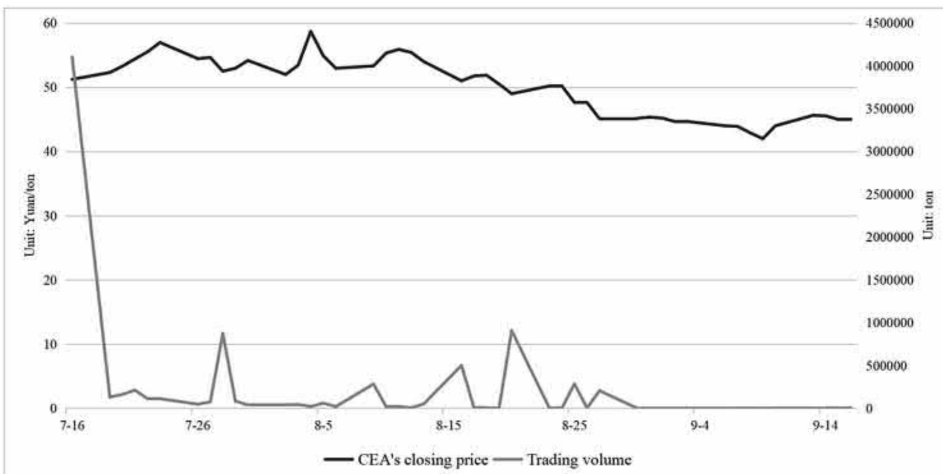


At present, China's low-carbon economy and carbon emission trading are in the primary stage of their development (Chang *et al.*, 2019). In September 2020, Xi Jinping, President of China, announced at the 75th session of the United Nations (UN) General Assembly that China will strengthen its contributions and implement more policies and measures to achieve the goal of cutting down carbon dioxide emissions by 2030 thus achieving carbon neutrality by 2060 (30·60 goals). In December 2020, China announced its commitment that towards 2030, Chinese CO_2 emissions per unit of GDP will be 65% lower than in 2005, the proportion of non-fossil energy in primary energy consumption will reach 25%, forest stock will increase by 6 billion cubic meters over 2005, and total installed capacity of wind and solar power will reach more than 1.2 billion kilowatts (Xinhua News Agency, 2020). In 2021, China has also promulgated regulations such as Guiding Opinions of the State Council on Accelerating the Establishment and Improvement of a Green and Low-Carbon Circular Development Economic System (State Council of the People's Republic of China, 2021) and Administrative Measures for Carbon Emission Trading (Trial) (Ministry of Ecology and Environment [MEE], 2021), and has even announced the first one-year performance cycle of China's carbon market from January 1 onwards. The State Council's executive meeting on July 7 proposed the establishment of a monetary policy to support carbon reduction (Xinhua News Agency, 2021a). Report on the work of the government (Li, 2021) has clearly proposed implementation of special financial policies to support green and low-carbon economy and introduce new tools for carbon emission reduction.

On July 16, 2021, China's long awaited National Carbon Emission Trading Scheme, the world's largest carbon market or China Carbon Emission Trade Exchange (CCETE) was listed. More than 2,000 power plants, accounting for more than 40 percent of the country's carbon emissions, entered the market as the first batch of traders, responsible for more than 4 billion tons of greenhouse gas emissions. Under this scheme, companies were assigned emission targets at the beginning of the year and after trading they were required to submit compliance report to the government. Companies that have surplus target will be able to sell in this market and those polluting will have to buy surplus and submit emission statement accordingly. As of September 16, 2021, CCETE's cumulative trading volume of Chinese Emission Allowance (CEAs) was 8,457,531 tons, with a cumulative trading volume of 416,898,493.8 yuan (Shanghai Environment and Energy Exchange, 2021). Judging from its trading volume, the CCETE is gradually subsiding from its initial activity, and is likely to show characteristics of the previous pilot carbon market (Figure 4). In the next 1-3 years, eight energy-intensive industries, including iron and steel, non-ferrous metals, petrochemicals, chemicals, building materials, paper making, electric power and aviation, will all be included in the national carbon trading market. Towards a low-carbon future, few products are expected to be launched in next few years. Further, the national carbon market is expected to open up to institutional and individual investors next year, with brisk trading. Its cost currently accounts for less than 1% of electricity price and is expected to increase significantly in the next 2-3 years (Yang *et al.*, 2021).

It can be said that with the opening of the CCETE, China's carbon trading system has moved from a local pilot to a national one with the trading volume and activity ushering in a new stage of development. As a regulatory tool, financial products can guide the production and operation activities of enterprises through market means (Wang *et al.*, 2021), while national policies can guide the general direction of enterprises' production at the macro level (Jiang *et al.*, 2016). Although the carbon finance project has expanded a variety of products, its main product is green bonds, and the number of available financial products are still low in number. China has the world's largest green bond market currently, but banks issue debt through regulatory arbitrage rather than the cost of funding mechanism (Cao *et al.*, 2021). At present, the investment in green finance has decreased, and there are still many small and medium-sized enterprises who though committed to a low carbon cause, are facing financial difficulties. Many business entrepreneurs and investors have not yet understood the crucial role of carbon finance, as a branch of the financial industry, bringing about economic benefits. This lack of awareness has also impacted people's participation in the process (Yang *et al.*, 2016). China's climate governance is undergoing a period of transition. The formulation of policies provides guidance for the development of enterprises (An *et al.*, 2021), improves the international influence of Chinese industries (Qi *et al.*, 2021), and provides economic subsidies.

Figure 4. Market situation within two months after CCETE was built
Source: Shanghai Environment and Energy Exchange



However, the coercive means of laws and regulations adopted by the state have few drawbacks. The legal system of carbon emission trading in China being in nascent stage of its development, cannot effectively protect the rights and interests of both sides of the transaction. Few complications further increase the cost of investment and financing. The market entry threshold is too high to reach a balance between preventing market speculation and encouraging companies to voluntarily reduce emissions. All these negative trends have a potential to hamper China's efforts to achieve the Sustainable Development Goals or live up to their commitment towards climate action.

In order to explore the role and responsibility of enterprises and governments in climate change and understand the current situation of sustainable development in China, studying carbon finance and its corresponding policies is necessary. With the establishment of the national carbon emission trading market and continuous improvement of relevant laws and regulations, China's carbon financial market is definitely making a headway towards 2030 with great scope for low-carbon future. This chapter intends to analyze the characteristics of the current Chinese carbon market, the role of the Chinese government in the carbon market, and the specific Chinese case studies, so as to find out the prevailing shortcomings and the steps that can be taken towards improvement.

The following literature review will summarize the current status of China's carbon finance market, then briefly introduce the features of Chinese carbon financial market, followed by a brief discussion of the role of Chinese government in promoting carbon finance along with case analysis. Finally, this chapter provides advice to the future development of China's carbon market from various perspectives, including innovation, capacity building, policy making, financial institutions, and information disclosure.

LITERATURE REVIEW

The commitment to realize reduction of CO_2 emissions by 2030 and hit carbon neutrality by 2060 popularly known as the 30·60 goals in China, demand that industrial transformation and sustainable development go hand in hand. The goal of The Paris Agreement (UN, 2015b) is to reduce global warming. Achieving this herculean task requires that every country commit itself towards achieving a carbon neutral world. United Nations has defined Climate neutrality which is sometimes referred to as carbon neutrality, zero net or net zero, as a process of restoring the balance of the planet, in terms of achieving the percentage emissions to a state that prevailed one and a half centuries ago (Figueres, 2015). The European Parliament (Guillot, 2019) offers the definition that "Carbon neutrality means having a balance between emitting carbon and absorbing carbon from the atmosphere in carbon sinks." China indeed has an ambitious plan as per its unique prevailing local conditions with respect to development needs (Xinhua News Agency, 2021b).

There is no final conclusion yet on whether China's increasing carbon emissions are driven by production or consumption. The fact that it is consistently rising is basically driven by positive economic output and increased energy consumption (Huang *et al.*, 2018; Ma *et al.*, 2019; Zhang & Da, 2015). Developing country such as China, which is characterized by relatively weak environmental protection policy and constraints as to, foreign direct investment (FDI) has by default led to more CO_2 emissions (Ansari *et al.*, 2019; Liu *et al.*, 2021). However, according to Zhang (2011), China's financial development, especially in the wake of increasing role of financial intermediaries, has been a vital factor contributing to increase in carbon emissions. According to Wang *et al.* (2014), China's current carbon policy's main problem is that the key decisions on the production side, need to incorporate proposed emission reduction targets. Further, China's carbon emission regional heterogeneity problems are not given enough appropriate attention as well (Wu *et al.*, 2020; Zhang *et al.*, 2021).

The Emissions Trading Scheme (ETS) is an important market-oriented environmental policy in a market economy system (Ouyang *et al.*, 2020). As a developing country with strategic significance, the construction of China's carbon market can not only solve the issues with respect to increasing global carbon emissions, but also provide valuable and unique experience for other developing countries (Wen *et al.*, 2020). Currently, China's pilot carbon market is small scale with low market efficiency and low market activity coupled with price fluctuations (Liu *et al.*, 2019; Wang *et al.*, 2019; X. Z. Yang *et al.*, 2020). Though, carbon market's different rules and regulations will affect the efficiency of its operation (Zhang *et al.*, 2015), China's CETS is being widely recognized globally as an effective policy tool to promote carbon neutrality (W. Zhang *et al.*, 2020; Y. J. Zhang *et al.*, 2020).

The construction and continuous improvement of carbon finance market is slated to contribute towards achievement of the 30·60 goals. By using macro-prudential financial regulation, banks have expanded the availability of credit flows to support low-carbon activities (Campiglio, 2016). Ding *et al.* (2019) revealed that a higher level of carbon tax greatly affects the rate of carbon emissions. Carbon subsidies further enable a company to make a transition towards low-carbon future and a cleaner production (Cao *et al.*, 2017). This further supports enterprises to move in the direction of energy conservation and environmental protection through regulating market activities (Jung *et al.*, 2018).

Environmental regulation can not only restrict CO_2 emission in China, but also influence the cycle of energy consumption (Zhao *et al.*, 2020). Even if any policy has been designed keeping a short-term goal in mind and overlaps with China's low carbon economy policy (Yang *et al.*, 2019), there is still scope for emission reduction (Akram *et al.*, 2020; Li *et al.*, 2020).

The following sections will demonstrate the characteristics of China's carbon finance market with more specific data.

CHARACTERISTICS OF CHINA'S CARBON FINANCE MARKET

Composition of China's Carbon Finance Market

The carbon financial market in China is particularly dominated by carbon trading with very few participants, being a pilot project in various provinces and cities. Carbon trading is a market-based system that is specifically aimed at reducing carbon dioxide emitted by burning fossil fuels. Cap and trade schemes, as well as a regulated carbon market are a big attraction for government and industry as it brings along an easy mechanism of implementation towards achieving 30·60 goals.

When it comes to carbon financial market, China mainly focuses on trading a variety of carbon products including spot investments, forwards, futures and bonds. The carbon emission trading market started with the Clean Development Mechanism (CDM). The Notice on Carrying out the Pilot work in Carbon Emission Trading (National Development and Reform Commission [NDRC], 2011) proposed to gradually carry out the pilot market of carbon emission trading. Meanwhile, as per Interim Measures for the management of greenhouse gas voluntary emission reduction (NDRC, 2014), it was decided that initially there would be trading in carbon emission rights and subsequently other trading products will be added over a period of time. In addition to the aforementioned quota and Chinese Certified Emissions Reductions (CCER) trading, carbon exchanges in *Beijing* and *Guangzhou* have also established Voluntary Emission Reduction (VER) trading platforms to encourage investors to participate in more diversified carbon emission trading activities.

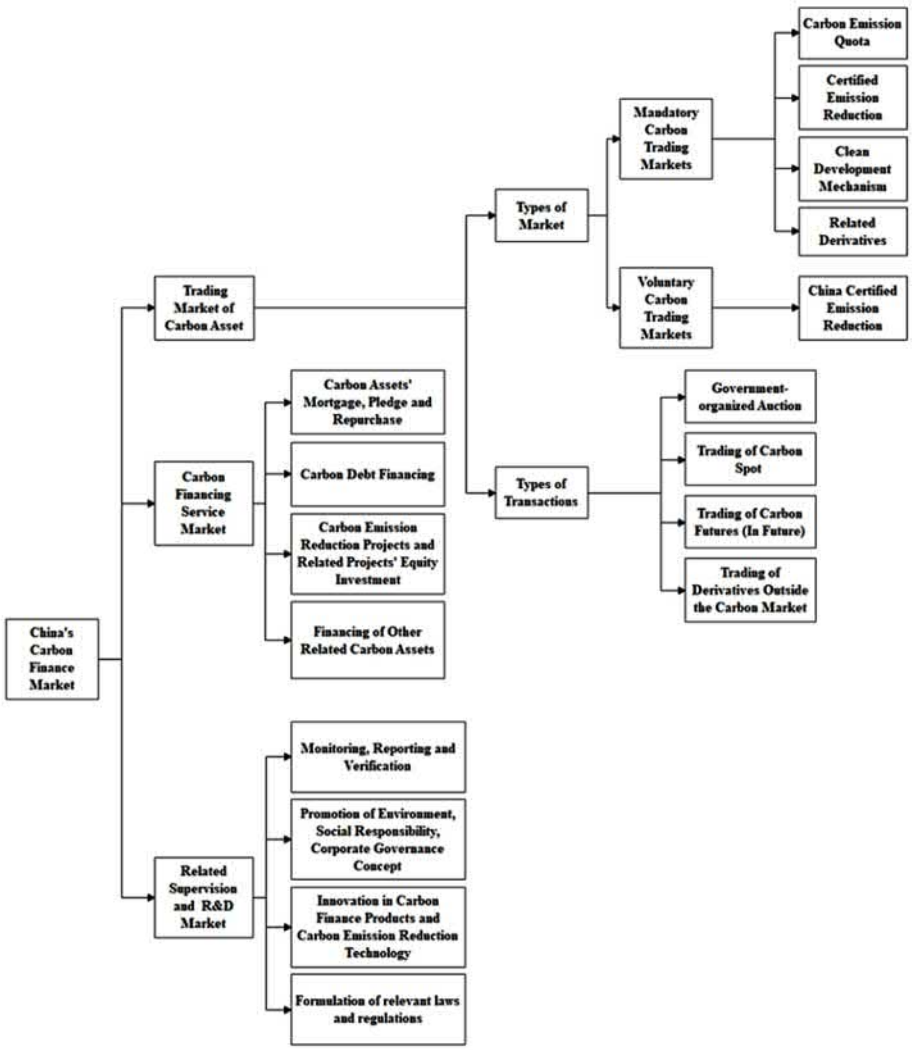
Table 1. Seven pilot carbon market in China

City/Province	Date of Establishment	Cumulative carbon emission trading volume from birth to June 2021 (Unit: trillion yuan)	Cumulative trading volume of carbon emission quota from birth to June 2021 (Unit: brillion ton)
Shenzhen	June 18, 2013	0.73	27.11
Shanghai	November 26, 2013	0.52	17.40
Beijing	November 28, 2013	0.91	14.62
Guangdong	December 20, 2013	1.59	77.55
Tianjin	December 26, 2013	0.20	9.20
Hubei	April 2, 2014	1.69	78.28
Chongqing	June 20, 2014	0.05	8.69

Source: http://www.tanpaifang.com/

Sources: http://www.tanpaifang.com/

Figure 5. Composition of China's carbon finance market
Sources: China Finance 40 Forum and each carbon exchange websites



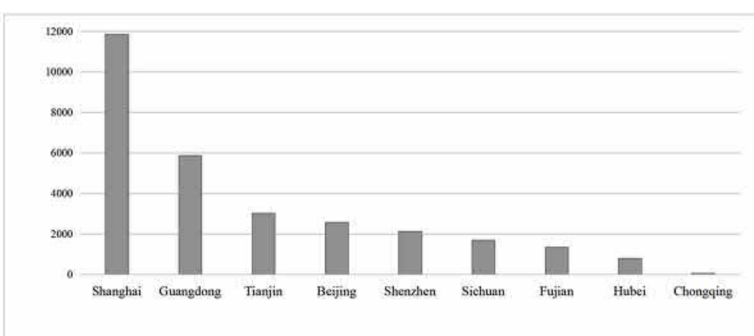
As of June 1, 2021, China's largest carbon financial market in 7 pilot cities recorded a total carbon trading volume 586.6234 million yuan. According to the 2019-2020 National Carbon Emission Trading Quota Implementation Plan issued on December 30, 2020, the carbon emission quotas for 2019 and 2020 which were allocated and traded in 2021, accounted for 70% of the total pre allocated amount, and the remaining 30% was issued after the carbon emission accounting for 2019-2020 was completed. The pre distribution quota was about 5.6 billion tons and if calculated according to the carbon price of 30 yuan per ton, the market value turns out to be 168 billion yuan (Yang & team, 2021).

CDM project market, which first focused on developing carbon market in China, resulted into satisfactory achievements. As of April 1, 2021, the number of CDM registered projects in China reached 3861. From the perspective of its registration, China's CDM projects have developed rapidly between period from 2006 to 2012, where a whopping 3,791 projects were registered and filed in 7 years. After 2013, the rate of CDM registered projects slowed down as a result of EU carbon emission system restricting the offset of CDM projects, resulting in a sharp reduction in CDM projects in China, which earlier accounted for the highest proportion. The projects are mainly concentrated in areas around *Sichuan*, *Yunnan*, *Inner Mongolia Autonomous Region*, *Gansu* and *Shandong* province, and the total number of projects is 1,521, accounting for almost 39% of total number of projects. These CDM projects that have been registered mainly focus on wind energy and hydraulic, recording a number of 2,851 projects accounting for 73.84% of total number of projects (NDRC, 2015).

In 2013, China drawing inspiration from the CDM of the Kyoto Protocol (UN, 1997) undertook planning on constructing CCER as per unique and local conditions prevailing in China. The pilot carbon markets have offsets ranging from 5% to 10%. Before 2017, CCER project registration had been stopped due to its limited contribution in reducing greenhouse gas emissions and insufficiently standardized individual projects in the implementation process. As per the Interim Measures for the management of greenhouse gas voluntary emission reduction (NDRC, 2012), a total of 2871 CCER approved projects and 861 registered projects were carried out from 2012 to 2017, mainly including wind power, photovoltaic, methane recovery, hydro power, biomass energy utilization, waste incineration and other fields. As of May 30, 2021, China's CCER projects have traded 294 million tons of carbon, with Shanghai and Guangdong leading in CCER trading volume, the total trading volume being119 million tons in Shanghai market, accounting for 40.4% of the national total, followed by Guangzhou, accounting for more than 20% (Figure 6).

In December 2020, the Measures for the Administration of Carbon Emissions Trading (Trial) (Draft for comments) clearly included CCER back into the carbon trading market (Environmental Development Fund, 2020). In February 2021, the MEE issued the Administrative Measures for Carbon Emission Trading (Trial), indicating that CCER certification could be restarted for renewable energy, forestry carbon sequestration and methane utilization projects. As of May 30, 2021, the cumulative trading volume of CCER in China's carbon market in 2021 was 30.67 million tons. According to the average price of CCER listed in the most active Shanghai CCER secondary market, the price of CCER showed a relatively upward trend. However, due to the time invested in construction of the carbon emission trading market in each province and the unique pace of economic development of each province, the carbon market of each province in China is different from the other (Carbon Neutrality Committee, 2021).

Figure 6. Accumulative trading volume of China's pilot CCER projects as of May 30, 2021 (Unit: 10,000 tons)
Source: HuaBao Securities

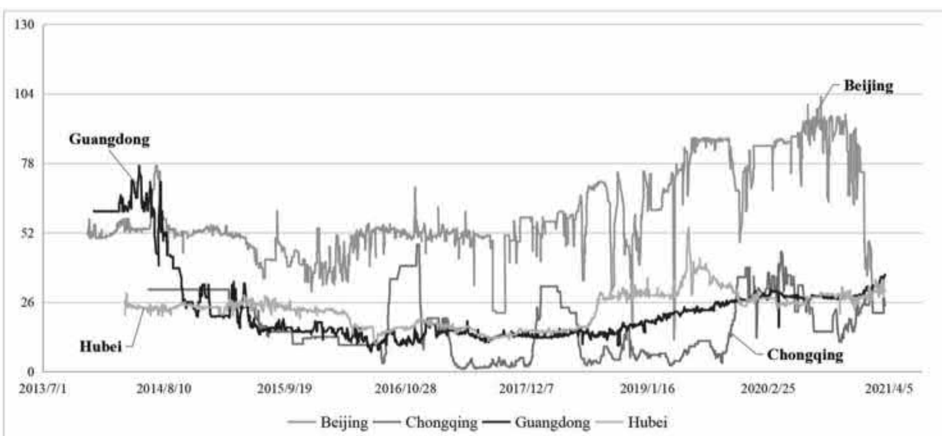


Carbon Price

Carbon pricing which is in the form of a carbon tax or carbon emission trading is a method of applying a cost to greenhouse gas emissions so that polluters can be pushed towards reducing pollution caused by combustion of coal, oil and gas. As far as China's carbon pricing is concerned, the same is not uniform across the country, and the price is generally low, with a significant amount of volatility in the market.

China began to develop its carbon trading market during the second commitment period of the Kyoto Protocol (2013-2020), and currently it is in the stage of comprehensive expansion from the standpoint of world market (Liu *et al.*, 2017). As of June 2021, China's carbon market reached 5,866.234 million yuan and 241.309 million was the total volume of trade. From the global perspective, the carbon price in China is generally low with a weak market stability. At current pace of carbon price, China will not be able to achieve its 2030 target of reducing carbon emissions by 42% from 2015 levels (Wang & Wang, 2021). According to the report of a survey, carbon price in China (Slater *et al.*, 2020) is expected to rise to 71 yuan/ton in 2025 and 93 yuan/ton by the end of the next decade. If the carbon price in China rises too fast in the short term, it might turn out to be harmful for enterprises in the long run.

Figure 7. Historical carbon prices at China's pilot exchanges as of the first quarter of 2021 (Unit: yuan)
Sources: CSMAR, www.tanpaifang.com and each carbon exchange websites



As per the usual price theory, in a perfectly competitive market, the carbon price should be equal to the marginal cost of emission reduction. However, China's carbon price is set by each province's carbon exchange, which leads to different carbon prices. While evaluating how carbon prices have fluctuated on account of exchange since they were established, it can be seen in figure 7 that Beijing's trading price has been very high for most of the time during last 16 years. Thus, it will be reasonable to say that the fluctuation of carbon price shows convergence. With the passage of time, the fluctuation of carbon price will gradually change from being relatively volatile to being stable. At present, only Guangdong province has achieved convergence. However, the price of carbon on the other exchanges generally fluctuates around 25 yuan, rarely above 50 yuan a ton. In terms of actual demand, the price of carbon permit is slightly lower (Figures 7a and 7b). As per the report published by The World Bank, the Paris Agreement's target quota price is between 40 to 80 Euros, which makes it nearly impossible for China to achieve the expected emission reduction target within the estimated time. In addition, these fluctuating carbon prices cannot truly reflect the emission reduction performance of enterprises (Y. Li *et al.*, 2021).

Products Related to Carbon Finance in China

There are many types of financial products circulating in China's secondary carbon market, but they are still not comprehensive. The total number of innovative carbon financial products is small, which is difficult to meet the demand. China's secondary carbon market though rich in product categories, has relatively few numbers of products (Tables 2 and 3). Carbon finance places great emphasis on addressing climate change and low-carbon transition, with economic activities, market players, investment projects and related assets following a clear path to low-carbon and zero carbon (Chen *et al.*, 2021). In recent years, pilot regions in China have successively launched a variety of innovative carbon financial products, such as carbon neutral bonds, carbon forward, and carbon emission right credit pledge financing. Enterprises in *Beijing*, *Hubei*, *Shenzhen*, *Guangzhou* and other pilot places have tried to carry out relevant carbon emission trading financial derivatives services, mainly focusing on funds, bonds, pledge financing, repurchase financing and other project. However, the challenge continues to remain the limited scale of operation as a result of which financial institutions continue to be in the exploratory stage of accepting the financing method with carbon emission right as collateral, and vast majority of transactions being the "first order".

The development of China's financial industry owes its growth majorly to implementation of green credit policy. Today, China is leading the world in this area and innovation in technology, such as use of big data, artificial intelligence, Internet of things, has further added to growth of this sector adding great value to the country. Green credit has not only become an important profit growth point for banks, but also one of the most important marketing strategies of modern commercial banks, helping them in building the visibility (Cheng & Huang, 2021). At present, green credit accounts for 10% of loan balance, and green bond accounts for less than 2% of credit debt. All these factors point towards the fact that the concept of carbon financing and carbon financial derivatives still needs further innovation. State-owned enterprises are the majority of participants in China's carbon market. But there is a significant difference between the enthusiasm of enterprises to participate in the primary market and the secondary market (Song *et al.*, 2019). Most enterprises participating in the carbon market regard the allocation of carbon emission quotas in the primary market as a political obligation, accompanied by their own enthusiasm for trading activities. By contrast, they lack such willingness and participation in the secondary market (Deng *et al.*, 2018). Thus, it can be concluded that the current secondary carbon market in China is largely affecting the investment efficiency and market participation.

Table 2. Carbon finance primary products

Projects	Legal Basis	Way To Perform	Content
Allocation of Carbon Emission Quota	Interim Measures for the Administration of Carbon Emission Right Trading	Compulsory	•The provincial government allocates its own carbon quota to enterprises. • Each pilot exchange sets its own rules.
CCER	Interim Measures for the Administration of Voluntary Greenhouse Gas Emission Reduction Trading	Voluntary	•Third party certification of participating institutions, state record. • Encouraging investment in areas or industries with lower emission reduction costs has reduced the overall emission reduction performance costs.

Sources: King & Wood Mallesons

Table 3. Part of the first case of carbon financial products in China

	Product	Case
Carbon Financial Derivatives	Carbon Forward	• 2021.7.16 *Huaxia* Bank and National Energy Group *Longyuan* (Beijing) Carbon Asset Management Technology Co., LTD. Carbon forward transaction letter of guarantee business.
	Carbon Futures	• Not yet. On April 19, 2021, Guangzhou Futures Exchange will inaugurate, and it is expected that carbon emission rights futures will be the first to appear here.
	Carbon Swaps	• On June 15, 2015, the first "carbon emission right OTC trading contract" was signed. CITIC Securities Co., LTD. and Beijing Beijing Energy carbon Asset Management Co., LTD conduct swap transactions in the form of "non standardized written contract", and entrust Beijing Environment Exchange to be responsible for margin supervision and contract settlement.
	Carbon Fund	• In November 2014, China *Huaneng* Group CO., LTD and Lion Fund jointly released the first "carbon emission Right Special Asset Management Plan" fund filed by the regulatory authorities in Hubei Province, and the initial scale was designed to be 30 million yuan.
	Carbon Bonds	• On May 12, 2014, China's first "carbon bond" -- CGN Wind Power Co., LTD Medium-term Notes with additional carbon revenue was announced to be issued in Shenzhen, with an amount of 1 billion yuan and a maturity of 5 years.
Carbon Finance Innovative Products	Carbon Pledge and Carbon Mortgage	• On September 9, 2014, *Hubei Yihua* Group Co., Ltd. used 2.1 million tons of carbon emission quota as collateral and obtained a loan of RMB 40 million from Industrial Bank.CO., LTD for energy conservation and emission reduction. It is the first pledge loan of carbon emission rights in China. • On December 25, 2014, China *Huadian* Group New energy Development Co. LTD in Guangzhou University Town, the first domestic carbon emission right mortgage financing business, recently obtained 10 million yuan of carbon quota mortgage financing from *Shanghai Pudong* Development Bank and overdraft credit of corporate account of emission control enterprises with Guangdong carbon quota.
	Carbon Trust	• On April 8, 2015, the first carbon trust fund launched by *Hubei* carbon emission trading center and China Merchants Bank *Guojin* Investment Co., Ltd. was officially launched in city Wuhan. The capital scale of the first phase is 50 million yuan.

Sources: Collated from relevant research data of each pilot carbon market

Carbon Financing Market in China

Chinese carbon financing market is still in the initial stage of development. Though, the basic institutional structure of China's carbon finance market is sound, its overall scale and influence need to be improved.

Table 4. Part of institution in the carbon finance market

	Organization name	Brief introduction	Performance of duties
Leading institutions	The National Development and Reform Commission (NDRC)	• Under the State Council lead, it is the highest level supervision department, responsible for development direction guidance and policy formulation.	• A series of laws and regulations have been introduced to ensure the development of China's carbon finance market.
	China Clean Development Mechanism Project Management Center	• Provide CDM project review, registration, tracking testing, information consulting and other services, under the management of the NDRC.	• CDM projects assist in development.
	China Clean Development Mechanism Fund Management Center	• To provide access to financing for CDM projects, managed by the Ministry of Finance.	
Regulators	Pilot carbon exchanges	• Conduct supervision in their respective jurisdictions in various forms, such as establishing trading rules, limiting registration conditions, and establishing various trading modes, so as to accumulate experience through innovation.	• It should continue to improve the carbon financial trading system and accumulate experience for the national carbon market. However, due to the different standards of different exchanges, it is not conducive to unified measurement and direct comparison.
	Third party verification and certification bodies	• Responsible for verifying the certified emission reduction of CDM project. There are 19 in all, and most of them are from abroad.	• Can speed up the project approval progress and reduce the cost.
Intermediary service agency	Commercial Banks	• Main 2 of them: Industrial Bank (China's only "Equator banks") and Shanghai Pudong Development Bank that have provided new wealth management products and financing channels.	• Entangled in the risk balance between profit maximization and social responsibility, most commercial banks do not have high participation rate and their services are still insufficient.
	Insurance company	• It also provides innovative products such as environmental pollution liability insurance and smog health insurance, and indirectly uses funds to support the development of China's carbon reduction cause.	• Limited by the regulatory system, there are limited carbon financial markets available for participation. Still in the research and development stage, the service mode is single.
	Securities company	• Mainly carry out spot trading. It promote product innovation such as environmental verification of listed companies and carbon-neutral debt.	• Related financial derivatives transactions are few, but it has become one of the main fronts of carbon finance innovation.
	Carbon fund	• At present, the two major funds are government funds: China Clean Development Mechanism Fund and China Green Carbon Fund, which open up financing channels for more enterprises.	• The carbon fund, which has not yet been fully self-financing, is still in the development stage with a relatively small scale and a relatively single source of capital.
	Law office	• Provide legal services. King & Wood, for example, specializes in CDM project development and promotes the establishment and revision of relevant laws and regulations while providing legal services.	• Its service object and content are relatively single, and still need to further development.

Source: Research on the Internal Operation and Management Mechanism of Carbon Financial Transaction in China and each institution's website

IMPACT OF GOVERNMENT POLICY

As opposed to carbon market in Europe, China's carbon market was defined as a policy tool for achieving sustainable development and promoting enterprises' low-carbon transformation even before its construction. Chinese government is widely recognized as the founder and promoter of the carbon market in China. Most developing countries have a rapid economic growth rate, but it leads to many serious environmental problems (Liu *et al.*, 2020). Companies emphasizing on political linkages is a common phenomenon in developing countries (Claessens *et al.*, 2008), and emerging market economies often obtain valuable resources by establishing political relations (Li & Zhang, 2015). As the world's largest developing country, China's economic development depends on the government's strong policy guidance. For example, despite market-oriented reforms aimed at reducing administrative involvement in allocation (D. Yang *et al.*, 2020), the Chinese government still has a significant influence on the allocation of basic resources.

China is a country with multiple levels of governance whereby each level has a corresponding responsibility for reducing emissions. In China, local governments are not only the environmental policy maker, but also the recipients of indicators assessment and this grassroots movement has set the pace for the development of carbon market and carbon finance in China. Market-based trading mechanism is an important means for the Chinese government to control environmental pollution. Since the 30·60 goals were proposed, the central and local governments in China developed a series of policies, aimed at promoting enterprises to strengthen their efforts thereby inspiring many market participants and opening the way for the low-carbon transition (Table 5). The relevant legislation of carbon emission trading in China has experienced the process of "from bottom to up" and "from local to central". Chinese government is constantly innovating and improving relevant laws, regulations and policies, so as to mobilize the enthusiasm of enterprises for low-carbon development and enhance the participation of the financial industry and consumers. In addition, the Chinese government has also been improving its work efficiency through measures such as streamlining administration and delegating power, combating corruption and upholding integrity. For example, the organizing department of the Central Committee of the Communist Party of China issued the Opinions on Further Regulating party and Government Leading Cadres' Part-time Jobs (Posts) (Document No.18) on October 19, 2013 (National Health Commission, 2021). The main content of this regulation is to restrict government officials from participating in high-level management positions of enterprises and eradication of corruption (Xu, 2018).

The establishment of a sound market information disclosure mechanism is crucial to the development of China's carbon financial market. Despite the failure of the much-anticipated mandatory environmental disclosure requirement for listed companies in China in 2020, the government has been maintaining its stance of going ahead with environmental information disclosure.

The government policies in China have been designed to ensure the long-term development of China's carbon financial market. Firstly, China has recognized the legality of carbon emission permits as part of its national legislation, so as to realize the commercialization of these permits. Secondly, the carbon emission trading policy under the "mandatory" mechanism can realize the "double control" of the total energy consumption, stimulate the emission reduction potential of enterprises, and improve the technical research level. Without any enforcement mechanism and government regulation, the innovation needed to develop low-carbon solutions will be difficult to achieve (Pestre, 2019). With the increase in number of environmental regulations, many enterprises in emerging market and transition economies have established political links to offset the pressure of environmental regulation, rather than strengthen their green technology innovation (Chen *et al.*, 2011). Chinese authorities as a result are reluctant to open the carbon market to financial institutions for risk control reason. Although China's carbon market was set up by the Chinese government, government officials are not direct market participants, so it is impossible for them to know the real picture on the ground. This also causes problems such as price fluctuations and single product categories. Political connections have a potential of negatively impacting companies (Chan, 2020; Q. G. Liu *et al.*, 2013). They can lead to distortion in resource allocation and long-term investment strategies, as well as the long-term investment behavior of firms (Xu *et al.*, 2013). Qin and Zhang (2019) pointed out that de-politicization promotes innovation in enterprises. So, Chinese government bears a heavy responsibility on its shoulders to tap the maximum potential of the carbon market thereby achieving the goal of sustainable development.

Table 5. Part of the latest regulations relating to the 30·60 goals

	Time	Policy	Contents
The National Level	December 2020	White Paper on China's Energy development in the New Era	• Implement the new energy security strategy of "Four revolutions and one Cooperation".
	February 22, 2021	Guiding Opinions of The State Council on Accelerating the Establishment and Improvement of a Green, Low-carbon and Circular Economic System for Development	• Implement green planning, green design, green investment, green construction, green production, green circulation and green consumption in all aspects of the whole process, and establish and improve the economic system of green, low-carbon and circular development.
	March 5, 2021	Government Work report (2021)	• Optimize the industrial and energy mix, promote clean and efficient use of coal, and vigorously develop new energy sources. Special financial policies should be made to support green and low-carbon development, and set up tools to support carbon emission reduction.
	March 12, 2021	The 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Outline of the Long-term Goals for 2035	• In building a modern infrastructure system, implementing the strategy of making China a strong manufacturing country, and other aspects of green development, industrial layout optimization and structural adjustment, and strive to achieve the goal of 30 · 60.
	March 25, 2021	Opinions of The State Council on the division of Tasks in implementing the Report on the Work of the Government	• It sets 2021 targets for further improving ecological and environmental quality, reducing energy consumption per unit of GDP by around 3%, and continuing to reduce carbon emissions of major pollutants.
Local Government Level	January 29, 2021	Shanghai Included in the List of Carbon Emission Quota Management Units (2020 Edition) and Shanghai Carbon Emission Quota Allocation Plan in 2020	• It will carry out quota allocation and management in a standardized and orderly manner. "The plan" stipulates the allocation of total amount, allocation method, quota distribution, quota clearance and offset mechanism and other contents.
	May 13, 2021	Jiangsu Provincial Department of Ecology and Environment will promote carbon peak and carbon neutral work plan in 2021	• It has clearly promoted the provincial action plan, carried out the pilot carbon emission and environmental impact assessment management plan, promoted the regional coordination of carbon emission reduction and the prevention and control of air pollution, promoted the development and utilization of key industrial parks, and promoted the demonstration of low-carbon and low-carbon city parks.
	June 6, 2021	Guidelines on the carbon peak and carbon neutrality of Sichuan provincial enterprises	• It aims to give full play to the leading, demonstration and driving role of state-owned enterprises to promote low-carbon and green development. Promote the formation of a green and low-carbon development pattern.

Source: China Clean Air Policy Partnership

CHINESE CASE STUDIES

This part introduces three practical cases bringing about significance and contribution of carbon finance in China.

Table 6. Part of regulations related to China's environmental information disclosure

	Date	Title	Contents
Government	August 31, 2016	Guidelines on building a green financial system	• Gradually start the top-level construction of green finance policy in mainland China
	2017	A three-step plan for mandatory environmental disclosure	• The "three-step" strategy of environmental information disclosure is proposed, and the completion time of mandatory information disclosure is specified.
	October 29, 2020	Green Finance Regulations of Shenzhen Special Economic Zone	• Some financial institutions will be forced to disclose environmental information from January 1, 2022. Qualified banks, public funds, private funds and institutional investors will also be required to disclose environmental information from January 1, 2023.
	December 30, 2020	Reform plan for the legal disclosure system of environmental information	• Legal disclosure of environmental information is an important enterprise environmental management system and the basic content of ecological civilization system.
	February 2021	Guidelines on accelerating the Establishment and Improvement of a Green, Low-carbon and Circular Economic System for Development	• As the basis of laws and regulations, the implementation of environmental information disclosure will provide strong support for the development of green, low-carbon and circular economic system and green finance.
	June 28, 2021	The information disclosure content of the company that publicly issues securities and Format Guideline No. 2 - Content and format of annual Reports (2021 Revision)	• Companies are encouraged to disclose in regular reports the measures taken to reduce their carbon emissions and their results, as well as to consolidate and expand achievements in poverty alleviation and rural vitalization.
Carbon Exchanges	2018	Guidelines for environmental, Social Responsibility and Corporate Governance Information Disclosure of Listed companies in Shanghai Stock Exchange	• It strictly standardizes the disclosure content of listed companies in terms of environmental responsibility, social responsibility and corporate governance.
	December 18, 2019	Guidelines on Environmental, Social and Governance Reporting Listing Rules	• Listing documents must contain ESG information. New climate change disclosure requirements and revised environmental key indicators for fiscal years beginning after July 1, 2020.
	24 July, 2020	Revised initial public Offering Guidance letter	• The board of an IPO applicant is required to ensure that corporate governance and ESG governance mechanisms are in place during the listing process, with preparation for ESG disclosure as a necessary condition for the listing application.
	September 2020	Measures for Assessment of Information Disclosure of Listed Companies of The Shenzhen Stock Exchange (Revised in 2020)	• The ESG evaluation criteria of "whether to actively disclose the performance of environment, social responsibility and corporate governance (ESG), and whether the content of the report is substantial and complete" will be included in the information disclosure assessment of listed companies.
	October 2020	A consultation paper on fund managers' management and disclosure of climate-related risks	• From the perspective of investors, it proposes to amend the Code of Conduct for Fund Managers to enable fund managers to properly consider and disclose climate-related risks in their investment and risk management processes.

Sources: Central and local governments and carbon emission trading market website

Low-Carbon Cities and Eco-Cities Built by the Chinese Government: Taking Longgang District of Shenzhen City and Sino-Singapore Eco-City of Tianjin City as Examples

China has invested greatly in developing green as well as sustainable cities, launching a series of measures to promote "ecological civilization", such as eco-city and low-carbon city. The construction of national green cities in China has been completed in cooperation with foreign governments, as the success of the entire process depends heavily on the amount of funds brought by the sponsors (Hult, 2015), which usually is the government in most cases. Since building sustainable cities needs huge investments, it is a huge challenge for local governments. It is estimated that China's investment in green projects (such as ecological and low-carbon cities and renewable energy projects) between 2015 and 2020 is about 2.9 trillion yuan. Even if the government budget can complete the entire project sufficiently, it is difficult to ensure that the same will contribute to sustainable development achieving desired objectives in a way actually intended. Therefore, it is crucial to balance financial instruments and programs in order to draw funding from a variety of sources for ensuring the overall viability of eco-city projects (Zhan *et al.*, 2017).

By studying these cases, common features can be recognized whereby the government leads the projects and develops financing methods suitable to unique local conditions.

International Low-Carbon City of Shenzhen

The International Low-carbon City of Shenzhen (ILCC), a demonstration project of the China-EU Partnership on Sustainable Urbanization (CEUPSU), was launched in 2012 with the support of China's

National Development and Reform Commission, which is aimed at achieving development in an environmentally, socially and economically sustainable manner (Cheshmehzangi *et al.*, 2018; Shenzhen International Forum Low Carbon City, 2021). Its planned total area is 53.14 square kilometers, the scale of construction land is 19 square kilometers, and the basic ecological line control area reaches 63% (Shenzhen Longgang, 2021). In 2021, *Longgang* District's Government Work Report proposed to accelerate the promotion of green and low-carbon development. The same is expected to promote the development and construction of international low-carbon cities with high standards, implementation of projects relating to hydrogen energy industrial parks and other projects along with building a national low-carbon pioneer zone for sustainable development (Longgang District People's Government, 2021).

The new financing method adopted by ILCC is aimed at the overall planning of the village, innovating the financing method, developing the real estate and railway, as well as enhancing the construction of infrastructure.

Planning the village area as a whole (PVAW) is a new way of land preparation method, where state-owned land, collective land, individual non-agricultural land and other scattered land are clubbed together allowing local government, community and real estate developers to thereby plan its constructive use. The interests of local residents are incorporated into the redevelopment of community, economy, high-end industries and public utilities, so as to maximize the interests of the community and residents. As residents collectively use their land to invest in ILCC, PVAW aims at reducing government investment in land preparation method.

The investment and financing mode: construction of metros and property development is franchised to a subway company by local governments. The subway company then sublets the contracts for the real estate development to real estate companies, which in turn develop commercial buildings, lease and sell real estate, share the income with metro companies and realize the value-added of real estate. This makes a large part of financing of construction of infrastructure to be borne by market investors, thus reducing the overall pressure on local finance institutions (Zhan & De Jong, 2018).

Sino-Singapore Tianjin Eco-City

Sino-Singapore Tianjin Eco-City (SSTEC) is a major strategic cooperation project between the governments of China and Singapore. It is the world's first eco-city jointly developed by countries and this project was launched in September 2008 (China-Singapore Tianjin, 2021). By the end of 2020, 39 parks have been built and put into use in the eco-city, with a total green area of 1,049 hectares. There are 54 three-star green buildings, 68 sponge city pilot projects which have been completed, and the pilot construction of "waste free city" is also being carried out. The next move of SSTEC now is to move towards development of smart city (SSTEC, 2021).

SSTEC was established with "the strong support of the national government and the structural participation of foreign investment", receiving policy and financial support from the governments of China and Singapore. Local governments cooperated with the central government to finance the development of SSTEC by providing funds and tax rebates. The financial instruments used by SSTEC to support the construction of eco-cities include bank loans, corporate bonds, government funds, tax rebates, private capital and international assistance projects. Out of all the sources mentioned, bank loans and corporate bonds are the two main sources of funding for SSTEC. For example, the National Development and Reform Commission gave priority approval to SSTEC to issue corporate bonds worth 1.2 billion yuan. In addition, SSTEC has made innovations in the ownership structure as well. The establishment of Tianjin Eco-City Investment and Development Co., Ltd (TEID) has brought about great changes in equity structure and company operation, making the financing model of "government investment and government leading" more complicated. TEID has now moved away from performing the role of a traditional financing vehicle, delegating tasks to different specialized subsidiary, thereby allowing it to operate more like a business in the marketplace. In addition, the information and technology TEID gained from the construction of SSTEC has enabled in generating more revenue. This prevents companies from becoming financing tools for local governments. The ownership structure separates the functions of local governments and enterprises, which is conducive to the marketization of enterprises and improves the efficiency of economy as well as decision-making. In addition, the franchise agreement signed with the government is a guarantee for TEID and its subsidiaries to obtain sustainable operating assets and stable cash flow expectations, which further expands TEID's funding sources arousing the enthusiasm of enterprises to invest (Zhan & De Jong, 2017).

Innovation of Carbon Financial Products: Carbon Neutral Bonds

In response to the carbon neutral target, on February 9, 2021, the National Association of Financial Market Institutional Investors (NAFMII), under the aegis of the People's Bank of China, actively implemented the green development concept in the bond market. Carbon neutral bond was launched, and the funds raised were used for green projects with carbon emission reduction benefits. According to the definition set by the Association (NAFMII, 2021b), carbon neutral debt financing instrument is a type of green bond, which is a debt financing instrument that raises funds specifically for green projects with carbon emission reduction benefits.

As of July 8, 2021, a total of 111 carbon neutral bonds were issued in the market, with a total issuance of 120.593 billion yuan (Bao, 2021). Although the scale of issuing carbon neutral bonds has decreased in the past three months, the proportion of carbon neutral bonds in relation to issuance scale of green bonds has reached 44.77% within half year of its creation, thus effectively leading the way for funds to be invested in green and low-carbon industries. As of July 10, 2021, a total of 73.938 billion carbon neutral bonds were issued in the inter-bank market and 46.766 billion carbon neutral bonds were issued in the exchange market, with clean energy projects accounting for 56%. Its main varieties include debt financing instruments, corporate bonds and asset-backed securities. At present, carbon neutral bonds are generally issued by large state-owned enterprises. The reports reveal that the issuance scale of AAA subjects accounts for 96% of the stock market scale, and AA+ and AA account for 2% respectively. In terms of the nature of enterprises, central enterprises account for 77% of the stock issuance, and state-owned enterprises and private enterprises account for 18% and 5% respectively. In addition, on the whole, the credit qualifications of the issuers of carbon neutral corporate bonds and carbon neutral debt financing instruments are AA+, AAA and other high level credit qualifications belong to central enterprises and local state-owned enterprises. Carbon neutral bonds are publicly issued and in terms of bond maturity, the time period is generally short term such as 2 or 3 years. The funded projects are mainly clean energy projects relating to hydropower, wind power, photovoltaic power generation, nuclear power and pumped storage, as well as rail transit and low-carbon green building projects (Zen & Wu, 2021).

As compared to other carbon financial products, carbon neutral bonds have a better mechanism. For example, in its March 18 notice, the NAFMII clarified the scope of raising carbon neutral bonds, project evaluation, fund raising, administrative requirements, and made mandatory the timing of information disclosure (Gao, 2021). At the same time, NAFMII (2021a) issued policies to encourage enterprises to register and issue carbon- neutral bonds, such as opening up a green channel for the registration and evaluation of carbon neutral bonds, providing them with special marks, encouraging the research and development of medium and long-term products, and encouraging enterprises to register and issue innovative products of structural debt financing instruments such as green asset-backed notes supported by the cash flow generated by carbon emission reduction projects.

Carbon Finance Projects: Take Qingdao Kc Blue New Energy Co., Ltd. as an Example

Qingdao Kc Blue New Energy Co., Ltd. (Kc Blue) is a green enterprise committed to environmental protection, which is mainly engaged in refrigeration, heating and air conditioning equipment production and heat pump host and heat exchanger's research and development. In 2011, its chairman returned to his hometown to start his own business with the "world's first and international leading" raw sewage heating technology. This technology takes heat from underground sewage, replaces air and surface water, thereby producing a higher amount of energy. As compared to traditional methods, it saves 50% of initial investment, 30% of operating cost, and does not even produce smog. The project was awarded "National Science and Technology Benefiting the People Project" by the Ministry of Science and Technology. Due to its strong market demand, the enterprise is overwhelmed with orders and is urgently looking for funding to build a new production base. Further, in 2016, Kc Blue was listed on the New Third Board Market (that's China's over-the-counter market, established in 2006) and successfully landed on the capital market, realizing 10 million square meters of new energy heating device, saving 46,000 tons of coal and reducing 114,000 tons of emission of carbon dioxide annually (Zhang & Zadek, 2015). In 2017, Kc Blue led the design and construction of the country's first urban central heating overall clean renovation project, which was used as a model project of the national "blue sky protection". In 2019, Kc Blue fully promoted and improved the planning, design and construction of various projects, and completed the construction of *Hongdao* energy station of *Ji-Qing high-speed railway*. The station too functions in a unique way so as to conserve energy (Kc Blue New Energy, 2018). Thus, it is visibly clear that financial investment has made the development of low-carbon enterprises a smooth process.

Kc Blue's experience is not unique. Based on the diversity of carbon market products, carbon finance provides carbon finance services to various government projects and companies, helping them access financing and the necessary industry information for achieving sustainable development.

SUGGESTIONS FOR THE FUTURE DEVELOPMENT OF CARBON FINANCE

Business Innovation Activities

Technological innovation will play an important role in enabling the industry to achieve carbon emission reduction and optimum utilization of capital resources simultaneously (Ma *et al.*, 2021). For example, research on manufacturing enterprises shows that every 1% increase in the level of low-carbon technology will increase the operating performance of manufacturing industry by 0.2% (F. Li *et al.*, 2021).

The government as well as business enterprise sector to focus more on enhancing technological innovation thereby paving a way for a brighter future for all mankind. The government can carry out structural reform in an environment-friendly way, for instance by promoting the development of renewable energy (Dong *et al.*, 2021), so as to provide a safe and stable environment for business innovation. For enterprises, it is necessary to integrate carbon emission reduction into all aspects of their operations, such as performance appraisal and investment decisions, making full use of advanced technologies like the big data, cloud computing and artificial intelligence, to promote business transformation through innovation and improvement in production capacity and efficiency. The UN's Sustainable Development Goal Number 13 related to taking climate action by cutting carbon to net zero and building resilience against physical impact of climate change, requires that along with the measures to contain carbon emissions, innovative ways to simultaneously address the emerging momentary issues be also introduced (UN, 2015a).

Capacity Building

Human capital is a significant determinant of ecological and carbon footprint in order to assess the extent of environmental degradation in the short and long term (Wang, 2021). But Salahodjaev (2018) believes that the carbon trading system lacks potential. On one hand, due to inherent challenges in the system, the market is restricted and limited and on the other hand, the carbon industry demands skilled workforce with professional expertise during the construction stage.

There is an urgent need for strengthening capacity building in this sector. Banking institutions can strengthen cooperation with experts or other related institutions, and introduce more professionals with environmental, energy efficiency, chemical, energy and other professional backgrounds. Further, they should continue to develop more effective trading manuals, establish databases, and actively provide market information and training services to enhance capacity building efforts. In addition, universities can also include carbon market research into its curriculum to introduce students to this sector thereby encouraging them to polish and hone their skills for being absorbed into the industry in the near future.

Construction of Carbon Market

Some regulations and policies in China are not conducive to carbon financing schemes, and it often takes a long time for policies to upgrade. The design and implementation of the pilot project is the responsibility of local governments, but only a few government officials have knowledge and expertise to handle trading activities and markets. Professionals in the field of finance have the expertise to provide advice, but only few of them are involved in the decision-making process. In addition, official data and regulatory standards for emissions are far from mature and its inconsistency makes it even more difficult for financial institutions to assess the economic risks or environmental viability associated with carbon finance applications (Adams, 2013). Though, there are many theories about the legalities concerning carbon emission rights in academic circles, but there is no consensus yet among the academia (Giurco *et al.*, 2014; Karsenty *et al.*, 2014).

Appropriate environmental regulations have been shown to have a positive impact on reducing carbon emissions, and scholars have pointed out that political relations can help enterprises overcome financing constraints, obtain innovative resources, benefits, subsidies, and influence long-term decisions (Atsu & Adams, 2021). The central government can legislate to determine the legality of carbon emission rights ensuring the implementation of relevant policies, so as to reduce the trading risks of financial institutions, enterprises and investors. Further, significant efforts can also be made for providing incentives for local governments including their officials such as providing prize money and publicly rewarding good performance. Central and local governments need to formulate more reasonable carbon tax policies and implement post-assessment system for carbon financial policies, such as setting up carbon emission trading platforms and implementing various forms of carbon emission trading schemes (Jabbour *et al.*, 2020; Li & Masui, 2019; Qin *et al.*, 2016). Avoiding aggressive carbon reduction measures that are not tailored to local conditions, can also be of consequence in the long run.

Financial Institutions

Currently, only the carbon spot market is allowed in China, but it has become less attractive to financial services providers and investors, because they are not allowed to speculate on future price rise or fall and take risks. There is also a prevailing misunderstanding about carbon emission rights and their financial attributes, resulting in the lack of integration between the financial industry and carbon trading system. The role of financial development in shaping the ecosystem depends on the allocation of financial resources. According to the analysis by the National Center for Climate Strategy and International Cooperation on China's current sources of climate finance and its future demand for climate finance, China needs at least 3.5 trillion yuan per year to achieve its 30·60 target (Center for China and Globalization, 2021). At present, the annual supply of funds is only 525.6 billion yuan, with a shortage of more than 2.5 trillion yuan per year (Liu, 2021). As for the carbon financial market, the funds of the traditional financial industry cannot be released in a timely manner, thereby resulting into issues such as insufficient funds in the early stage of development leading to excessive dependence on government financial subsidies for financing.

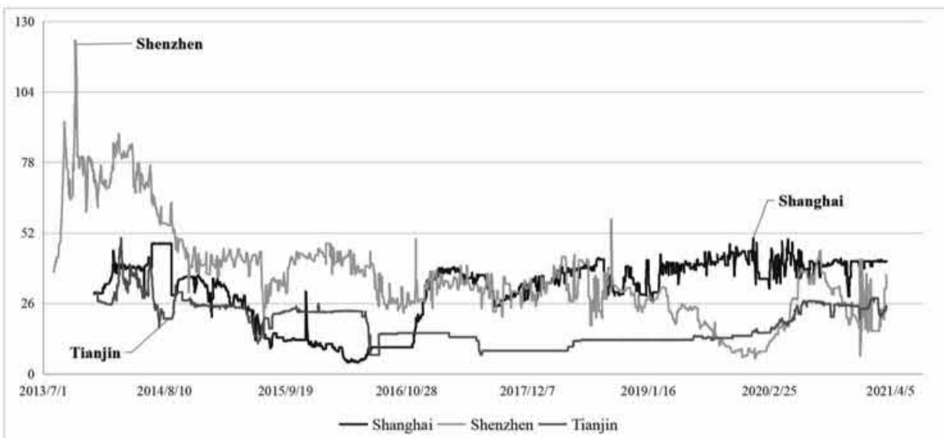
This kind of scenario demands comprehensive promotion of the combination of construction of a robust national carbon finance market coupled with, reforms in the trading system. Financial institutions need to increase their efforts for spreading awareness about carbon emission rights. Proactively leading innovation by introducing low carbon derivative financial instruments, can also lead to progress in this sector.

Information Disclosure

From the beginning of introduction of green finance system in China, the mandatory disclosure plan for 2017 to 2020 was made clear. Although enterprises agreed with the importance of information disclosure, they have been concerned more about the loss of competitiveness caused by the impact of negative information disclosure. Chinese carbon information disclosure mainly relates to non-financial carbon information, and financial carbon information disclosure level is even lower than the average of carbon information disclosure (Li *et al.*, 2019). In addition, the environmental information disclosure of Chinese enterprises is not systematically in place, thus there being no unified carbon information disclosure mechanism. Only 65 Chinese listed companies from 12 industries participated in Carbon Disclosure Project (CDP) which called for environmental information disclosure in 2020. Though the participation was high 2019, but it is still considered very less. Chinese firms are unwilling to respond to CDP surveys because of the proprietary costs of information disclosure (Simpson, 2021). Most of the disclosed enterprises choose Corporate Social Responsibility (CSR) and Environment, Social Responsibility, Corporate Governance (ESG) information disclosure. Although ESG is a relatively widely used form of information disclosure in China, and capital market participants increasingly pay attention to ESG of listed companies, it still lacks a unified approach as ESG's overall investment scale is small, and the overall evaluation score is low (Wang & Xiao, 2020).

It is thus suggested that enterprises should strengthen their awareness of carbon information disclosure, and each carbon financial trading center should constantly improve ESG information disclosure guidelines. To a certain extent, the social pressure on enterprises brought about by media reports can push investors to pay attention to carbon information disclosure, reduce information asymmetry, improve the quality of investment decisions, and strengthen the risk reduction of financial institutions and investors in the carbon market (Li *et al.*, 2017; Schmidt *et al.*, 2013).

Figure 8. ESG rating status of Chinese listed companies in 2020
Source: Research Report on Environmental, Social and Governance of Chinese Listed Companies



CONCLUSION

This chapter analyzes the current status and characteristics of carbon finance, the role of the government in the development of the carbon market, and few practical case studies of carbon finance in China. It also discusses the issues plaguing China's carbon finance sector thereafter introducing some valuable suggestions.

Although China's carbon financing market is still in its infancy, it has indeed contributed to reduction of CO_2 emissions. The construction and development of China's carbon finance market is led by the government, which has been driving the whole process by issuing laws, regulations and formulating development goals from time to time. Relevant financial institutions have also continuously innovated various carbon finance related products and intermediary services. Carbon financing plays an important role in helping environment-friendly enterprises reduce their operating costs. As a result of efforts of the Chinese government in past few years, increasing number of people have started realizing the role of carbon finance, thus opening the era of accelerated development of carbon finance.

Prior to July 16, 2021, China has not established a unified national carbon market, the carbon market was previously established and supervised by provinces and cities, resulting into instability in the national carbon price and its high fluctuation, with little space for the survival and development in the future.

The anomalies in the policy system, lack of relevant product categories, and information asymmetry make carbon finance a very unattractive market at this stage for the investors. In the future, though the development of carbon finance leading the way to sustainable development will be the general trend, but for that to happen relevant market participants need continuous support to play an active and more useful role in carbon finance market. To achieve the 30·60 goals, China needs the continued solidarity of stakeholders on both sides of the supply and demand. In order to coordinate the relationship between all parties and achieve the goal of 1+1>2, China's policy makers need to be bold and innovative so as to not only maintain the status quo but also achieve better results. By properly dividing the functions of various departments, streamlining administration and delegating power, the potential of all stakeholders can be put to constructive use thereby tapping the carbon financial market in the most value creating manner paving the way to sustainable development.

This chapter focuses on China's carbon finance, without making a horizontal comparison with other carbon markets in the world, so as to draw a more representative conclusion. In addition, because the national carbon market has just been established in China and is in its nascent stage of development, the experience and conclusions of pilot carbon markets may not be applicable to the future. As the time passes by, there will be expansion of research in this area which will further contribute to the development of carbon financial market.

DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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KEY TERMS AND DEFINITIONS

Carbon Disclosure Project: A project that helps companies to disclose their environmental impact and dependence on the natural resources and as well as related management strategies. The data that is collected along with the information disclosed is helpful for making informed decisions towards taking concrete actions towards sustainable economy.

China Certified Emission Reductions: Under this system, the government sets a limit on amount of greenhouse gas emissions that companies can emit during a certain period. The emission reduction certificate obtained by enterprises thereafter through the implementation of projects to reduce greenhouse gases, can be used to offset part of the carbon emissions upon the fulfillment of the contract.

Chinese Emission Allowance: The main trading product in China's carbon emissions trading market currently. In the pilot carbon market in China, Shenzhen, Guangdong and Tianjin adopted the initial distribution mode of free distribution mainly and paid distribution supplemented in the initial pilot stage, while other pilot cities adopted free distribution mode.

Clean Development Mechanism: Under this mechanism, any country that has an emission reduction commitment under Kyoto Protocol can implement a project to minimize greenhouse gas emissions in developing country. It assists non-parties in carrying out a plan for sustainable development.

Corporate Social Responsibility: It refers to a company's responsibility towards its employees, consumers, community, and the environment. Under this concept, a company makes a conscious effort to integrate social and environmental concerns in its business operations.

Emissions Trading Scheme: A market-based energy conservation and emission reduction policy tool whereby emitters can trade units to meet their emission targets or implement internal emission reduction measures to reduce emissions and make profits. It has two main types: cap-and-trade systems and baseline and credit systems.

Environment, Social, and Corporate Governance (ESG): It is an investment concept and a set of standards that enterprises use. It basically evaluates a company's performance in terms of how responsibly they conduct their operations respecting the environment, how it manages its relationships with employees, suppliers, customers and community and how it exercises leadership. These three core factors measure sustainability and ethical impact in corporate or business investment.

Paris Agreement: It is a legally binding international treaty on climate change. It was adopted at the Paris Climate Change Conference in 2015, with the main goal to limit the rise in average global temperatures to less than 2 degrees Celsius above pre-industrial times and to try to limit the rise to 1.5 degrees Celsius.

Voluntary Emission Reduction: It is a scheme where industries and individuals voluntarily and in public interest, compensate for their emissions. It is also referred as verifiable emission reduction and is usually created by projects which are verified outside Kyoto Protocol's Clean Development Mechanism. It provides financing channels for carbon emission reduction projects that cannot be developed by CDM, thereby enriching carbon market products.

Chapter 13
Technological Innovation and Financialization for the Environment:
The Case of Pakistan

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ABSTRACT

This chapter examines the asymmetric link between technological innovation and financialization in Pakistan for the period 1980-2019. The non-linear autoregressive distributed lag (NARDL) model proposed by Shin et al. is applied to achieve the research objective. The numerical estimates based on annual data explain that an asymmetric relationship exists between financialization and environmental degradation and between technological innovations and environmental degradation in the long run. An increase in financialization and regression in technology stimulates environmental degradation while a decline in financialization and progress in technology improves environmental quality in Pakistan. Based on empirical evidence, the research emphasizes the suitable channelization of financial institutions towards environmentally friendly projects and formulation of those policies that encourage energy-efficient technologies.

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INTRODUCTION

Environmental degradation and its threatening effect on natural word and human life has become a challenge for policymakers and researchers worldwide. Environmental changes and global warming occur due to burning of fossil fuels and deforestation. Governments are highly conscious to reduce the adverse effect of environmental pollution without compromising economic development. The solution of devastating effect of environmental pollution has even become more important for developing economies. Rapid expansion in energy demand and relax environmental regulations in these economies are deteriorating the already overwhelming situation of environmental pollution. Now, it has become a universal agenda to reduce the emissions of toxic pollutants in the environment. In this regard, sustainable development goal 13 and Paris agreement (2015) are important steps to reduce the emissions of greenhouse gases at global level.

To control environmental pollution, the major structural changes are required in production and consumption. There is more likely that nations have to sacrifice the upward trends in economic development to improve environmental quality. In this situation, a well-developed financial system is required that adjust lower growth rate and support industrial re-structuring. Financialization has appeared to be a major economic factor in the past few decades. However, in the present research, the impact of financialization on environmental degradation is discussed. Financialization can impact the environmental degradation through four different channels (Yuxiang and Chen, 2011).

1. *Capitalization Effect*: According to this, financialization can improve environmental quality if investment is made on environmentally friendly projects. However, the same effect can deteriorate environmental quality when funds are transferred on energy intensive projects (Kong, 2021).
2. *Technology Effect*: This effect has both favorable and harmful effects on environmental degradation: favorable because financialization encourage innovations to promote green technologies and harmful because new technologies can increase the demand for energy.
3. *Income Effect*: Financialization helps to increase the income of households that in turn is spent for the purchase of environmentally friendly products and as a consequence environmental quality may improve. However, income effect can also deteriorate environmental quality due the usage of energy consuming products.
4. *Regulation Effect*: Regulated banks granted more loans to invest in green technologies can help to improve environmental quality. Empirically, the role of financialization in environmental deterioration has been mostly discussed after the global financial crisis. It is indicated in literature that financialization has both positive and negative effect on environmental degradation (Shahbaz and Hoang, 2019; Amin *et al*., 2020; Lahiani, 2020; Destek and Manga, 2021; Kong, 2021).

Now a days, technological progress is considered to be a prerequisite for improving environmental quality. Torras and Boyce (1998) stated that technological progress supported commercial activities that in turn reduce environmental degradation. The use of new innovative technology in energy sector can reduce environmental pollution by encouraging the consumption of renewable energy sources (Vukina *et al*., 1999). However, developing countries have limited access to high-cost environmental technology due to fund constraint. As a consequence, developing economies are still dependent on production structure that is based on non-renewable energy sources. On contrary, developed economies are using environmentally friendly technologies in production processes because they can easily obtain necessary funds through financial system. Thus, it is clear that financialization process directly or indirectly contribute to reduce environmental degradation. There is also debate that financialization process deteriorates environmental quality through various reasons. Firstly, countries attract foreign direct investment to develop financial system and support economic growth at the cost of environmental destruction. Secondly, financial instruments make it easier for consumers to buy big ticket items such as cars, refrigerators, air conditioners and microwave ovens. These products are large consumers of energy and significantly contributing to already devastating environmental situation. Finally, there is an increase in energy consumption and in turn environmental degradation because financialization process makes it easier and less expensive for business sector to borrow financial capital and use them to expand existing projects and create new ones (Zhang, 2011). In addition to above mentioned arguments, there are some empirical studies that suggest insignificant relationship between financialization and environmental pollution.

Pakistan is the 6th most populous country of the world and its economic growth depends on agriculture sector and manufacturing industries. However, unplanned industrial policies and soft environmental regulations encourage industrialists to increase output on large scale without protecting environment. The lack of use of new technology in the production system is another reason for environmental degradation in Pakistan. The financial sector of Pakistan is mostly bank based; however, capital market is developing very rapidly. Market capitalization reached its highest level of 9370.6 billion Pakistani rupees in 2017. The provision of domestic credit from financial sector showed an upward trend from 1980 to 2019. It was reported 59% of GDP in 2019 while it was 48.5% of GDP in 1980. Financial markets of Pakistan offer credit facility to households, industrial communities and business groups. Pakistan environmental protection agency was established in 1993 whereas national environmental policy was introduced in 2005 with the aim to protect environment and to improve the quality of life of people through sustainable development. However, a little progress has been seen in the implementation of this policy. The industrial and transportation sector of Pakistan is increasing pollution very rapidly and deteriorating the environmental quality. The above-mentioned debate makes Pakistan a persuasive candidate for current research. Therefore, the aim of current research is to scrutinize the impact of financialization and technological innovation on environmental degradation in Pakistan.

This chapter contributes to the prior literature in fourfold.

1. It is the first attempt in the case of Pakistan that evaluate the asymmetric effect of financialization and technological innovation on environmental degradation.
2. This research uses financial development index composed of various sub-indices to measure financialization process instead of using private credit that is widely utilized in empirical literature
3. The research applies the nonlinear autoregressive distributed lag (NARDL) model that can capture the asymmetries i.e., both positive and negative impacts of the financialization and technological innovation on environmental degradation. Thus, this technique provides better and consistent results as compared to conventional estimation methods.
4. This study provides us very important policy suggestions for Pakistan economy in order to control environmental degradation and may also be generalized for other countries having similar characteristics in the region.

LITERATURE REVIEW

Financialization and Environmental Degradation

Distinct findings are seen on the link between financialization and environmental degradation in prior empirical literature. The main view states that developed financial markets improve environmental quality in parallel with increase in economic growth and the adoption of new technologies and implementation of rules and laws regarding the protection of environment (Islam *et al*., 2013). Plethora of empirical studies such as Tamazian *et al*. (2009), Zhang (2011), Nasreen and Anwar (2014), Başarir & Çakir (2015), Mugableh (2015), Kim and Park (2016), Tahir *et al.* (2020), Destak and Manga (2021), Ibrahim and Vo (2021), Yang *et al*. (2021) supported this positive effect of financialization on environmental quality.

In contrast, the opposite view explains that expansion in economic growth due to financialization increases industrial pollution and deteriorates environmental quality (Jansen, 1996). Empirically, Tamazian and Rao (2010), Farhani and Ozturk (2015), Le *et al*. (2020), and Khan *et al*. (2021) are in favor of negative effect of financialization on environmental quality. Insignificant effect of financialization on environment is reported by Dogan and Turkekul (2015), Abid (2016) and Rasiah *et al.* (2018). The studies of Lahiani (2020) and Kong (2021) show an asymmetric relationship between these two factors.

In the case of Pakistan, Muhammad and Fatima (2013) and Raza and Nida (2018) claimed the damaging effect of financialization on environment while the good effects of financialization on environment are reported by Shahbaz *et al.* (2011). Khan *et al*. (2020) demonstrates the mixed effect of financialization on environment, that is, the growth of stock market is deteriorating the environment while the growth of domestic credit is improving the environmental quality in Pakistan. (For details see Table 1). The controversial findings of prior studies encourage us to examine the role of financial development in the environmental degradation of Pakistan.

Technological Innovation and Environmental Degradation

Endogenous growth theory states that production efficiency is enhanced as a result of rise in R&D expenditures. However, effect of technological innovation on environmental quality is not clear (Romer, 1990). It is a general belief that environmental quality improves as a result of innovative technologies. For instance, Ang (2009) in the case of China; Ibrahiem (2020) in the case of Egypt; Yang and Li (2017) in the case of China; Dinda (2018) in the case of United States; Churchill *et al.* (2019) in the case of G7 countries conclude that technological innovation greatly contributes to improving environmental quality by reducing energy consumption and enhancing energy efficiency.

Some scholars, for example, Cheng *et al.* (2019) in the case of OECD countries; Masoudi *et al.* (2020) in 30 countries; Su *et al.* (2021) in the case of BRICS economies; Khan *et al.* (2021) in the case of Belt and Road Innovative (BRI) countries found that technological innovation may harm environmental quality through increased production, capital and energy investment. Hang and Yuan-Sheng (2011) found inverted U-shaped link between technological innovation and carbon emission in China. Direct reduction of CO2 in OECD countries as a result of innovative technology is supported by Cheng *et al.* (2021). In the case of Pakistan, Nizam *et al.* (2020) noted that progress in information and communication technology is a major driver of CO_2 emission.

Table 1. Impact of financialization on environmental degradation: An empirical view

Author(s)	Sample Period	Country/Region	Methodology	Findings			
				Improving Environmental Quality	Deteriorating Environmental Quality	Insignificant Effect	Inverted U-Shaped/ Asymmetric Effect
Tamazian *et al.* (2009)	1992-2004	BRIC countries	Reduced form modeling approach	✓			
Tamazian and Rao (2010)	1993-2004	24 Transitional economies	Random effect and GMM		✓		
Shahbaz *et al.* (2011)	1972-2009	Pakistan	ARDL	✓			
Muhammad and Fatima (2013)	1971-2011	Pakistan	ARDL		✓		
Başarir and Çakir (2015)	1995-2010	Emerging countries	Panel data regression	✓			
Mugableh (2015)	1976-2010	Jordan	ARDL	✓			
Farhani and Ozturk (2015)	1971-2012	Tunisia	ARDL		✓		
Omri *et al.* (2015)	1990-2011	MENA countries	GMM			✓	
Dogan and Turkekul (2015)	1960-2010	USA	ARDL			✓	
Abid (2016)	1996-2010	SSA countries	GMM			✓	
Xing *et al.* (2017)	2000-2013	China	PMG	✓			
Rasiah *et al.* (2018)	1970-2016	ASEAN countries	Panel data regression			✓	
Raza and Nida (2018)	1972-2014	Pakistan	Johansen's cointegration		✓		
Lahiani (2020)	1977-2013	China	NARDL				✓
Le *et al.* (2020)	2004-2014	31 Asian countries	Pooled OLS, Fixed effect regression		✓		
Khan *et al.* (2020)	1982-2018	Pakistan	Dynamic ARDL	✓			
Kim *et al.* (2020)	1989-2013	Advanced and developing countries	Panel data analysis				✓
Hunjra *et al.* (2020)	1984-2018	South Asian region	GLS technique		✓		
Tahir *et al.* (2020)	1990-2014	South Asian region	Panel data analysis		✓		
Kong (2021)	1985-2019	China	NARDL		✓		✓
Destek and Manga (2021)	1995-2016	BEM countries	Panel cointegration		✓		
Ibrahim and Vo (2021)	1991-2014	Industrialized countries	GMM		✓		
Sharma *et al.* (2021)	1990-2015	Emerging Asian countries	CS-ARDL		✓		
Yang *et al.* (2021)	1990-2017	GCC countries		✓	✓		
Khan *et al.* (2021)	2000-2014	BRI countries	GMM				

Note: BRIC= Brazil, Russia, India and China; ASEAN=Association of Southeast Asian Nations; BEM=Big emerging markets; SSA=Sub-Saharan Africa; MENA=Middle East and North Africa; GCC= Gulf Corporation countries; BRI= Belt and Road Innovative; GMM= Generalized Methods of Moment; ARDL= Auto-Regressive Distributed Lag; NARDL=Non-linear Auto-Regressive Distributed Lag; PMG= Pooled Mean Group; GLS = Generalized Least Square.

There are few studies that examined the causal connection between technological innovation and carbon emission and found insignificant relation between two variables. Fei *et al*. (2014) noted insignificant causal connection between technological development and environment in the case of New Zealand and bidirectional causal connection between these two variables. Irandoust (2016) reported insignificant causality between technology progress and air pollution in Denmark, Finland and Sweden and Norway. Similarly, Ali *et al*. (2016) and Chen and Lee (2020) in their studies concluded that technological advancement has no role in mitigating environmental pollution in Malaysia and 96 economies of the globe, respectively (for details see Table 2).

To sum up, the impact of financialization on environmental quality as well as technological innovation on environmental quality is controversial and demand further exploration. Moreover, there is no prior study exist that examined the non-linear impact of financial development and technological innovation on CO_2 emission in the case of Pakistan. Therefore, the evidence of present research will contribute to the literature on the financial development-technological innovation and CO_2 emission by considering the case of Pakistan.

THEORETICAL FRAMEWORK AND METHODOLOGY

This study used the IPAT environmental model (Ehrlich and Holdren, 1971) in order to examine the link between financialization, technological innovation and CO_2 emissions. The IPAT environmental model can be described as follows:

$$I = P \times A \times T \tag{1}$$

Where

I = Environmental impact,
P= Population
A= Economic Activities
T= Level of Technology

This model is purely conceptual and cannot be directly used for empirical analysis. Dietz and Rosa (1994, 1997) augmented IPAT model into a STIRPAT (Stochastic Impacts by Regression on Population, Affluence and Technology) model to explain the impact of R&D activities on environment. Following Destek and Manga (2021), empirical model of his study is based on STIRPAT model and the population variable is replaced with by some countable variables measured in per capita form. Thus, empirical model can be written as:

$$EDeg_t = \gamma_0 + \gamma_1 FIN_t + \gamma_2 Tinnov_t + \gamma_3 G_t + \gamma_4 EU_t + \mu_t \tag{2}$$

where $EDeg_t$ denotes environmental degradation and proxied by CO_2 emission, FIN_t represents financialization, $Tinnov_t$ is technological innovations, G_t is economic growth, EU_t is energy usage and μt is a random term. The log transformation of $Tinnovt_,$ Gt and EUt is used in empirical estimation. A time-series data from the period 1980 to 2019 is used to compute the nonlinear link between environmental degradation and its determinants in Pakistan. The detail of variables and data sources is described in Table 3.

Table 2. Impact of technological innovations on environmental degradation: An empirical view

Author(s)	Sample Period	Country/Region	Methodology	Findings			
				Improving Environmental Quality	Deteriorating Environmental Quality	Insignificant Effect	Inverted U-Shaped/ Asymmetric Effect
Ali *et al.* (2016)	1985-2012	Malaysia	ARDL			✓	
Irandoust (2016)	1975-2012	Nordic countries	VAR			✓	
Álvarez-Herránz *et al.* (2017)	1990-2014	OECD countries	V-lag distribution model	✓			
Yii and Geetha (2017)	1971-2013	Malaysia	VECM	✓			
Dinda (2018)	1963-2010	United States	VECM	✓			
Fan & Hossain (2018)	1974-2016	China and India	ARDL			✓	
Youssef et al. (2018)	1980-2017	Indonesia	FMOLS and DOLS	✓			
Mensah *et al.* (2018)	1990-2014	OECD countries	FMOLS	✓			
Dauda *et al.* (2019)	1990-2016	18 developed and developing countries	FMOLS and DOLS	✓			
Ganda (2019)	2000-2014	OECD countries	GMM	✓			
Chen and Lee (2020)	1996-2018	96 economies	Spatial econometric analysis			✓	
Zameer *et al.* (2020)	1985-2017	India	ARDL and VECM		✓		
Masoudi *et al.* (2020)	1990-2016	30 countries	Quantile regression		✓		
Nizam *et al.* (2020)	1975-2017	Pakistan	ARDL		✓		
Kumail and Ali (2020)	1990-2017	Pakistan	ARDL	✓			
Destek and Manga (2021)	1995-2016	BEM economies	Panel cointegration	✓			
Ibrahim and Vo (2021)	1991-2014	Industrialized countries	GMM		✓		
Khan *et al.* (2021)	2000-2014	BRI countries	GMM		✓		
Cheng *et al.* (2021)	1996-2015	OECD countries	Quantile regression				✓

Note: OECD= Organization for Economic Cooperation and Development; BRICS= Brazil, Russia, India, China and South Africa; BEM= Big Emerging Markets; ARDL=

Auto-Regressive Distributed Lag; VAR=Vector Auto-Regressive; VECM= Vector Error Correction Model; FMOLS= Fully Modified Ordinary Least Square; DOLS= Dynamic

Ordinary Least Square; GMM= Generalized Methods of Moment.

Table 3. Detail of variables and data sources

Symbol	Variable	Description	Reference	Data
ED_{eg}	CO_2 emission	Per capita CO_2 emission (metric tons)	Ali et al. (2016); Mensah *et al.* (2018); Tsaurai (2019); Hunjra *et al.* (2020)	WDI
FIN	Financialization	Financial development index	Amin *et al.* (2020); Destek and Manga (2021)	IMF
Tinnov	Technological innovation	Total no. of patent application	Bonilla *et al.* (2014); Ali et al. (2016); Mensah *et al.* (2018); Destek and Manga (2021)	WDI
G	Economic growth	Per capita real GDP	Tsaurai (2019); Lahiani (2020); Kong (2021)	WDI
EU	Energy use	Per capita energy usage (Kg of oil equivalent	Chen and Lee (2020); Hunjra *et al.* (2020); Destek and Manga (2021)	WDI

The estimation of Eq. (2) in current form describes long-run impact of variables on ED_{eg}. In order to compute the short-run impacts of selected variables on environmental degradation, following Pesaran *et al.* (2001) error correction format of variables is estimated:

$$\begin{aligned}\Delta EDeg_t = \gamma_0 + \sum_{j=1}^{n}\gamma_{1j}\Delta EDeg_{t-j} + \sum_{j=0}^{n}\varphi_{1j}\Delta FIN_{t-j} + \sum_{j=0}^{n}\phi_{1j}\Delta Tinnov_t + \sum_{j=0}^{n}\vartheta_{1j}\Delta G_t \\ + \sum_{j=0}^{n}\psi_{1j}\Delta EU_t + \sigma_1 EDeg_{t-1} + \sigma_2 FIN_{t-1} + \sigma_3 Tinnov_{t-1} + \sigma_4 G_{t-1} + \sigma_5 EU_{t-1} + \mu_t\end{aligned} \quad (3)$$

One of the vital advantages of Eq. (3) is that both short-run and long-run impacts are computed in a single step. The coefficient on first differenced variables in Eq. (3) reflect the short-run estimates while coefficient's of σ's explains the long-run estimates. Eq. (3) can evaluate the short-run and long-run impact of financialization, technological innovation and auxiliary variables on environmental degradation but it cannot compute the asymmetric effects of financialization and technological innovation. Therefore, in order to capture the asymmetric impacts of financialization and technological innovation, the nonlinear autoregressive distributed lag (NARDL) model is applied (Shin e*t al.,* 2014). NARDL methodology used the partial sum concept which can be written as:

$$FIN_t^{+} = \sum_{j=1}^{t}\Delta FIN_j^{+} = \sum_{j=1}^{t}\max(\Delta FIN_j^{+}, 0) \quad (4a)$$

$$FIN_t^{-} = \sum_{j=1}^{t}\Delta FIN_j^{-} = \sum_{j=1}^{t}\min(\Delta FIN_j^{-}, 0) \quad (4b)$$

$$Tinnov_t^{+} = \sum_{j=1}^{t}\Delta Tinnov_j^{+} = \sum_{j=1}^{t}\max(\Delta Tinnov_j^{+}, 0) \quad (4c)$$

$$Tinnov_t^- = \sum_{j=1}^{t} \Delta Tinnov_j^- = \sum_{j=1}^{t} \max(\Delta Tinnov_j^-, 0) \tag{4d}$$

Where FIN_t^+, FIN_t^- and $Tinnov_t^+, Tinnov_t^-$ are the partial sum of positive and negative shocks in financialization and technological innovation respectively.

Following Pesaran *et al.* (2001), the FIN_t is replaced by FIN_t^+, FIN_t^- and $Tinnov_t$ by $Tinnov_t^+, Tinnov_t^-$ to find the error correction specification of Eq. (2) which can be written as:

$$\begin{aligned}\Delta EDeg_t = &\sum_{j=1}^{n} \theta_j \Delta EDeg_{t-j} + \sum_{j=0}^{n} \left(\phi_j^+ \Delta FIN_{t-j}^+ + \phi_j^- \Delta fsi_{t-j}^-\right) \\ &+ \sum_{j=0}^{n} \left(\tau_j^+ \Delta Tinnov_{t-j}^+ + \tau_j^- \Delta Tinnov_{t-j}^-\right) + \sum_{j=0}^{n} \vartheta_j \Delta G_{t-j} + \sum_{j=0}^{n} \tau_j \Delta EU_{t-j} + \upsilon_1 \Delta EDeg_{t-j} \\ &+ \upsilon_2 FIN_{t-j}^+ + \upsilon_3 FIN_{t-j}^- + \upsilon_4 Tinnov_{t-j}^+ + \upsilon_5 Tinnov_{t-j}^- + \upsilon_6 G_{t-j} + \upsilon_7 EU_{t-j} + \varepsilon_t\end{aligned} \tag{5}$$

After estimating Eq. (5), additional asymmetry propositions could be tested. For instance, short-run impacts of financialization will be asymmetric if the coefficient of ΔFIN_j^+ is different from coefficient of ΔFIN_j^-. With the application of Wald test, if the null hypothesis $\phi_j^+ = \phi_j^-$ is rejected, then the asymmetric effect of financialization would be confirmed. However, the long-run asymmetric effect of financialization on EDeg can be established if the null hypothesis of $+v_2/v_1 = -v_2/v_1$ could be rejected. The same proposition would be tested for $Tinnov_t$.

EMPIRICAL FINDINGS

Table 4 presents the preliminary statistics of five selected variables and shows that environmental degradation variable has the highest average value followed by economic growth and technological innovation. Technological innovation variable shows highest volatility while financial innovation variable presents least volatility. Moreover, the distribution of all the variables except financial development is negatively skewed. The Jarque-Bera normality test reports that the null of normality is only rejected in the case of technological innovation, hence indicates that the variable of technological innovation deviates from normality while other variables are normally distributed.

Prior to the application of ARDL model, the stationary status of variables should be checked as the model requires that the maximum order of stationary of variables should not exceed two. Thus, the ADF and PP unit root tests are applied and findings are reported in Table 5. The findings show that null of non-stationary is accepted at level form while rejected at first difference. Hence, it can be concluded that all variables ($EDeg_t$, FIN_t, $Tinnov_t$, G_t, EU_t) are first difference stationary and appropriate for the estimation of ARDL model.

Table 6 shows the numerical estimates of ARDL and NARDL models. Panel A highlights the short-run and long-run estimates of ARDL model. The negative and significant value of speed of adjustment parameter (ECM) indicate that the estimated ARDL model is stable. The significant value of F-bound confirm the long-run association between $EDeg_t$, FIN_t, $Tinnov_t$, G_t, and EU_t in Pakistan. Table 6 also demonstrates the short-run and long-run estimates of NARDL. The estimation of NARDL with financialization and technological innovation are decomposed into positive and negative partial sums. The significant statistics of F-bound and ECM confirm the presence of cointegration and convergence of variables towards long-run equilibrium. Furthermore, the significant statistics of asymmetry test confirms the presence of asymmetric long-run association between variables.

Besides, various diagnostic and statistical tests are reported in Panel B and C. The outcomes of these tests explain that the selected model does not show any statistical issue. The existence of asymmetric linkage between financialization and environmental degradation; between technological innovation and environmental degradation is estimated by applying Wald test. The outcomes confirm that the effect of both positive and negative changes is not same and thus, provides evidence for the existence of asymmetric hypothesis.

Table 4. Preliminary analysis of variables

Variables	$EDeg_t$	FIN_t	$Tinnov_t$	G_t	EU_t
Mean	0.863	0.250	6.078	6.731	6.048
Median	0.885	0.230	6.790	6.708	6.096
Max.	0.956	0.390	7.460	7.123	6.215
Min.	0.739	0.160	6.006	6.314	5.759
S.D.	0.062	0.061	0.424	0.209	0.123
Skewness	-0.501	0.780	-0.106	-0.107	-0.925
Kurtosis	2.096	2.463	1.818	2.224	2.650
J-B (Prob.)	0.111	0.584	0.005	0.239	0.886

Table 5. Unit root tests

Variables	ADF (Augmented Dickey Fuller)				PP (Phillips-Perron)			
	Intercept		Trend and Intercept		Intercept		Trend and Intercept	
	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference
$EDeg_t$	-2.100	-2.666***	1.236	5.629***	-2.099	-8.791***	-0.434	-2.217**
FIN_t	-1.808	-5.139***	-1.633	-5.135***	-1.899	-5.139***	-1.734	-5.139***
$Tinnov_t$	-1.808	-5.139***	-1.633	-5.135***	-1.899	-5.139***	-1.734	-5.135***
G_t	-0.289	-3.817***	-2.408	-3.747***	-0.943	-3.871***	-2.529	-3.747***
EU_t	-3.650**	-4.576***	-0.710	-5.736***	-3.502**	-4.622***	-0.722	-5.723***

Note: *, ** and *** shows the significance at 10%, 5% and 1% level respectively.

Table 6. ARDL and NARDL empirical results

$EDeg_t$ (Dependent Variable)				
	ARDL		**NARDL**	
	Coefficient	**Probability**	**Coefficient**	**Probability**
Panel A: Short-run estimates				
ΔFIN_t	0.168	0.650		
ΔFIN_t^+			0.142	0.089
ΔFIN_t^-			-0.106	0.672
ΔFIN_{t-1}^-			0.154	0.494
$\Delta Tinnov_t$	-0.244	0.030		
$\Delta Tinnov_{t-1}$	-0.372	0.072		
$\Delta Tinnov_t^+$			-0.263	0.040
$\Delta Tinnov_{t-1}^+$			-0.158	0.218
$\Delta Tinnov_t^-$			0.219	0.072
ΔG_t	-0.316	0.149	-0.582	0.001
ΔEU_t	0.572	0.041	0.479	0.000
ΔEU_{t-1}	0.378	0.088	0.215	0.028
Long-run estimates				
FIN_t	0.152	0.074		
FIN_t^+			0.102	0.072
FIN_t^-			-0.064	0.093
$Tinnov_t$	-0.743	0.000		
$Tinnov_t^+$			-0.470	0.051
$Tinnov_t^-$			0.508	0.079
G_t	-0.456	0.030	-0.279	0.010
EU_t	0.429	0.000	0.554	0.069
Panel B: Diagnostic tests				
F-bound	6.192*		5.086*	
ECM	-0.265	0.020	0.347	0.045
Asymmetry			-4.371**	

continues on following page

Table 6. Continued

$EDeg_t$ (Dependent Variable)				
	ARDL		NARDL	
	Coefficient	Probability	Coefficient	Probability
LM_{test}	1.093		1.105	
BP_{test}	0.686		1.003	
$RESET_{test}$	1.245		0.942	
$Adj-R^2$	0.89		0.90	
Panel C: Wald test for asymmetry				
W_{LR}, *FIN*	6.306**		W_{SR}, *FIN*	6.939**
W_{LR}, *Tinnov*	7.230**		W_{SR}, *Tinnov*	8.015**s

Note: *, ** and *** shows the significance at 10%, 5% and 1% level respectively.

DISCUSSION

The short-run estimates of ARDL depicts that financialization has positive but insignificant impact on environmental degradation while technological innovation stimulates environmental quality. Besides, economic growth has no role in deteriorating environmental quality in short-run. Energy use appear to be a significant factor in deteriorating environmental quality in Pakistan over the period of short-run.

The long-run estimates of ARDL model explain that the process of financialization is detrimental for environmental quality, that is, a 1% increase in FIN_t leads to deteriorate the environmental quality by 0.152%. This finding indicates that after the financial reforms of 1990s, Pakistani banks has provided loans on easy terms to consumers and investors. Due to lack of implementation of environmental rules and regulations, investors or business community spent these loans to establish new ventures and to buy big machines that emit more pollution in the environment. Similarly, consumers spent loans on the purchase of big-ticket items like automobiles, refrigerators and air condition etc. which are big source of carbon emission in the economy. The studies of Muhammad and Fatima (2013) and Raza and Nida (2018) report the similar finding in the case of Pakistan.

Furthermore, the findings of auxiliary variables indicate that energy consumption stimulates environmental pollution while economic growth mitigates environmental pollution in Pakistan in long-run. The coefficient of economic growth is negative and significant suggesting that the rise in economic growth is associated with reduction in environmental degradation of 0.456%. Furthermore, the growth in Pakistan is based on the production of primary products that are energy-intensive and lack environmental laws thus leads to deteriorated environmental quality. The results are consistent with the findings of Solarin *et al.* (2017) and Zafar *et al.* (2019). Besides, various diagnostic tests are applied which indicates that there is no statistical issue in the estimated model.

Table 6 also demonstrates the short-run and long-run estimates of NARDL. NARDL model accounts for asymmetries in the long-run and short-run relationships between CO_2 emissions, financialization and technological innovation while controlling for the influence of economic growth and energy consumption. For this purpose, the estimation of NARDL with financialization and technological innovation are decomposed into positive and negative partial sums. The significant statistics of F-bound and ECM confirm the presence of cointegration and convergence of variables towards long-run equilibrium. Furthermore, the significant statistics of asymmetry test confirms the presence of asymmetric long-run association between variables. The short-run outcomes indicate that a positive change in financialization enhances environmental pollution in the short run. Similarly, a positive change in technology lessens environmental pollution while a negative change in technology enhances environmental pollution. The coefficients of auxiliary variables support the short-run results of ARDL. The long-run findings elucidate that a positive change in financialization significantly contributing to environment degradation while a negative change in financialization leads to improving environmental quality in Pakistan. The estimates are in line with the study of Le *et al.* (2020); Lahiani (2020) and Kong (2021). Similarly, a 1% improvement in technological progress reduces environmental pollution by 0.47%, whereas a 1% decline in technological progress enhance environmental pollution by 0.508%. The outcomes are in consonance with Yang and Li (2017); Ibrahiem (2020); Destek and Manga (2021). In addition, increase in economic growth is conducive for environment while increase in energy use is harmful for environmental quality in Pakistan.

CONCLUSION

This chapter aims to examine the asymmetric link between technological innovation, financialization and environmental degradation using annual data for the period 1980-2019 in the case of Pakistan. For this purpose, the asymmetric cointegration method developed by Shin *et al.* (2014) is employed. The numerical estimates explain that positive and negative change in financialization has different effect on environmental quality in long-term, that is, a positive change in financialization enhance environmental degradation while a negative change in financialization improve environmental quality. This result corroborates with the findings of Le *et al.* (2020); Lahiani (2020) and Kong (2021). Similarly, the positive and negative change in technological innovation significantly affected environmental quality in long-term. A positive shock in technological progression is conducive for environment while a negative shock in technological progression is dangerous for environmental quality. Yang and Li (2017); Ibrahiem (2020) and Destek and Manga (2021) found similar findings in their empirical studies. The ARDL results show positive impact of financialization on environmental degradation and in line with the study of Raza and Nida (2018); Majeed and Mazhar (2019) and Koengkan *et al.* (2019) while the impact of technological innovation is found to be negative on environmental degradation and support the study of Nizam *et al.* (2020); Kumail *et al.* (2020) and Cheng *et al.* (2021).

The significance of Wald test further confirms the long-run asymmetry. Overall, these findings demonstrate that it is imperative to consider the asymmetric linkage between environmental quality and macroeconomic indicators. Moreover, the evidence helps to understand the inconclusive findings of prior studies about the positive impact of financialization and technological innovations on environmental quality.

The outcomes of this chapter suggest some important recommendations. Financialization process deteriorate environmental quality in Pakistan by promoting investment in dirty industries in the country. Suitable channelization of financialization towards environmentally friendly projects without compromising economic growth will be beneficial for Pakistan. Government should impose heavy taxes on the usage of fossil fuel energy and provides subsidies in the usage of clean energy. The government should introduce penalty mechanism for dirty industries and motor vehicles that emit pollution in the environment. Technological progress is helpful for improving environmental quality. Thus, policy makers need to formulate those policies that encourage more efficient energy technologies.

DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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Chapter 14
Determinants of Carbon Emission Prices:
Evidence From the European Union

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ABSTRACT

Carbon emission allowances are considered an important policy instrument to prevent an undesirable increase in the Earth's temperature caused by the excess of greenhouse gases in the atmosphere. Most of the existing literature modeled the behavior of allowance prices before the implementation of regulatory measures such as the market stability reserve mechanism. In this chapter, the main determinants of the carbon emissions allowance prices in the European Union are examined, applying econometric models—ARCH and GARCH—that take into consideration the allowances supply in the future market, the energy prices, the stock indices, and the regulatory measures. The results depicted that the most relevant variables affecting the allowance prices were the regulatory measures that mainly restrict the number of allowances available. Understanding the dynamics of the variables that impact these prices can help policymakers to address the oversupply of allowances by sending correct price signals to the market participants.

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INTRODUCTION

The GHG emissions, derived from human activities, are considered the main global market failure, since they affect all countries indistinctly. They are one of the most cited examples of negative externality, as depicted by economic theory (Rezai, 2012). In a market economy, consumption and investment decisions are guided by prices, once prices convey information about products and services such as: (i) scarcity (ii) quality and (iii) productivity. However, in market economies, current prices say nothing about the consequences, or side effects, of our consumption and investment decisions.

The absence of correct price signs that take into consideration side effects is considered a market failure as it promotes an inefficient allocation of resources by the market. This absence leads to a loss of social welfare by rewarding behaviors with harmful consequences to the environment and the society.

The mainstream economic theory endorses government intervention in the market to correct such failures. In this context, intervention should be made to implement mechanisms that aim to encourage and regulate the internalization of externalities. Just as prices guide the decisions of economic agents, mechanisms that incorporate into prices of goods and services the costs of the effects of climate change are part of the solution.

Governments and policy makers are recommended to intervene through a series of public policies, such as command and control tools and carbon pricing, aiming to address these failures. Among the international experiences using carbon pricing tools, the Emissions Trading Systems (ETS) have been gaining prominence in the last decade (Narassimhan, 2018; Rafay, 2022).

In an ETS, the government sets a cap on the volume of greenhouse gas pollution, measured in tonnes of carbon dioxide equivalent (tCO_2e) [1] that can be emitted each year. Companies and facilities that participate in the system must hold allowances, issued by the government, for each tCO_2e they emit within one calendar year. Companies and facilities buy in public auctions and/or receive from the government such allowances and trade them depending on the volume of their emissions and marginal abatement costs. The ETS tends to change relative prices, making carbon intensive products and activities more expansive and, thus, creating market incentives for investments in cleaner products and technologies.

There are two main types of instruments that can provide an explicit price on carbon: (i) the emissions trading system (ETS); and (ii) the carbon taxes. Assuming that there is perfect information on the market, both instruments can internalize externalities in a cost-effective way and achieve equivalent results. The main difference between the two instruments is in the price formation process. In the case of the carbon tax, the Government determines exogenously the price to be paid for one tCO_2 emitted and allows the market to adjust the equilibrium emissions quantities. Whereas in the ETS, the Government sets an emissions' cap for a given period, converts it into emission allowances, allocates them among regulated companies and lets the market find the equilibrium price of one tCO_2 emitted by using supply and demand forces.

The distribution of allowances among companies can be done by three main methods. The first one is the implementation of auctions, in which the regulator sells the allowance to the covered companies. The second is the free allocation of allowances using industry by using *benchmarking* parameters, in which regulated entities receive permissions based on their activities or on some sector efficiency parameters, usually adjusted by a correction factor. Finally, the third method is the free allocation of allowances using grandfathering parameters, in which entities receive allowances based on their historical emissions. Although less common, it is also possible to have a hybrid distribution mechanism, in which a portion of the permissions are allocated for free and the rest is auctioned, or grandfathering.

These allowances are then negotiated between regulated companies in some government-defined environment, usually on some stock exchanges, creating a market for buying and selling the allowances. Thus, in this system, the carbon price is figured out by the dynamics of the supply and demand market itself, encouraging companies to seek the most cost-effective way of complying with the established ceiling (cap), minimizing the cost to society. The end of a trading period is determined by the regulator. At this stage, the participants of the ETS must deliver a number of allowances equivalent to their actual emissions verified in the corresponding period. If the volume of emissions is greater than the allowances delivered, sanctions are applied in the form of fines, administrative measures, among others.

As of December 2020, there were 21 ETS initiatives operating globally, at different levels of government, covering 6 $GtCO_2e$. The year of 2020 has also been marked by the first ETS in Latin America, as Mexico launched its own system. Other new ETSs are scheduled to be implemented in 2021, including Germany, the United Kingdom and China. Once implemented, these systems are expected to cover 8.7 Gt/CO_2e, representing 16.1% of total global emissions (WB, 2020).

The European Union Emissions Trading System (EU ETS) stands out among the already implemented ETSs. This system has been in force since 2005, covering 45% of the GHGs launched by the 28 Member States, in addition to Norway, Iceland and Liechtenstein, which makes it the largest and most advanced implemented carbon market in the world. The EU ETS has continuously been reformulated and improved; its fourth stage began in 2021.

One of the main lessons learned throughout its different phases was the importance of mechanisms that help to address oversupply of allowances and to stabilize carbon prices volatility by sending correct price signals to the market participants. The EU ETS has tried different approaches to address such issues. In a first attempt to reduce the surplus of allowances, the EU temporarily removed 900 million allowances from auctions in 2014-2016. In 2015, a decision to develop a *market stability reserve* (MSR) was adopted. This instrument should permit authorities to increase or decrease the number of European Union Allowance (EUA) in the market, following clear rules, in order to allow the price to be balanced at a reasonable level. The MSR started operating in January 2019.

Seemingly such initiatives have been reflected lately on carbon prices in the secondary market lately. However, most of the existing literature about carbon prices and cap-and-trade instruments has modeled the behavior of emissions allowances prices before the implementation of the market stability mechanisms using mainly Auto Regressive Integrated Moving Average (ARIMA) models or hybrid approaches, combining econometrics techniques and machine learning algorithms. Furthermore, the main literature has not been studying the determinants of EUA prices in the secondary market.

Hence, the aim of this chapter is to develop an econometric model to identify the main determinants of European Union Allowances price movements in the secondary market considering the market stability reserve mechanism. For that, ARCH (autoregressive conditionally heteroscedastic) and GARCH (generalized autoregressive conditionally heteroscedastic) regression models are used for the period 2008-2020.

THE EUROPEAN UNION EMISSION TRADING SYSTEM

The European Union Emissions Trading System (EU-ETS) was introduced under the United Nations Framework Convention on Climate Change as a result of the Kyoto Protocol. In the Protocol, the European Union (EU) committed itself to reducing its GHG emissions by 8% compared to 1990 emissions. To meet this target, the EU proposed the implementation of an emissions trading system in June 1998.

The proposal was followed by a series of studies on energy security strategies, discussions in committees of the European Parliament and legal frameworks. After being agreed by all 25 EU Member States at the time, *the EU-ETS* went into operation on 1 January 2005 with three main objectives: (i) meeting environmental targets; (ii) provide cost-effective decarbonization; and (iii) provide a good carbon price discovery.

Since its inception, the EU-ETS has been growing and incorporating new countries, sectors, types of gases and lowering the emissions ceiling. Until December 2019, the system had the participation of its 28 member states, in addition to Iceland, Liechtenstein and Norway. The EU-ETS now covers more than 11,000 facilities in several sectors, such as the electricity sectors (combustion facility with a capacity of more than 20 MW), oil refineries, industries that use coal furnaces, steel mills, cement plants, glass, brick, ceramics, pulp and paper and the aviation sector. Regarding greenhouse gases, the EU-ETS currently covers three gases – CO_2, NO_2, and per fluorinated compounds (PFCs). The emissions ceiling has been reduced to 1.8 $GtCO_2e$, which corresponds to about 45% of the EU GHG emissions. The SCE-EU consists of consecutive trade periods. As of 2021, this system is at the beginning of its fourth phase (ICAP, 2020).

The first phase of negotiation, considered a "learning phase", lasted from 2005 to 2007. This phase was characterized by a decentralized method for the determination of emission caps. In this phase, the annual cap was determined by the sum of all caps established in each National Allocation Plans of member states, reaching 2,096 $MtCO_2e$. The expected results were not achieved. At the time, the data available poorly informed policymakers, to set the caps and most of the EUA were allocated free of charge to the participating companies. As a result, the volume of emissions were overestimated and this surplus of allowances in the market caused a drastic drop in the prices of allowances at the end of the first phase (WB, 2021).

The second phase overlapped with the targets set out in the Kyoto Protocol, i.e., from 2008 to 2012. This phase is characterized by the inclusion of Iceland, Liechtenstein and Norway in the ETS, by the inclusion of the aviation sector in 2012 and by the persistence of the surplus of allowances problem. The emission cap of 2,049 $MtCO_2e$ was determined using the same method of Phase 1. The allocation of EUA was also similar to the first phase, about 90% of the allowances were allocated free of charge and the other 10% were allocated through auctions in Germany, United Kingdom, Netherlands, Austria, Ireland, Hungary, Czech Republic and Lithuania. The surplus of allowances grew even greater after the 2008 economic crisis which caused emissions to fall faster than anticipated, as is possible to observe in Figure 1 (ICAP, 2020).

In the third phase (2013-2020), a single cap of 2,084 $MtCO_2e$ was stipulated for stationary emission sources. It is worth noting that a rate of reduction of 1.74% per year was determined, which corresponded to a linear annual decrease of 38.3 million allowances. This phase was characterized by the inclusion of new sectors, by the increase in funds raised in the allowances auctions and by the introduction of management of allowances mechanisms. The allowances auctions were deepened, reaching 57% of total allowances. From 2013 to 2018, the funds raised in auction soared from EUR $4 billion to EUR $14 billion (EU, 2020).

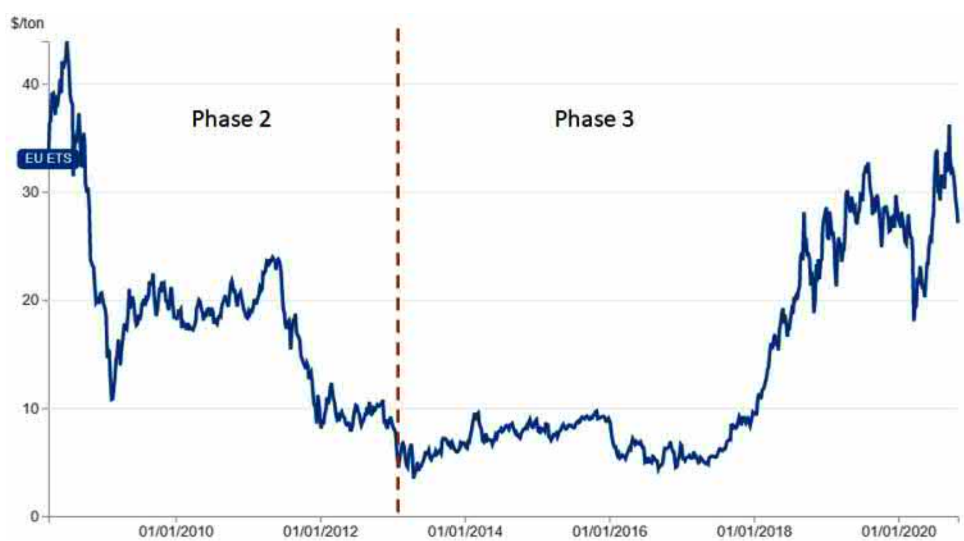
One of the main characteristics of this phase was the introduction of two mechanisms in order to address the oversupply of Allowances in the short term to avoid price collapse, as observed in previous phases. The first mechanisms postponed some scheduled auctions in 2013, 2014 and 2015 to reduce 900 million allowances in the market. The second mechanism, implemented only in 2019, refers to the creation of the *Market Stability Reserve (MSR).* The main objective of the MSR is to address and prevent the historical imbalance between supply and demand of allowances and also to improve resilience to future shocks (EU, 2020).

In January 2021, Phase 4 of the European SCE (2021-2030) came into operation. This phase foresees an increase in the pace of annual emission cuts required by the sectors concerned from 1.74% to 2.2%. This increase in annual emissions cut rates is in line with the 2030 *European New Green Deal targets,* as well as the 2050 carbon neutrality target of the IPCC's 1.5°C special report (EU, 2020). In addition, a central component of Phase 4 is updating the free allocation parameters of allowances which will be adjusted annually by technology to reflect changes in production (ICAP, 2020).

During the fourth phase, the EU-ETS plans to strengthen the Market Stability Reserve (MSR). It is expected that between 2021 and 2023, 24% of the surplus will be placed in the MSR, instead of the regular rate of 12%. From 2023, the licenses held in the MSR that exceed the auction volume of the previous year will be invalidated. Member States may also invalidate some of the allowances to reflect additional policies in the energy sector, for example a gradual elimination of coal. Other changes planned for this phase are new financial support mechanisms to promote low-carbon innovation and support the sector's modernization efforts and the energy sectors of low-income Member States (ICAP, 2020).

Therefore, one of the main lessons learned of the EU-ETS is the importance of mechanisms to stabilize EUA prices in both markets, the primary and the secondary market. Under an ETS, the primary market includes the first events in which a carbon allowance changes hands for a price, usually an auction at which the government sells allowances. A secondary market operates in the same way, and comprises all subsequent transactions, being much larger in terms of volumes of allowances exchanged. Secondary markets arise to meet compliance entities' needs to manage their position and reduce their risk to price changes.

Figure 1. Evolution of European Union allowances prices – 03/2008 to 10/2020
Source: ICAP, 2021



An EU ETS operator can access the secondary carbon market to buy allowances through multiple routes: i) trading directly with other companies covered by the System; ii) buying or selling from intermediaries, e.g. banks and specialist traders; iii) using the services of a broker; and iv) joining one of the several exchanges that list carbon allowance products. A well-functioning secondary market is of high importance for efficient intermediation. A clear price signal from the secondary market is also important as a reference point for individual bidders in the auctions and for ensuring a competitive outcome. In Figure 1, it is possible to see that in the last decade EUAs have registered a long period with low prices. However, since 2018, before the actual implementation of MSR, the EUA prices have started increasing anticipating the reduction of allowances in the secondary market.

The first major test of the MSR was the economic crisis caused by the COVID19 pandemic in the first half of 2020. The price of the EUA, which had started the year 2020 around EUR $24, fell 37% in March, reaching EUR $15. At this time, the newly created MSR was used, which reversed the trend of prices and expectations, causing EUA prices to return to pre-pandemic levels in June 2020 (Kock *et al.*, 2020).

Different studies have been trying to identify main determinants of EUA prices. The next section presents recent studies and methods to determine the EUA prices.

LITERATURE REVIEW

There are several studies that seek to explain the determinants of carbon price. Most of them used autoregressive models in which the only explanatory variable was the carbon price in the past. One example is the research of Ji *et al.* (2019), which introduced an ARIMA-CNN-LSTM model to forecast the carbon future price. The ARIMA-CNN-LSTM model employs the ARIMA model and the deep neural network structure that combines the CNN and LSTM layers to capture linear and nonlinear data features. In an ARIMA-CNN-LSTM model structure, the ARIMA was used to capture the linear features. The Convolutional Neural Network (CNN) was applied to capture the hierarchical data structure while the Long Short Term Memory network (LSTM) was used to capture the long-term dependencies in the data. The authors adopted the weekly futures price of the carbon in the EU emission trading system as the main research dataset, without exogenous variables. The dataset covered the period from 2008 to 2019.

Hao *et al.* (2020) modelled carbon price using a novel hybrid model based on feature selection and a multi-objective optimization algorithm for autoregressive forecasting, without exogenous variables. The datasets, which were collected from the Shenzhen, China and European Union Emissions Trading Scheme daily carbon, considered the period between 2014 and 2017. For the later period, 2017 to 2019, Huang *et al.* (2021) combined econometric (GARCH) and artificial intelligence methods to forecast the daily price of EUA futures. The authors also did not consider exogenous variables. Also applying artificial intelligence models, Sun and Huang (2020) proposed a hybrid model for carbon price forecasting, introducing a secondary decomposition algorithm. The back propagation neural network model optimized by genetic algorithm was utilized for prediction. Beijing and Shanghai carbon markets were chosen due to the volume, turnover and activity of the Beijing carbon market, and the upcoming national carbon emission trading platform and settlement system that would still be set up in Shanghai. The data from the opening date of each market starts in 2013 and ends in 2019.

Another article that included no exogenous variables was Jianwei *et al.* (2021). The authors conducted a denoising-hybridization procedure, which is a hybrid model of extreme-point symmetric mode decomposition (ESMD), kernel independent component analysis (KICA) and least squares support vector regression (LSSVR) to predict the carbon price. Four ECX carbon futures prices matured in December 2016, December 2017, December 2018 and December 2019 were considered as a dataset. Also using different strategies to forecast carbon prices without exogenous variables, Lu *et al.* (2020) applied machine learning methods to predict the daily carbon price and trading volume of eight carbon markets in China, including Beijing, Shenzhen, Guangdong, Hubei, Shanghai, Fujian, Tianjin, Chongqing between 2016 and 2019.

Besides these articles that used past carbon price as the only explanatory variable, other authors were willing to extract more information about the price fluctuations, still without making use of exogenous variables. Xu *et al.* (2020) presented a carbon price prediction model by using time series complex network analysis technology and extreme learning machine algorithm. In the model, the authors mapped the carbon price data into a carbon price network, and then extracted the effective information of carbon price fluctuations by using the network topology, and used the extracted effective information to reconstruct the carbon price sample data. To test the validity of the model, they selected the carbon emission price data of the second, third and transition stages of the European Union Emissions Trading System (2013-2018), and the results showed that the method can improve the predictive accuracy of the model.

Another study that proposed a method to extract information about price fluctuations with no exogenous variables was the one of Tian and Hao (2020), which performed a chaotic analysis based on the maximum Lyapunov exponent and determined the appropriate distribution functions based on a newly proposed hybrid optimization algorithm. In the forecasting model, the phase space reconstruction technique was applied to reconstruct the sequences decomposed by variational mode decomposition due to the chaotic characteristics of the carbon price series. Then, an adaptive neuro-fuzzy inference system model was trained by the newly proposed hybrid optimization algorithm using carbon price data of the European Union Emissions Trading System and Shenzhen of China from 2013 to 2017.

Some authors introduced policy measures as an important factor to predict carbon price. Song *et al.* (2019) developed a fuzzy stochastic model to predict carbon price in China under the effect of demand-related policies. The authors analyzed the demand-related policy formulated in the second developing-phase of the Shanghai Environment and Energy Exchange from 2016 to 2018 and predicted the price trend after each demand-related policy publication. The authors concluded that the simulated results supported the idea that the supply of free allowances was excessive, even though it had shown a decreasing trend in period II. This finding indicated that market liquidity derives from policy speculation, rather than actual trading demands, a result which further supported the leading role of policy in the carbon market. According to the authors, the government still needed to expand the diversity of demand-related policies, by either increasing the proportion of auction or decreasing the supply of allowances, to absorb the excess of free allowances.

Xu and Salem (2021) explained that, traded as a financial asset, carbon allowances are vulnerable to internal and external shocks and little is known about potential carbon price bubbles in China. These explosive episodes were closely related to immature market mechanisms and policy implementations. The authors applied the Generalized Sup Augmented Dickey-Fuller (GSADF) test, which allowed the detection of multiple bubbles, as well as the date stamping of bubbles in carbon prices. The empirical results, using a dataset between 2014 and 2017, found three bubbles in the Guangdong pilot, two bubbles in the Tianjin pilot, and one bubble in the Hubei pilot.

Also using policy measures to explain carbon prices, Ji *et al.* (2021) applied a structural break test and an autoregressive distributed lag model in the Chinese carbon emissions trading scheme pilots, between 2013 and 2019. The results indicated that oversupply of allowances, low auction prices and use of China certified emission reductions would cause a remarkable decline in carbon prices. The expansion of the carbon market and centralized trading would raise carbon prices. Oil prices were positively correlated with carbon prices, and coal prices were negatively related with carbon prices (Bayramov & Islamli, 2022). Carbon-intensive product prices also affected carbon prices. Chemical prices were positively linked with carbon prices in Shenzhen, while negatively related with those in Beijing and Shanghai, due to differences in sectorial coverage. Non-ferrous prices had positive impacts on carbon prices in Beijing but negative impacts on those in Shenzhen, due to differences in industrial structure. Financial markets and weather had limited impacts on carbon prices.

Ren *et al.* (2020) applied a GARCH model and adopted an intelligent optimization method (a genetic algorithm) to find the optimal scenario to simulate the reaction of carbon prices to regulatory announcements in China. The Shanghai, Guangdong and Hubei pilot carbon markets were taken as case studies, from 2013 to 2017. The results showed that China's pilot carbon markets had achieved the weak form of efficiency, since the allowance allocation plan would affect the carbon price trend, and the allowance auction impact on the carbon price was not decisive.

A comparison between Phases I and II is conducted by Creti *et al.* (2012) estimating cointegration regressions for each period separately. According to their results, while the oil prices have a positive relation with EUA prices for the entire period, economic activity measured through financial data shows different results, being positively correlated only during Phase I.

Another set of authors inserted energy prices as exogenous variables to explain carbon prices. Adekoya (2021) examined the predictive role of energy prices in the forecast of European Union carbon allowance prices, using the Feasible Quasi Generalized Least Squares estimator. The results showed that the carbon allowance prices were significantly predicted by all the energy prices considered, namely crude oil price (Brent), natural gas price and coal price. However, the relation was greater for oil prices, indicating the stronger influence of the global crude oil market and its vulnerability to shocks compared to the global coal market (Kilinc-Ata, 2022).

Batten *et al.* (2021) also investigated the extent to that key energy prices (coal, gas, oil and electricity) and weather explain EUA prices, and whether this relationship changed since full auctioning came into effect in 2013, by using two structural breaks. Energy prices were found to impact the carbon price in phase III of the EU ETS. However, Ordinary Least Squares modelling based solely on energy prices explained only 12% of carbon price variation. Weather variables did not affect the carbon price except for unanticipated temperature changes and the authors consider this result an indication that it is not the level of temperature that impacts the carbon price, but rather it is unanticipated changes in temperature that matter. The required data from 2013-2017 included spot prices for EUAs, obtained from the Intercontinental Exchange data on DataStream, and the Intercontinental Exchange auction results.

Duan *et al.* (2021) uncovered the marginal impacts of energy prices (oil, coal and natural gas) on carbon price variations across carbon-energy price distributions in Phase III of the European Union Emission Trading Scheme (EU ETS). Applying a novel Quantile-on-Quantile (QQ) regression and the causality-in-quantiles approach, the empirical results demonstrated negative impacts of energy prices on carbon prices. Concerning different energy sources, the impacts of both oil and coal prices showed an increase along with a rise in carbon quantiles. The absolute values of their impacts were much greater than that of the gas price impacts. Using Intercontinental Exchange (ICE) as the main source of data, the authors collected daily data of Brent crude oil futures prices, ECX EUA carbon futures prices, UK natural gas futures prices, and Rotterdam coal futures prices, from 2013 to 2019.

Koch *et al.* (2014) have focused specifically on the main determinants of price falls through regression analysis of carbon prices on a set of energy and economic variables. They found a significant relationship between EUA prices and both economic activity measures and other fossil fuels prices.

Besides energy variables, some studies introduced financial market variables, such as stock prices, to explain carbon prices. Li *et al.* (2020) used a neural network model to simulate the long-term trends of EU ETS futures products price in scenarios that represent the typical features of a carbon trading market, based on a dataset comprised of multiple sources, including Euro stoxx600 index, coal and crude oil prices, natural gas prices and European clean energy company stock prices. The time span of each variable in that research is from 2013 to 2017. The results show that the magnitude of economic development's effect on carbon price was the largest among other factors, with the shortest duration. In comparison, the effect of black energy consumption was weaker, but its lasting duration is the longest. Additionally, the impact of clean energy development on carbon price was similar to that of black energy, but the effect magnitude and lasting duration were relatively smaller. According to the authors, these findings suggested three viable directions for the development of China's carbon trading market in the future i.e. adjusting total quotas in accordance with economic development, establishing market price stabilization mechanisms, and developing clean energy.

Also using stock indexes as exogenous variables, Zhu *et al.* (2019) proposed a multiscale analysis model to explore and identify the carbon price drivers at different time-scales. By introducing the latest multivariate empirical mode decomposition, carbon price and its potential drivers were decomposed into several groups of simple modes with specific economic meanings. The cointegration techniques, error correction model and Newey–West estimator were combined to capture the carbon price drivers at similar timescales. Illustrated by the samples of the European Union Emissions Trading System from 2009 to 2016, among the most important drivers of carbon price, electricity price and stock index showed positive impacts, while coal price showed a negative impact.

Another study focused on the relation between EUA and financial instruments is the one of Tan *et al.* (2020), which develops a network analysis of both return and volatility for several financial assets and energy commodities. They concluded that EUA and oil markets were closely connected, much more than other financial assets such as national currencies or risk measures (Rafay & Farid, 2015). Although their volatilities seem to present different drivers, their behavior is similar in regard to other relevant financial variables.

Some authors introduced several variables to explain carbon prices, including those related to weather and institutional conditions. Meng *et al.* (2019) proposed a mixed data sampling regression model and back propagation neural network to perform real-time forecasting of weekly carbon prices in China's Shenzhen carbon market, using data from 2014 to 2017. In addition to daily energy, economy and weather conditions, an environmental factor was introduced into predictive indicators. The empirical results showed that the carbon price is more sensitive to coal, temperature and air quality index than to other factors.

Zhao *et al.* (2017) studied the long-run relationship between carbon price in Chinese ETS pilots and its influential variables: coal price, economic activity (represented by an industrial index), temperature and carbon price in the European market. Due to the existence of structural breaks in every variable, cointegration approaches that consider one and two structural breaks were applied. The dataset included information from 2013 to 2016. Results showed that there was a long-run cointegration relationship between carbon price and those factors. The cointegration model with structural breaks outperformed conventional cointegration models insofar it could better explain the actual relationship. Except for the economy variable in Shanghai, all variables played a significant role on carbon price, among which coal price was the dominant factor.

Best and Zhang (2020) used panel models from 2014 to 2019 to determine which exogenous variables, as energy reserves and institutional variables, explained continuous carbon-pricing variables for a global sample of countries. They found that larger coal reserves per capita had a negative effect on the carbon-price levels. Control of corruption is a key governance variable that has been positively associated with carbon-pricing outcomes. Another important political dimension was the degree of political globalization. For economic resources, there was evidence that larger stocks of domestic credit help to enable carbon pricing. There was some evidence indicating that climate change awareness was positively associated with carbon pricing.

Bento and Gianfrate (2020) tested whether the macroeconomic, regulatory, industry, and firm-specific characteristics, such as technological attributes and institutional context, affect the disclosed level of the Internal Carbon Pricing (ICP), by using panel models. ICP reflects an emerging set of practices voluntarily adopted by companies to embed climate footprint in operations and business models, being usually higher than allowances prices. The authors examined the information that had been collected by the Carbon Disclosure Project in several reports. The results showed that the institutional context influences the choice of internal carbon prices, as companies with headquarters in a country with high GDP per capita are more likely to adopt stringent carbon prices. The authors also concluded there was a positive and significant relationship between internal carbon price and both board independence and energy sector. At last, they observed that contextual variables on the economy and regulation were found to explain more of the carbon pricing behavior of companies than industry and firm's characteristics put together.

A set of studies applied a computable general equilibrium model, focusing on macroeconomic effects to predict carbon prices. Lin and Jia (2019) assessed the influencing factors of emission trading price (industry coverage, the annual decline factor, and free allowance rate) and analyzed the impact mechanism in detail. The results showed that ETS price and emission reduction had a significant positive correlation. Fewer industries, higher annual decline factor, and higher free allowance rate would push ETS price up. The authors also found that ETS prices were unpredictable when the mechanism is not yet fully determined because of the high relationship between ETS price and the mechanism of ETS.

Garaffa *et al.* (2021) assessed the distributional effects of carbon pricing on Brazilian households, using data from 2008 and 2009. The authors applied a multi-regional Computable General Equilibrium (CGE) model with representation of multiple households according to a family expenditure survey. Results showed that carbon pricing avoids further carbon intensive infrastructure lock-in by further promoting biomass in electricity generation and biofuels in the transportation sector. Lump-sum transfers from carbon revenue helped boost income of lower deciles up to +4.5%, while targeting transfers to most vulnerable groups led to an income growth of +42.2% by 2030. Brazil has a large gap in terms of effective carbon pricing when compared to other countries that could be addressed in the context of the ongoing tax reform debate, with carbon revenue contributing to the financing of social spending.

It is clear that in the last few years several studies have intended to explain the determinants of carbon prices, using different techniques, such as econometric models, artificial intelligence, neural networks, and computable general equilibrium models, and also several variables, such as past carbon price, policy measures, institutional and financial variables, energy prices and macroeconomic variables. The most interesting results for this chapter showed a connection between carbon prices and policy measures, as well energy prices. Financial variables certainly were necessary because of the similar fluctuations with carbon prices, typically derived from stock markets. The stock market information signals economic conditions as well.

DATA AND MODEL ESTIMATIONS

Identifying the main drivers of price movements is particularly important since European carbon pricing went through significant drops during past phases, despite its recent surge. Such behavior could reduce firms' incentive to transition towards low carbon technologies. Despite that, the literature focused on studying the association of carbon pricing to financial variables, such as financial assets and bonds, paying little attention to economic and regulatory interventions over EUA prices, as can be noticed in the previous section. In this chapter, the carbon futures market price was modeled with the following equation:

$$P.EUA_t = \beta + \theta V.EUA_t + \delta EnergyPrices_t + \gamma MarketIndex_t + \mu RegulatoryMeasures_t + \epsilon_t$$

Where $P.EUA_t$ stands for the EU ETS carbon market price at period t and is the dependent variable for both models estimated in this chapter, while $V.EUA_t$ represents the total volume traded at period t and is included as an explanatory variable. Both time series were obtained from the EEX website. The other regressors included aim to comprise the main drivers of carbon price's fundamentals, as presented by the literature and taken into account by policymakers. The first of those is $EnergyPrices_t$, which includes two different reference prices, Brent for oil and Henry Hub for natural gas, both series were obtained from the US Energy Information Administration. To consider the relation of carbon market prices with both financial variables and the level of economic activity, two relevant European stock indexes were included in the regression: London and Frankfurt. These variables were taken from the Financial Times and the Börse Frankfurt's website, respectively. Finally, $RegularMeasures_t$ stands for a set of three dummies: (i) the start of the Paris Agreement in January 2016, establishing goals for parties which signed this binding international treaty on climate change; (ii) the MSR implementation, during Phase 3, in January 2019, searching price stability by allowances control; and (iii) the MSR interventions to reduce or elevate the cap of allowances. The ϵt statistical error is modeled as a conditional heteroscedastic process. Both ARCH (autoregressive conditionally heteroscedastic) and GARCH (generalized autoregressive conditionally heteroscedastic) models are tried. The ARCH (1) specification is the following:

$$\epsilon_t = v_t \sigma_t$$

Where v_t and σ_t are independent random variables such that v_t ~i.i.d.(0,1) and

$$\sigma_t^2 = \omega + \alpha_1 \epsilon_{t-1}^2$$

The GARCH (1,1) specification replaces the last equation by:

$$\sigma_t^2 = \omega + \alpha_1 \epsilon_{t-1}^2 + \phi_1 \sigma_{t-1}^2$$

Our dataset has daily frequency starting from July 4, 2008 and extending up to October 9, 2020.

A negative sign is expected for the coefficient of the volume variable, since the greater the number of future contracts on offer, the lower its price. For the international price variables of Brent oil and natural gas Henry Hub, a positive sign is expected, reflecting the greater economic activity and the increased demand for carbon credits. In turn, a positive sign is expected for the coefficient of the stock exchange variables, based on the idea that good expectation about macroeconomic conditions leads to rises in industrial economic activity, the need for a larger amount of carbon trading, and, consequently, higher prices. Also, stock exchange variables reflect speculative movements that could run through the allowances market.

Regulatory dummies are tested to verify the adherence of prices to changes in regulatory policies related to carbon credits. Regarding these variables, the parameters signs depend on how those measures relate with market expectations when announced. If the regulatory innovation reduces the supply of licenses above expectations, the market should react positively, buying contracts and raising prices, thus having a positive sign. If the measure reduces the license offer below expectations, the market may react negatively, selling contracts and reducing prices, thus showing a negative sign. If the measure meets the agents' expectations, the variable should not be significant.

As carbon pricing is after all part of the secondary market, it is expected to display volatility patterns characteristic of financial series. Financial series typically exhibit time-varying volatility behavior as well as clusters of volatility in which periods of high variation in prices are followed by periods of more stable behavior. Models usually adopted for the study of financial series, such as (G)ARCH, were tested for our dataset of daily and volatile variables.

In the first place, Augmented Dickey-Fuller unit root tests on the set of variables were conducted. The results are presented in Table 1.

Table 1. Presence of unit root – ADF test.

Variables	Unit Root
Carbon secondary market price	✔
Carbon secondary market volume	
Henry Hub price	
Brent price	✔
Frankfurt Stock Index	✔
London Stock Index	✔
Dow Jones Stock Index	✔

Since carbon secondary market volume and Henry Hub price did not present unit root, cointegration models are not necessary. However, since all the other variables presented unit root, the (G)ARCH models were run in first differences.

An ARCH (autoregressive conditionally heteroscedastic) regression models the variance of a time series[2] and is used to describe a volatile variance, which could present a lasting trend or simply short periods of increased variation. Such models were created in the context of econometric and finance problems having to deal with the variation of investments or stock prices per time period. For that reason, it is commonly suggested that the dependent variable used in those models should be either the ratio of losses/gains to last period's value, or the logarithm of the ratio of present value to last period's value. Both specifications were tested, nevertheless there were no advantages in terms of the best fit modeling.

Autocorrelation Function and Partial Autocorrelation Function plots for both the carbon secondary market price and its difference are depicted in Figure 2 and Figure 3, respectively. Those plots are used as identification tools to set the ARMA model for the series.

Figure 2. ACF of carbon secondary market price

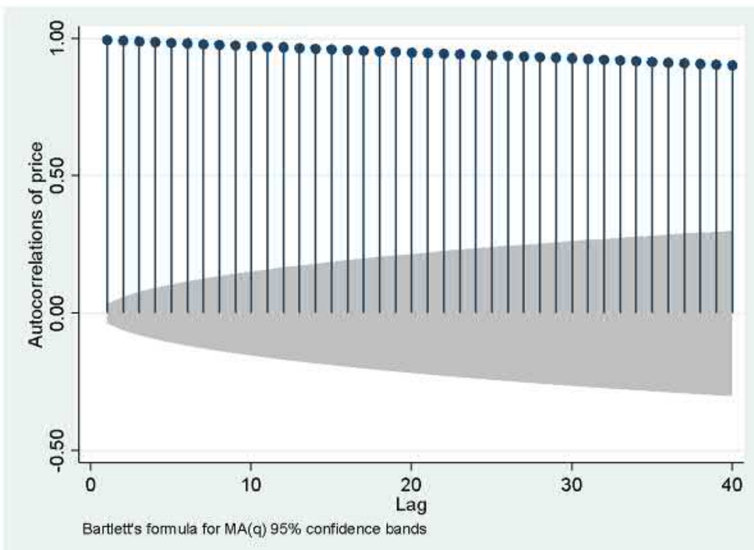
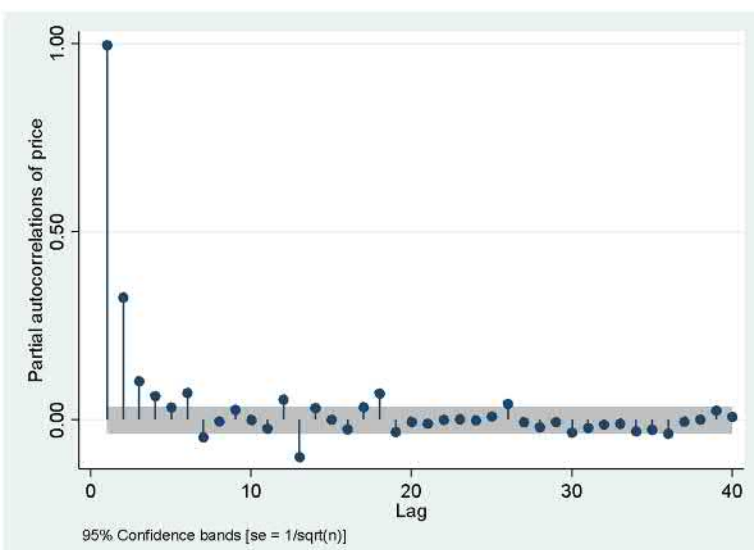


Figure 3. PACF of carbon secondary market price.



Before taking the first difference, ACF slowly decreases, indicating the presence of a unit root, as already discussed above, and the PACF suggests an AR(2) or an AR(3) behavior.

Figure 4. ACF of first differenced carbon secondary market price

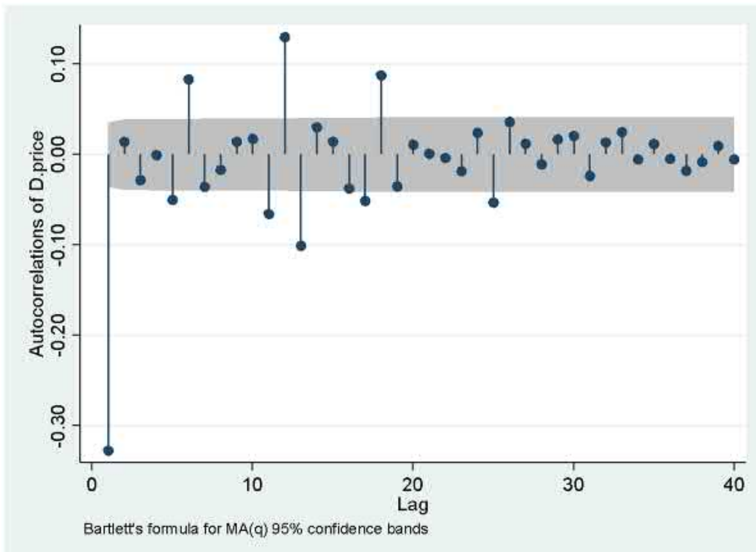
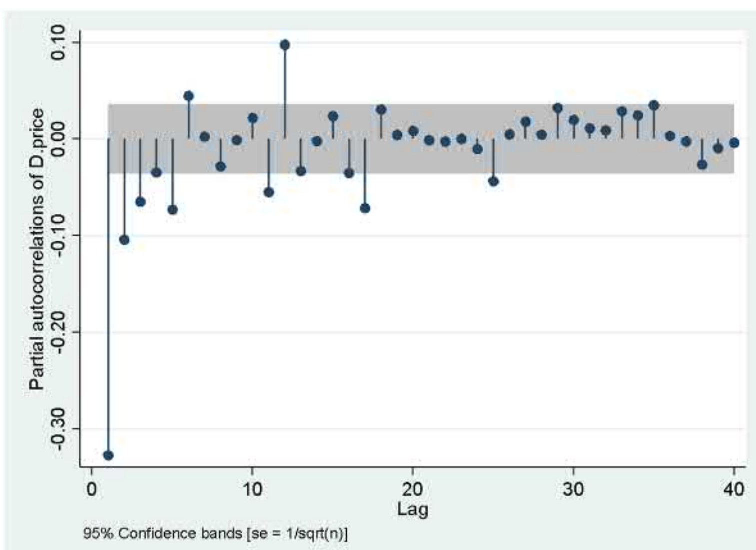


Figure 5. PACF of first differenced carbon secondary market price.



After differentiating the series, both plots suggest either an ARMA (3,1) or an ARMA (2,1). Despite this result, both ARCH and GARCH models were reported, considering robust estimations for the standard errors and directly considering their variance for the estimation. Table 2 presents the results for the

ARCH models. They show that the volume of EUA in the secondary market did not affect prices. Agents take the decision to sell or buy by looking at other variables instead, especially regulatory measures and economic activity, as presented in Table 2.

Industrial activity was represented by the two energy prices variables, since increasing fuel prices are usually connected with higher industrial activity. Brent price showed positive value and was statistically significant, while Henry Hub price was not. As it was expected, a higher level of economic activity leads to higher carbon emissions and, therefore, demand for the EUA also grows. Additionally, the effect of market speculation was isolated by introducing stock exchange market indexes, both Frankfurt Stock Index and London Stock Index. Just the first one was significant and had a positive value. This indicates that macroeconomic expectations and/or speculative movements in the stock exchange market runs through the allowances market.

The variable MSR interventions were positive and statistically significant, indicating the supply of licenses was reduced above expectations and the market reacted positively, buying contracts and raising prices, thus having a positive sign. The MSR interventions variable showed the most important estimated parameter between all explanatory variables, of 0.0845, which may indicate that future allowances prices were 0.0845 euros higher because of these interventions.

Seasonal dummies and Friday dummy, representing the last day of the week or the secondary market closure, were not statistically significant.

ARCH(1) with AR(1) and MA(1) components were ran, which were also significant. AR specifies the autoregressive terms of the structural model disturbance to be included in the model and MA specifies the moving-average terms to be included in the model for the white-noise disturbances.

In its turn, the GARCH model was estimated with the inclusion of one period lagged for both the dependent (price) and the exogenous variables. Table 3 shows the results for the GARCH model. The price of the day before was negative and statistically significant, indicating that an elevation in price in period t-1 is usually followed by a reduction of the price on period t, which is possibly due to the usual daily volatility of the variable. Something that, by its turn, reinforces the desirability to use estimations that are capable of modeling volatility. The volume of EUA was negative and significant as expected.

For this specification both Brent and Henry Hub prices were significant, however while the Brent's coefficient remained positive, the Henry Hub's presented a negative sign. Such a negative result was rather counterintuitive, since the expected impact was a positive relation between industrial use of energy and the need for allowances. One could imagine that the impact of energy prices has two sides, that is, supply and demand. If Henry Hub price is determined more by the demand side, a rise in gas demand could increase the price of gas and the need for allowances, increasing EUA's prices (positive relation). Instead, if Henry Hub price is determined more by the supply side of the market, a drop in gas supply raises the price of gas, but economic activity also reduces, impacting negatively the EUA prices. Finally, it is also necessary to take into account that natural gas is much less pollutant than oil, which could be responsible for influencing this opposite pattern.

Stock exchange market variables were not significant. Possibly, the connection between the stock and carbon markets was represented by the volatility of the GARCH component. What could suggest that the linkage of EUA's price and economic activity is better represented by its relation with fuels than with financial variables?

Table 2. ARCH model results.

ARCH Model	Coefficient	Not Robust		Robust	
		Z Statistic	P-Value	Z Statistic	P-Value
Carbon secondary market volume	-0.003	-1.94	0.052	-1.08	0.282
Brent price	0.0544***	10.65	0.000	5.39	0.000
Henry Hub price	0.0726	1.66	0.096	1.09	0.278
Frankfurt Stock Index	0.0005***	3.5	0.000	3.11	0.002
London Stock Index	0.0003	1.26	0.209	0.89	0.372
Phase 3	0.0118	0.41	0.681	0.41	0.682
Paris Agreement	-0.0208(1)	-0.39	0.700	-1.35	0.177
Cap measures	0.0845***	1.59	0.112	2.74	0.006
Fridays	0.0343	1.12	0.261	1.41	0.159
Seasonal Dummies					
Jan	-0.0902**	-1.6	0.109	-2.11	0.035
Fev	-0.0372	-0.72	0.472	-0.83	0.406
Mar	-0.0871**	-1.83	0.067	-2.06	0.040
Apr	-0.0155	-0.26	0.795	-0.38	0.702
May	-0.0364	-0.52	0.601	-0.92	0.365
Jun	0.0037	0.07	0.945	0.09	0.928
Jul	-0.0466	-0.83	0.404	-1.16	0.247
Aug	0.0157	0.31	0.754	0.35	0.726
Sep	-0.0524	-1.24	0.213	-0.83	0.408
Oct(1)	-0.0071(1)	-1.39	0.164	-1.59	0.113
Nov	-0.055	-0.98	0.325	-1.29	0.198
Constant	0.0283	0.68	0.494	0.77	0.444
ARMA and ARCH					
AR1	-0.8161***	-3.66	0.000	-2.32	0.020
AR2	-0.0464	-1.13	0.259	-0.47	0.636
MA1	0.679**	3.05	0.002	1.98	0.048
SIGMA2	0.196***	67.19	0.000	67.15	0.000

*** Significance level of 1%. ** Significance level of 5%. *Significance level of 10%. (1) P-value between 10% and 25%. Significance is only considered for the robust estimations of the standard deviation.

Finally, another regulatory measure gained statistical significance in the GARCH model: the MSR implementation during Phase 3. While the coefficient associated with the cap measures kept its sign from the ARCH model, the one associated with Phase 3 was negative. This result indicates that the MSR implementation was followed by a price fall that could have been provoked by low expectations of allowance reduction, which led the market to react negatively, selling contracts and reducing prices. MSR implementation (Phase 3) and MSR interventions (Cap measures) showed the most important estimated parameters, of -0.3361 and 0.2329, respectively, and the future allowances prices were 0.3361 euros lower and 0.2329 euros higher because of the MSR implementation and MSR intervention, respectively.

At last, the auto-regressive and the moving average components used for modeling volatility were statistically significant. The smaller magnitude of the auto-regressive component indicates both the stability of the process responsible for setting the EUA's price volatility, but also a smaller persistence of shocks.

In summary, regulatory measures are even more relevant than other explanatory variables as observed by the level of the coefficients. Such results highlight the importance of policy maker decisions in the carbon market and is the main contribution of this chapter, as discussed in the following section.

Table 3. GARCH model results.

GARCH Model	Coefficient	No Robust		Robust	
		Z Statistic	P-Value	Z Statistic	P-Value
L1 Carbon secondary market price	-0.0190***	-5.63	0.000	-2.99	0.003
L1 Carbon secondary market volume	-0.0034*	-2.54	0.011	-1.93	0.054
L1 Brent price	0.0032**	4.34	0.000	2.32	0.020
L1 Henry Hub price	-0.0614***	-5.88	0.000	-3.09	0.002
L1 Frankfurt Stock Index	0.00003	1.91	0.057	1.04	0.299
L1 London Stock Index	-0.00004	-1.1	0.270	-0.65	0.518
Phase 3	-0.3361***	-9.7	0.000	-3.46	0.001
Paris Agreement	-0.04(1)	-1.92	0.055	-1.47	0.141
Cap measures	0.2329***	4.77	0.000	2.92	0.003
Fridays	-0.0169	-1.04	0.299	-0.9	0.367
Seasonal Dummies					
Jan	-0.2098***	-4.87	0.000	-2.97	0.003
Fev	-0.1532**	-4.03	0.000	-2.41	0.016
Mar	-0.1234(1)	-3.49	0.000	-1.59	0.111
Apr	-0.1164(1)	-3.05	0.002	-1.47	0.141
May	-0.0912(1)	-2.44	0.014	-1.36	0.173
Jun	-0.1318**	-3.65	0.000	-1.97	0.049
Jul	-0.1074(1)	-2.99	0.003	-1.61	0.108
Aug	-0.0464	-1.37	0.171	-0.72	0.469
Sep	-0.116*	-3.09	0.002	-1.69	0.090
Oct	-0.0061	-1.67	0.094	-0.91	0.364
Nov	-0.1028(1)	-2.85	0.004	-1.55	0.121
Constant	0.5882***	5.09	0.000	2.73	0.006
ARCH and GARCH					
ARCH	0.261***	4.91	0.000	3.94	0.000
GARCH	0.768***	16.29	0.000	11.47	0.000

*** Significance level of 1%. ** Significance level of 5%. *Significance level of 10%. (1) P-value between 10% and 25%. Significance is only considered for the robust estimations of the standard deviation. L1 is *lag(1)* of variables (x_{t-1}).

RESULTS AND DISCUSSION

The results of ARCH and GARCH models showed that financial and energy variables are not the only drivers to explain carbon price trends. Policy measures also played an important role in dictating the secondary price movements in the carbon market.

Most of the studies presented in this chapter used the carbon price in the past to predict the future price. The signs of the parameter were ambiguous in these studies: some of them showed a positive relation, others, a negative one, depending on the market (Chinese or European) and the chosen period. In our model, the lagged price presented a negative sign, showing that a higher price in the past was followed by a decline in the next period. This behavior was expected, since there are market adjustments.

It is important to explain that, in our study, the goal was not to predict the future price observing only the price movements through ARIMA models. Instead, our study intended to determine which variables explain the price trends. Because of that, other variables were introduced, such as financial, energy and policy measures variables as exogenous components. The financial variables were maintained, as in the literature, to consider the investor's motive and economic movements.

The results showed that the parameter of stock indexes in Frankfurt and London was not statistically significant when it was introduced GARCH components. It is possible that the addition of GARCH components helped to explain the volatility of carbon prices that was previously explained by stock indexes.

Energy prices played an important role in the model, although the two variables (oil and natural gas prices) presented different parameter signs. The oil price parameter was positive, which indicated that the use of oil increased the carbon license demand and also the carbon prices. However, the natural gas price parameter was negative. In the literature, it was common for studies to adopt oil or coal, the most polluting energy sources. The natural gas negative price sign obtained in our study is a novelty in the literature. highlighted that the natural gas market behavior should be different from that of the oil market, considering also that this energy source is less pollutant.

In the literature, the policy measures were used as control variables, but not as important components to foresee price volatility. In our model, for Phase 3 the parameter was negative, which indicates that the prices declined after the announcement of Phase 3. For the second policy measure variable, Cap Measures, the obtained sign was positive. It can be concluded that the positively affected the expectations of the market related to the carbon market fundamentals, increasing the demand for carbon allowances and also the future carbon prices.

There are several differences between our study and the literature, especially related to goals and the importance given to policy measures variables. While most of the literature focuses on forecasting prices, our goal is to find the explanatory variables of carbon prices and to investigate the role of policy measures.

CONCLUSION AND RECOMMENDATIONS

As discussed in the previous sections, carbon emission allowances have been considered an important policy instrument to control for the excess of greenhouse gases in the atmosphere (Bunyaminu & Yakubu, 2022). The correct balance between price and quantity of carbon emission allowances is key for a successful implementation of any carbon trading system.

In this chapter the variables were investigated that might have some impact on the European Union Allowances' prices and their trends after the market is operational. For such a task, several variables of control were introduced. Initially, as a proxy of the economic activity in the short run, the daily variations of either Frankfurt or London Stock Exchanges are used. Nevertheless, the results showed that the economic activity in the short run was not significant to explain the variations in the EUA prices. In other words, seasonal or daily movements of those stock exchanges did not affect the price of allowances in the EU.

The influence of fuel prices – considering the prices of oil as negotiated in Europe (Brent) and of natural gas in Louisiana in the US (Henry Hub) – upon the EUA future prices was also analyzed. The results showed that EUA future prices tend to increase as oil prices rise. This can be considered an expected result once a rise in fuel prices is usually connected with higher industrial activity and higher GHG emissions, which, for its turn, boosts the demand of allowances to offset such additional emissions.

It is worth noticing that in the GARCH model, natural gas prices were also significant regarding its impacts on EUA future prices. However, unlike the oil prices, natural gas prices were negatively correlated with the prices of EUA. In other words, a rise in the natural gas prices tends to reduce the EUA future prices. A possible explanation to this finding could rely on the fact that natural gas prices have been more sensitive to shifts of its supply side rather than of its demand side. Shifts in the natural gas supply in Europe have been caused mainly by geopolitical moves of Russia, the largest supplier in the region that, quite often, changes the disposable quantities of natural gas to Europe. A drop in the amount of natural gas available to the EU countries might have a negative impact on their economic activity and, thus, less emissions occur. Consequently, the need for carbon allowances to offset such emissions diminishes, leading to a drop in EUA future prices. Nevertheless, further investigation should be carried on to clarify the rationale behind the result that was found.

Finally, and more important, the three regulatory measures that were tested proved to be crucial to explain the EUA price movements. Either (i) the launch of Paris Agreement in January 2016, establishing goals for parties which signed this binding international treaty on climate change; (ii) the implementation of the *market stability reserve* in January 2019, aiming price stability by EUA emissions' quantity control; and (iii) the sequential interventions through the *market stability reserve* reducing the amount of allowances, such as in May 2019 and in August 2020, had, all of them, substantial impacts on the EUA future prices.

More precisely this last measure – the implementation of the market stability reserve – had a positive and statistically significant impact. As observed, a reduction in the supply of allowances resulted in an increase in the allowances future prices even above what was previously expected by the market participants. In other words, restrictions on the number of allowances tends to lead the participants to anticipate scarcity and propels up the prices of these allowances.

It is worth noticing that the identification of the main drivers for European Union Allowances prices and how the *market stability reserve* affects them are crucial to understand the dynamics of the allowances' prices and thus to achieve a reasonable price fluctuation. One of the most undesirable results of the carbon markets is that either the prices stay too low, discouraging the pursuit for processes and measures that lead to emissions reductions, or they skyrocket so fast, causing a supply shock in the economies.

Practical implications of the findings summarized in this chapter are related to the fact that acting through regulatory measures, and especially implementing the *market stability reserve* mechanism, can be a useful form to efficiently intervene in emissions trading systems already in place. Moreover, these actions can notably play a key role as many countries and regions throughout the globe have not yet implemented their emissions trading systems. Avoiding the prices of allowances to get trapped into the extremes, either too low or too high, is key to achieving a balanced trend for the allowances' prices. Certainly, reaching reasonable levels of carbon prices will send correct signals to the market participants towards the expected emissions targets needed.

DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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KEY TERMS AND DEFINITIONS

ARCH: Autoregressive conditionally heteroscedastic.
ECX: Carbon future prices.
EU ETS: European Union Emissions Trading Systems.
EUA: European emission allowances of carbon.
GARCH: Generalized autoregressive conditionally heteroscedastic.
GHG: Greenhouse gases.
IPCC: Intergovernmental Panel on Climate Change.
MAC: Marginal abatement costs.
MSR: Market stability reserve.

ENDNOTES

1 A carbon dioxide equivalent or CO2 equivalent, abbreviated as CO2-eq is a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential.

2 As explained by the Eberly College of Science from Penn State, available in https://online.stat.psu.edu/stat510/lesson/11/11.1.

Chapter 15
Environmental Performance and Capital Structure:
Evidence From Asia

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ABSTRACT

This chapter aims to examine the effect of environmental performance (EP) on the capital structure of firms. Non-financial firms of 12 Asian countries over the period of 2007–2018 are used as the study sample. The results indicate that EP generally has a positive effect on the leverage of firms. When country-level variables such as financial system and legal system are considered, the results are more significant. Specifically, EP positively (negatively) affects leverage in civil (common) law countries. EP also positively (negatively) affects leverage in countries with bank-based (market-based) financial systems. A more in-depth analysis further reveals that the financial system plays a more important role than the legal system in determining the effect of EP on leverage.

INTRODUCTION

Climate change or global warming has been a rising concern worldwide. Although the reasons behind climate change are controversial, humans can always do something about it to mitigate its devastating impact. It has become a global consensus to tackle this problem altogether. Starting from late last century, Kyoto Protocol, the first international climate treaty, was first signed and ratified. It signifies global consensus and effort to combat climate change by setting the common goal to cut down on carbon emissions in the foreseeable future.

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Despite the global consensus to combat climate change, the extent of climate effort and its effectiveness vary across countries. Although some countries have made good improvements, others are lagging behind. Namely, environment performance (EP) varies depending on several factors, most of which are country-specific.[1] Improving EP clearly incurs cost, which is likely to be high for some industries or countries because they are less equipped to make related improvement. In addition to the costs incurred, compliance with climate-related regulations involves risks because firms tend to have lower profitability and become more indebted such that financial distress or bankruptcy become more possible under such circumstances. Given the costs and risks involved in improving EP, whether and how capital structure should be adjusted is worth exploring as it is one of key financial decisions of firms (Nosheen, *et al.,* 2016).

According to Mizutori and Guha-Sapir (2020), Asia tops the list in terms of the number of disasters during the period of 2000–2019, followed by Americas and Africa. Asia is the most affected continent for two reasons: it is the largest among all continents and its terrains are disaster-prone. High population density is also to blame. Most of the world's disasters over the last two decades are storms and floods, which are all related to climate change (Rafay, 2022) Asia is no exception. Given that Asia is the most affected continent by climate change, focusing on it to see whether any climate action or EP has bearings on capital structure of firms is worthwhile.

This chapter aims to examine whether and how EP improvement influences the capital structure of firms using non-financial firms in Asia as the study sample. The effect of EP improvement on the capital structure of firms is difficult to predict because several factors are at play (e.g., financing cost, risk, corporate governance (CG)). Nevertheless, this makes the research question all the more intriguing. For example, from the cost perspective, EP improvement entails higher costs for firms at least in the short run because of their compliance with climate-related regulations. As such, debt should reduce in response to rising cost, meaning that EP negatively affects the leverage of firms. However, in the long run, the positive effect of EP improvement on operating cost should be weaker or minimal because firms have sufficient time to make necessary adjustment to minimize the cost incurred. More importantly, as time goes by, financing cost should decrease because investors' consensus to combat climate change strengthens over time such that they are increasingly willing to invest. In addition, from the risk perspective, firms are expected to experience higher cash flow volatility at the early stage when they are required to comply with environmental laws and regulations. As firms invest increasingly more to improve EP though, the climate risk that they face will reduce. In sum, as costs and risks decrease over time, firms should be able to raise more debt as EP improves in the long run. EP should positively affect the leverage of firms under such circumstances.

Countries in Asia are diverse in terms of economic development, financial system, and legal origin, all of which are likely to influence EP's effect on the capital structure of firms. Hence, this chapter further investigates whether and how country variables such as financial and legal systems determine the effect of EP on the capital structure of firms. The study results provide important implications for Asian countries regarding whether and how to adjust capital structure in response to EP improvement.

LITERATURE REVIEW

Environmental Performance (EP)

Ever since humans started to recognize the impact of climate change in last century, EP has been a hot research issue. A school of research argues that improving EP incurs cost such that it may hurt business. Another school of thought holds that it pays to engage in EP improvement despite increased cost in the short run. The reason is that firms can gain from EP improvement in the long run after they pay for the environmental cost, and the environmental risk is better under control with EP improvement.

Existing literature extensively explores the effect of EP on firms, but most studies focus on how EP affects financial performance of firms. Most of the evidence suggests a positive effect of EP on financial performance, whereas scant information indicates a negative effect.

Capital Structure

Three major theories explain capital structure, and they are tradeoff, agency, and pecking order theories. According to tradeoff theory, firms balance marginal benefit and marginal cost of debt, so optimal capital structure exists. Based on agency theory, holding debt incurs agency cost of debt, so optimal capital structure is also predicted. Pecking order theory states that cash is the most preferred financing source, followed by debt and then equity. As debt is determined by hierarchical financing, there is no optimal capital structure (Myers 1984; Harris and Raviv 1988; Harris and Raviv 1991; Rafay *et al.,* 2014).

Research on capital structure abounds. Early research focuses on how capital structure is related to firm-specific determinants. Recent research explores the roles of country-specific factors in determining capital structure. To date, minimal research deals with the effect of EP on capital structure though. Hence, this chapter contributes to existing literature by examining this issue from the perspectives of cost and risk.[2]

EP and Capital Structure: A Cost Perspective

Existing literature on the relationship between EP and financing cost is inconclusive, depending on the countries examined and methodology. For example, the financial performance of firms may or may not improve with EP, suggesting that EP may incur higher cost (e.g., financing cost) such that financial performance worsens with EP.

Despite limited research on the link between EP and leverage or capital structure, most studies provide evidence directly or indirectly indicating a positive relationship between EP and leverage. For example, Kalash (2021) finds that EP positively affects leverage likely because EP contributes to a reduction in the cost of debt such that firms can afford to hold more debt as EP improves. Other studies find a negative effect of EP on the cost of debt although they do not directly examine the effect of EP on leverage. However, a decrease in the cost of debt or total cost implies an increase in leverage. For example, Boiral *et al*. (2012) find that mitigating greenhouse gas emissions of Canadian manufacturing firms helps them improve financial performance, suggesting a negative effect of EP on their production cost, which includes financing cost, among others. Muhammad *et al*. (2015) find that the reduced cost of financing resulting from improved EP and accompanying risk reduction contribute to a reduction in total cost borne by firms and transitively higher profitability. Du *et al*. (2017) find a negative effect of EP on the cost of debt, suggesting that "lenders applaud better environmental performance." Using firms in the real estate sector as sample, Eichholtz *et al*. (2019) find a negative effect of EP on the cost of debt. Fernández-Cuesta *et al*. (2019) examine the effect of EP on debt among European firms, and they find that the cost of debt reduces as EP improves and environmental risk reduces. Based on the sample consisting of the US and EU bonds, Chiesa *et al*. (2021) find that EP negatively affects the cost of debt.

Another stream of studies provide evidence indicating a negative effect of EP on the leverage of firms through the cost of debt. For example, Chen and Wang (2012) find that the ratification of Kyoto Protocol as well as the accompanying environmental compliance and subsequent improvement on EP has a negative effect on leverage. This suggests that EP results in an increase in the cost of debt. Fard *et al*. (2020) find that environmental regulations have a positive effect on the cost of bank loans, implying a negative effect of EP on leverage. Chang *et al*. (2021) find that corporate environmental liabilities have a negative effect on leverage, suggesting the presence of substitutability between environmental liabilities and financial liabilities. Their finding further hints on a negative effect of EP on leverage given the established positive link between corporate environmental liabilities and corporate social responsibilities (CSR) and that between CSR and EP (Chuang and Huang 2018). Using the Japanese firms as study sample, Suto and Takehara (2017) find a positive link between EP and the cost of debt, which is attributed to bank dependency.

EP and Capital Structure: A Risk Perspective

Existing literature appears to indicate a negative effect of EP on risk. For example, Khairollahi *et al*. (2016) find that EP as measured by reduction of carbon dioxide (CO_2) emissions has a negative effect on corporate risk, which in turn implies a positive effect of EP on leverage given the negative relationship between risk and leverage. Using the electric utility firms in the US as study sample, Gao and Connors (2011) find a positive effect of EP on leverage. They argue that poor EP involves high cash flow volatility associated with "potential regulatory changes and potential cleanup costs" and such a high risk reduces debt capacity. Using the polluting firms in the US as study sample, Dobler *et al*. (2014) find a negative relationship between EP and environmental risk. Using ASX-listed companies in Australia as study sample, Muhammad *et al*. (2015) find a negative relationship between EP and financial risk. Using US public traded firms as study sample, Sharfman and Fernando (2008) find a positive link between environmental risk management and the cost of debt. Given that environmental risk management results in EP improvement, EP is positively related to the cost of debt. Despite an increase in the cost of debt in response to better environmental risk management, Sharfman and Fernando (2008) find that EP has a net positive effect on leverage. This finding indicates that the negative effect of environment risk management on risk overwhelms its positive effect on the cost of debt. Other studies also provide ample evidence that poor EP leads to high financial risk of firms, implying a negative effect of EP on financial risk (e.g., Godfrey 2005; Capelle-Blancard and Laguna 2010; Lee and Garza-Gomez 2012; Dögl and Holtbrügge 2014).

In sum, the effect of EP on leverage remains inconclusive, with positive and negative effects being observed. The study results also depend on the countries examined. However, prior studies primarily assert that the cost of debt is the major channel through which EP affects leverage. On the one hand, improving EP means that environmental risk is contained and corporate profitability should increase and become more stabilized. As a result, creditors are willing to lend and the cost of debt decreases. On the other hand, improving EP usually involves compliance with environmental regulations, which is costly and causes firms to incur higher risk related to profitability. As a result, creditors are less willing to lend and the cost of debt increases.

Despite the opposing effects of EP on leverage, if the positive effect is more overwhelming than the negative effect, the net effect of EP on leverage will be positive. Hence, the following hypothesis is formulated:

H1: EP has a positive effect on leverage.

Legal System and EP's Effect on Leverage

Stulz (2005) first argues that country- and firm-level governance are mutually reinforcing. Namely, when country-level governance is good, CG is good, and vice versa. Prior studies indicate that country variables matter in determining CG (Doidge *et al*. 2007). For example, legal systems play a key role in determining CG across countries (La Porta *et al*. 2000; Anderson and Gupta 2009). Increasingly more evidence further indicates that country-level governance variables have an overriding effect on CG (Chen 2011; Chen and Yang 2017).

La Porta *et al*. (1998) construct the indexes for shareholder rights and creditor rights. They find that shareholder rights are generally stronger in common law countries than in civil law countries. The same goes for creditor rights. However, the results of statistical tests demonstrate that the difference in shareholder rights is more striking than that in creditor rights. Specifically, shareholder rights for common law countries are always significantly stronger when compared with all types of civil law countries, including German, French, and Scandinavian civil law countries. By contrast, creditor rights for common law countries are not necessarily significantly stronger when compared with civil law countries. Specifically, there is no significant difference in creditor rights between common law countries and German civil law countries. In addition, any difference in creditor rights between common law and other types of civil law countries is less significant than that in shareholder rights for the same comparison. Namely, shareholder rights are highly emphasized in common law countries compared with in civil law countries.

In common law countries where shareholder rights are stronger, shareholder activism is higher because shareholders are better protected and thus more incentivized to pursue their own benefits by exercising their rights to influence the management. Owing to higher shareholder activism, improving EP is likely to exacerbate the existing conflict of interests between shareholders and other creditors (Barros *et al*. 2021).[3] The underlying reason is that CG model in common law countries is essentially shareholder-based. EP improvement may not serve the best interest of shareholders. As such, the agency cost of debt should increase and debt should decrease under such circumstances, meaning that EP should have a negative effect on leverage under such circumstances. By contrast, in civil law countries where shareholder rights are weaker and the CG model is stakeholder-based, improving EP should serve the interests of all stakeholders, including shareholders and creditors. In addition, as shareholder rights are weak and shareholder activism is low, EP improvement should have minimal impact on any conflict between shareholders and creditors. The agency cost of debt should decrease and debt should increase, meaning that EP should have a positive effect on leverage under such circumstances. Based on the above discussion, the following hypothesis is formulated:

H2: EP has a positive (negative) effect on leverage for civil law (common law) countries.

Financial System and EP's Effect on Leverage

Financial system can be divided into two kinds, namely, bank-based and market-based financial system (Rafay & Farid, 2019). Bank-based financial system is a system where banks play a leading role in channeling funds from savers to borrowers, and firms raise funds primarily through banks instead of securities markets. By contrast, in market-based financial system, securities markets play a more important role in channeling funds, and firms raise funds primarily through securities markets rather than banks. In general, financial system tends to be bank-based (market-based) in developing (developed) countries because factors that contribute to market-based financial system are usually accompanied by high economic development. These factors include high levels of accounting regulation, shareholder protection, and national income; low levels of corruption and inflation; and unrestrictive banking regulations (Moradi *et al*. 2016; Rafay & Farid, 2018).

The effect of EP on leverage should vary between countries with bank-based system and those with market-based financial system. The cost of bank loans has been shown to increase as environmental regulations become stricter (Fard *et al*. 2020). The underlying reason is that banks consider that compliance with environmental regulations incurs high cost and risk. Hence, they charge higher interest to compensate for higher risk when extending loans to firms under such circumstances. This behavior of banks suggests that as EP improves and the compliance cost reduces as time goes by, bank loans should become less costly such that firms can get more loans from banks. When the financial system is bank-based, this phenomenon should be more pronounced and EP's positive effect on leverage should be stronger than when the financial system is market-based.

By contrast, when financial system is market-based, the securities markets usually view EP improvement as conducive to firm growth such that investors are willing to invest in firms that show EP improvement. Investors' investment can come in two forms, namely, debt and equity. Equity investment plays an important role in market-based financial system relative to bank-based financial system, so debt and equity increase in response to EP improvement. As such, the positive effect of EP on leverage may strengthen, weaken, or stay the same depending on the relative magnitude of increase in debt and equity in response to EP improvement. However, EP's positive effect on leverage should be less pronounced because equity also likely increases in response to EP improvement. Hence, compared with the case for bank-based financial system, any positive effect of EP on leverage should be weaker or become reversed in countries with a market-based financial system. On this basis, the following hypothesis is formulated:

H3: The positive effect of EP on leverage is stronger in countries with bank-based financial system than in those with market-based financial system.

METHODOLOGY

Data

The sample is comprised of non-financial firms from 12 countries over the period 2007 −2018.[4] Financial firms and non-financial firms that are related to governments are excluded because their goals and decision criteria are likely different. Prior research follows the same approach. Annual financial data for firm-specific variables are gathered from the Compustat Global Vantage database. Annual data for country-specific variables are gathered from different sources. Specifically, the data on total value of stocks traded are from World Bank. The data on GDP and real GDP growth are from International Monetary Fund. The data on legal system and financial system are from La Porta *et al*. (1998) and Demirgüç-Kunt and Levine (1999), respectively.

Table 1 consists of three panels. Panel A presents the mean values of variables across countries based on the full sample. Panels B (C) presents the mean values of variables across countries based on sample partitions by financial system (legal system). The entire sample contains 114,844 firm-year observations, which are effectively used in the model estimation. Leverage (LEV), the dependent variable in this study, is measured as the ratio of book value of total debt to book value of total assets. The mean value of the LEV for the entire sample ranges from 0.184 to 0.278, with the overall mean being 0.196.

Environmental performance (EP), the key variable in this study, is derived from Environmental Performance Index (EPI), which is constructed by Wendling *et al*. (2020). Since EPI for different years are not directly comparable, EPI is further manipulated to generate EP used in this study by standardizing it based on the mean value and standard deviation for each year from 2007 to 2018.

To examine whether and how financial system and legal system modify EP's effect on leverage, the following dummy variables are created. FS is a dummy variable that returns a value of one (zero) if a given country's financial system is market-based (bank-based). LS is a dummy variable that returns a value of one (zero) if a given country's legal system is common law (civil law) system. Given that some studies treat China and Vietnam as countries with the socialist law system rather than those with civil law system, two additional dummy variables (i.e., LS1 and LS2) are created to divide the sampled countries into three groups. Specifically, LS1 is a dummy variable that returns a value of one if a given country has a common law system and zero otherwise. LS2 is a dummy variable that returns a value of one if a given country has a socialist law system and zero otherwise. The civil law countries that exclude socialist law countries are thus indicated when LS1 and LS2 are zero.

Based on Chen and Wang (2012), the following control variables are included: asset tangibility (Tangibility), firm size (Size), growth opportunity (Growth), Profitability, Liquidity, tax rate (Tax), real GDP growth (RGDPG), and stock market development (Stock). Tangibility, a proxy of the collateral value of a firm's assets, is derived by dividing net fixed assets by book value of total assets. Tangibility is expected to be positively related to leverage because creditors are able to recover more loans in the event of default and thus are more willing to lend to firms when tangibility is higher. Size is the natural logarithm of book value of total sales.[5] A positive link between Size and LEV is expected because the probability of financial distress or bankruptcy decreases as firm size increases Growth is measured as Tobin's q (i.e., the ratio of book value of total assets less book value of equity plus market value of equity to book value of total assets). A negative link between Growth and LEV is expected because leverage should be reduced to minimize the conflict between shareholders and creditors when growth opportunities increase. Profitability is measured as the ratio of operating income to book value of total assets. It is expected to have a negative relationship with LEV based on the pecking order theory. Liquidity is the ratio of working capital (i.e., current asset minus current liability) to book value of total assets. It is expected to have a negative relationship with LEV based on the pecking order theory. Tax is income tax expense *divided* by pretax income, *which is earnings before interest and taxes (EBIT) less interest expense*. Given that debt is a tax shield, a positive link between Tax and LEV is expected based on the tradeoff theory. Aside from the above firm-specific determinants of leverage, country-specific variables such as real GDP growth rate (RGDPG) and stock market development (Stock) are also considered to control for differences across countries. RGDPG is expected to have a negative relationship with LEV because firms tend to increase equity and decrease debt when economy is picking up. Stock is derived by dividing stock market capitalization by GDP. A negative link between Stock and LEV is expected because equity is less costly and firms can raise more equity when stock market development is higher.

Prior to estimation, the observations are winsorized at the 5% and 95% levels to exclude extreme values from the sample.

Table 2 shows the correlation matrix of the variables used in this study and the variance inflation factors (VIFs) for the regression model. LEV correlates with its determinants, justifying their inclusion in the model. In addition, all VIF values are low with the highest being 1.97, so the multicollinearity concern is alleviated.

Model

Given that the data consist of multiple firms and years, a panel data model is appropriate. The fixed-effects panel data model is estimated based on the Hausman test results. Cluster-robust standard errors are estimated to compute z statistics and p-values in hypothesis testing.[6]

EMPIRICAL RESULTS

Effect of EP on Leverage

Table 3 presents the results based on the full sample. Columns 1 and 2 show the results regarding whether and how legal system modifies the effect of EP on leverage. Column 3 provides the results regarding whether and how financial system determines the effect of EP on leverage.

A quick glance reveals that the coefficient of EP is significantly positive across all columns, indicating that EP has a positive effect on leverage, consistent with H1. Focusing on the results in Column 1 where LS indicates common law countries, the effect of EP on leverage is measured as 0.019 – 0.023 LS, which equals 0.019 (−0.004) when a given country has a civil (common) law legal system. Hence, EP has a positive (negative) effect on leverage for civil (common) law countries, consistent with H2. In Column 2 where LS1 indicates common law countries and LS2 socialist law countries (i.e., China and Vietnam), the effect of EP on leverage is measured as 0.019 − 0.024 LS1, which equals 0.019 (−0.005) when a given country has a civil or socialist law (common law) legal system. Therefore, EP has a positive (negative) effect on leverage for civil or socialist law (common law) countries. The results continue to support H2. In Column 3, the effect of EP on leverage is measured as 0.020 – 0.026 FS, which equals 0.020 (−0.006) when a given country's financial system is bank- (market-) based. Thus, EP has a positive (negative) effect on leverage for countries with a bank-(market-) based financial system, consistent with H3.

Regarding the results on control variables, the coefficient of Tangibility is positive although insignificant, indicating a potential positive effect of the collateral value of a firm's assets on leverage. The coefficient of Size is significantly positive, indicating a positive effect of firm size on leverage. The coefficients of Growth, Profitability, Liquidity, and Tax are significantly negative, implying that leverage reduces as growth opportunities, profitability, liquidity, or tax expense increases. The coefficient of RGDPG is significantly positive, denoting a negative effect of real GDP growth rate on leverage. The coefficient of Stock is significantly negative, hinting that leverage decreases as stock market development increases. All the results are consistent with expectations except those for real GDP growth rate's effect on leverage.

Table 1. Summary statistics

Panel A. Full sample													
Country	**LEV**	**Tangibility**	**Size**	**Growth**	**Profitability**	**Liquidity**	**Tax**	**RGDPG**	**Stock**	**EP**	**LS**	**FS**	***N***
China	0.187	0.279	6.249	2.441	0.044	0.206	0.227	7.801	1.273	-0.313	0	0	26027
Cyprus	0.278	0.436	5.159	0.964	0.025	0.103	0.147	1.781	0.048	1.086	1	0	412
India	0.206	0.287	4.077	1.936	0.075	0.223	0.264	7.140	0.482	-1.446	1	0	1838
Israel	0.233	0.186	4.504	1.524	-0.023	0.252	0.190	3.633	0.266	1.026	1	0	2983
Japan	0.184	0.273	5.776	1.183	0.048	0.241	0.394	0.842	1.039	1.216	0	0	34308
Philippines	0.195	0.330	4.897	1.927	0.035	0.125	0.244	6.111	0.119	0.378	0	1	1320
Singapore	0.188	0.256	4.904	1.243	0.017	0.253	0.219	4.448	0.941	1.861	1	1	3841
South Korea	0.216	0.311	5.139	1.268	0.034	0.180	0.257	3.332	1.284	0.281	0	1	17861
Sri Lanka	0.221	0.484	3.280	1.296	0.060	0.108	0.226	5.455	0.043	-0.235	1	0	1719
Taiwan	0.186	0.276	4.814	1.422	0.032	0.290	0.234	3.138	1.855	0.465	0	0	16895
Thailand	0.218	0.364	4.689	1.562	0.054	0.171	0.202	3.406	0.659	0.021	1	1	4859
Vietnam	0.236	0.275	3.612	1.151	0.086	0.220	0.231	6.406	0.132	-1.123	0	0	2781
Total	0.196	0.286	5.405	1.564	0.041	0.224	0.281	3.814	1.151	0.449	0.136	0.243	114844
Panel B. sample partitions by financial system													
Country Group	**LEV**	**Tangibility**	**Size**	**Growth**	**Profitability**	**Liquidity**	**Tax**	**RGDPG**	**Stock**	**EP**	**LS**	**FS**	***N***
Bank-based financial system													
China	0.187	0.279	6.249	2.441	0.044	0.206	0.227	7.801	1.273	-0.313	0	0	26027
Cyprus	0.278	0.436	5.159	0.964	0.025	0.103	0.147	1.781	0.048	1.086	1	0	412
India	0.206	0.287	4.077	1.936	0.075	0.223	0.264	7.140	0.482	-1.446	1	0	1838
Israel	0.233	0.186	4.504	1.524	-0.023	0.252	0.190	3.633	0.266	1.026	1	0	2983
Japan	0.184	0.273	5.776	1.183	0.048	0.241	0.394	0.842	1.039	1.216	0	0	34308
Sri Lanka	0.221	0.484	3.280	1.296	0.060	0.108	0.226	5.455	0.043	-0.235	1	0	1719
Taiwan	0.186	0.276	4.814	1.422	0.032	0.290	0.234	3.138	1.855	0.465	0	0	16895
Vietnam	0.236	0.275	3.612	1.151	0.086	0.220	0.231	6.406	0.132	-1.123	0	0	2781
Total	0.190	0.278	5.530	1.634	0.043	0.236	0.294	3.873	1.176	0.446	0.080	0	86963
Market-based financial system													
Philippines	0.195	0.330	4.897	1.927	0.035	0.125	0.244	6.111	0.119	0.378	0	1	1320
Singapore	0.188	0.256	4.904	1.243	0.017	0.253	0.219	4.448	0.941	1.861	1	1	3841
South Korea	0.216	0.311	5.139	1.268	0.034	0.180	0.257	3.332	1.284	0.281	0	1	17861

continues on following page

Table 1. Continued

Thailand	0.218	0.364	4.689	1.562	0.054	0.171	0.202	3.406	0.659	0.021	1	1	4859
Total	0.212	0.314	5.017	1.347	0.035	0.186	0.242	3.630	1.073	0.458	0.312	1	27881
Panel C. sample partitions by legal system													
Country Group	**LEV**	**Tangibility**	**Size**	**Growth**	**Profitability**	**Liquidity**	**Tax**	**RGDPG**	**Stock**	**EP**	**LS**	**FS**	***N***
Civil law countries													
China	0.187	0.279	6.249	2.441	0.044	0.206	0.227	7.801	1.273	-0.313	0	0	26027
Japan	0.184	0.273	5.776	1.183	0.048	0.241	0.394	0.842	1.039	1.216	0	0	34308
Philippines	0.195	0.330	4.897	1.927	0.035	0.125	0.244	6.111	0.119	0.378	0	1	1320
South Korea	0.216	0.311	5.139	1.268	0.034	0.180	0.257	3.332	1.284	0.281	0	1	17861
Taiwan	0.186	0.276	4.814	1.422	0.032	0.290	0.234	3.138	1.855	0.465	0	0	16895
Vietnam	0.236	0.275	3.612	1.151	0.086	0.220	0.231	6.406	0.132	-1.123	0	0	2781
Total	0.193	0.283	5.549	1.578	0.043	0.227	0.292	3.733	1.246	0.442	0	0.193	99192
Common law countries													
Cyprus	0.278	0.436	5.159	0.964	0.025	0.103	0.147	1.781	0.048	1.086	1	0	412
India	0.206	0.287	4.077	1.936	0.075	0.223	0.264	7.140	0.482	-1.446	1	0	1838
Israel	0.233	0.186	4.504	1.524	-0.023	0.252	0.190	3.633	0.266	1.026	1	0	2983
Singapore	0.188	0.256	4.904	1.243	0.017	0.253	0.219	4.448	0.941	1.861	1	1	3841
Sri Lanka	0.221	0.484	3.280	1.296	0.060	0.108	0.226	5.455	0.043	-0.235	1	0	1719
Thailand	0.218	0.364	4.689	1.562	0.054	0.171	0.202	3.406	0.659	0.021	1	1	4859
Total	0.214	0.310	4.492	1.476	0.033	0.204	0.212	4.326	0.549	0.492	1.000	0.556	15652

Notes: LEV is the ratio of book value of total debt to book value of total assets. Tangibility is the ratio of net fixed assets to book value of total assets. Size is the natural logarithm of book value of total sales. Growth is Tobin's q (i.e., the ratio of book value of total assets less book value of equity plus market value of equity to book value of total assets). Profitability is the ratio of operating income to book value of total assets. Liquidity is the ratio of working capital to book value of total assets. Tax is income tax expense divided by pretax income. RGDPG is real GDP growth rate. Stock is the ratio of stock market capitalization to GDP. EP is Environmental Performance Index (EPI) (Wendling *et al*. 2020). LS is a dummy variable that returns a value of one (zero) if a given country's legal system is common law (civil law) system. FS is a dummy variable that returns a value of one (zero) if a given country's financial system is market-based (bank-based). *N* is the number of firm-year observations.

Table 2. Correlation matrix and variance inflation factors (VIFs)

	LEV	Tangibility	Size	Growth	Profitability	Liquidity	Tax	RGDPG	Stock	EP	LS	FS	VIF
LEV	1.000												
Tangibility	0.366	1.000											1.51
Size	0.180	0.148	1.000										1.25
Growth	-0.199	-0.166	-0.122	1.000									1.29
Profitability	-0.164	0.012	0.187	0.076	1.000								1.14
Liquidity	-0.618	-0.562	-0.240	0.182	0.177	1.000							1.68
Tax	-0.059	-0.047	0.109	-0.152	0.097	0.023	1.000						1.10
RGDPG	0.011	0.016	0.044	0.350	0.040	-0.051	-0.193	1.000					1.97
Stock	-0.047	-0.046	0.089	0.164	-0.013	0.071	-0.026	0.019	1.000				1.33
EP	-0.030	-0.059	0.040	-0.291	-0.061	0.068	0.192	-0.662	0.037	1.000			1.91
LS	0.042	0.047	-0.216	-0.032	-0.038	-0.033	-0.109	0.065	-0.446	0.023	1.000		1.47
FS	0.052	0.079	-0.131	-0.111	-0.039	-0.089	-0.088	-0.033	-0.082	0.007	0.290	1.000	1.14

Notes: LEV is the ratio of book value of total debt to book value of total assets. Tangibility is the ratio of net fixed assets to book value of total assets. Size is the natural logarithm of book value of total sales. Growth is Tobin's q (i.e., the ratio of book value of total assets less book value of equity plus market value of equity to book value of total assets). Profitability is the ratio of operating income to book value of total assets. Liquidity is the ratio of working capital to book value of total assets. Tax is income tax expense divided by pretax income. RGDPG is real GDP growth rate. Stock is the ratio of stock market capitalization to GDP. EP is Environmental Performance Index (EPI) (Wendling *et al*. 2020). LS is a dummy variable that returns a value of one (zero) if a given country's legal system is common law (civil law) system. FS is a dummy variable that returns a value of one (zero) if a given country's financial system is market-based (bank-based).

Legal System, Financial System and EP's Effect on Leverage

Table 4 presents the results based on sample partitions by financial system. The objective is to provide an insight into whether and how legal system matters in determining the effect of EP on leverage after controlling for financial system. In Columns 1 and 2 where a binary legal system variable is used (i.e., LS), the coefficient of LS×EP is insignificant, suggesting that legal system does not modify the effect of EP on leverage, regardless of the types of financial system. In Columns 3 and 4 where two dummy variables (i.e., LS1 and LS2) are used to distinguish between three legal systems (i.e., civil law, common law, and socialist law), the coefficients of all interaction variables are insignificant, suggesting that legal system does not modify the effect of EP on leverage, regardless of the types of financial system.[7] The results are consistent with those in Columns 1 and 2. Lastly, the results on control variables are generally consistent with those in Table 3. Of note, the coefficient of Stock is insignificant in Columns 2 and 4 where countries with market-based financial system are examined, suggesting that the observed negative effect of stock market development in Table 3 is driven by countries with bank-based financial system.

Table 3. EP's effect on leverage – full sample

Dependent variable: LEV	(1)	(2)	(3)
Independent variable			
Tangibility	0.015	0.015	0.014
	(0.009)	(0.009)	(0.009)
Size	0.043***	0.043***	0.043***
	(0.002)	(0.002)	(0.002)
Growth	-0.003***	-0.003***	-0.003***
	(0.001)	(0.001)	(0.001)
Profitability	-0.193***	-0.193***	-0.193***
	(0.010)	(0.010)	(0.010)
Liquidity	-0.305***	-0.305***	-0.305***
	(0.006)	(0.006)	(0.006)
Tax	-0.010***	-0.010***	-0.010***
	(0.001)	(0.001)	(0.001)
RGDPG	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)
Stock	-0.005***	-0.005***	-0.004***
	(0.001)	(0.001)	(0.001)
EP	0.019***	0.019***	0.020***
	(0.002)	(0.002)	(0.002)
LS×EP	-0.023***		
	(0.005)		
LS1×EP		-0.024***	
		(0.005)	
LS2×EP		-0.007	
		(0.012)	
FS×EP			-0.026***
			(0.005)
Constant	0.045***	0.044***	0.045***
	(0.012)	(0.012)	(0.012)
N	114844	114844	114844
n	13214	13214	13214
R^2	0.294	0.294	0.295

Notes: LEV is the ratio of book value of total debt to book value of total assets. Tangibility is the ratio of net fixed assets to book value of total assets. Size is the natural logarithm of book value of total sales. Growth is Tobin's q (i.e., the ratio of book value of total assets less book value of equity plus market value of equity to book value of total assets). Profitability is the ratio of operating income to book value of total assets. Liquidity is the ratio of working capital to book value of total assets. Tax is income tax expense divided by pretax income. RGDPG is real GDP growth rate. Stock is the ratio of stock market capitalization to GDP. EP is Environmental Performance Index (EPI) (Wendling *et al*. 2020). LS is a dummy variable that returns a value of one (zero) if a given country's legal system is common law (civil law) system. LS1 is a dummy variable that returns a value of one if a given country has a common law system and zero otherwise. LS2 is a dummy variable that returns a value of one if a given country has a socialist law system and zero otherwise. FS is a dummy variable that returns a value of one (zero) if a given country's financial system is market-based (bank-based). In all columns, year dummy variables are included to capture year-specific effects, but the results are saved for brevity. *N* and *n* represent the number of firm-year observations and that of firms, respectively. The numbers in the parentheses are robust standard errors. ***, **, and * stand for 1, 5 and 10% significant, respectively.

Table 4. Legal system vs. EP's effect on leverage – sample partitions by financial system

Dependent variable: LEV	(1)	(2)	(3)	(4)
Independent variable	**Bank-based**	**Market-based**	**Bank-based**	**Market-based**
Tangibility	0.002	0.039**	0.002	0.039**
	(0.011)	(0.016)	(0.011)	(0.016)
Size	0.040***	0.053***	0.040***	0.053***
	(0.002)	(0.005)	(0.002)	(0.005)
Growth	-0.004***	-0.001	-0.004***	-0.001
	(0.001)	(0.002)	(0.001)	(0.002)
Profitability	-0.200***	-0.189***	-0.200***	-0.189***
	(0.013)	(0.015)	(0.013)	(0.015)
Liquidity	-0.298***	-0.323***	-0.297***	-0.323***
	(0.007)	(0.011)	(0.007)	(0.011)
Tax	-0.008***	-0.016***	-0.008***	-0.016***
	(0.002)	(0.003)	(0.002)	(0.003)
RGDPG	0.003***	0.001**	0.003***	0.001**
	(0.000)	(0.001)	(0.000)	(0.001)
Stock	-0.007***	0.004	-0.007***	0.004
	(0.001)	(0.005)	(0.001)	(0.005)
EP	0.018***	-0.030**	0.018***	-0.030**
	(0.002)	(0.015)	(0.002)	(0.015)
LS×EP	0.020	0.013		
	(0.018)	(0.016)		
LS1×EP			0.020	0.013
			(0.018)	(0.016)
LS2×EP			-0.007	
			(0.012)	
Constant	0.058***	0.019	0.057***	0.019
	(0.013)	(0.025)	(0.014)	(0.025)
N	86963	27881	86963	27881
n	10138	3076	10138	3076
R^2	0.282	0.330	0.282	0.330

Notes: LEV is the ratio of book value of total debt to book value of total assets. Tangibility is the ratio of net fixed assets to book value of total assets. Size is the natural logarithm of book value of total sales. Growth is Tobin's q (i.e., the ratio of book value of total assets less book value of equity plus market value of equity to book value of total assets). Profitability is the ratio of operating income to book value of total assets. Liquidity is the ratio of working capital to book value of total assets. Tax is income tax expense divided by pretax income. RGDPG is real GDP growth rate. Stock is the ratio of stock market capitalization to GDP. EP is Environmental Performance Index (EPI) (Wendling *et al*. 2020). LS is a dummy variable that returns a value of one (zero) if a given country's legal system is common law (civil law) system. LS1 is a dummy variable that returns a value of one if a given country has a common law system and zero otherwise. LS2 is a dummy variable that returns a value of one if a given country has a socialist law system and zero otherwise. In all columns, year dummy variables are included to capture year-specific effects, but the results are saved for brevity. *N* and *n* represent the number of firm-year observations and that of firms, respectively. The numbers in the parentheses are robust standard errors. ***, **, and * stand for 1, 5 and 10% significant, respectively.

Table 5 presents the results based on sample partitions by legal system. The objective is to examine whether and how financial system matters in determining the effect of EP on leverage after controlling for legal system. In Columns 1 where civil law countries are examined, the coefficient of EP is significantly positive, whereas that of FS×EP is insignificant, suggesting that EP has a positive effect on leverage for civil law countries, regardless of the types of financial system. In Columns 2 where common law countries are examined, the coefficient of EP is insignificant, whereas that of FS×EP is significantly negative, suggesting that EP has a negative effect on leverage for common law countries when financial system is market-based, but it has no effect on leverage when financial system is bank-based. In Column 3 where civil law countries that exclude socialist law countries (i.e., China and Vietnam) are examined, the coefficients of EP and FS×EP are significantly positive, suggesting that EP has a positive effect on leverage for these civil law countries, and such a positive effect is stronger when financial system is market-based than bank-based. In Column 4 where socialist law countries are examined, the coefficient of EP is insignificant, whereas that of FS×EP is inestimable because these two countries have a common financial system (i.e., bank-based financial system). The results indicate that EP has no effect on leverage for these two socialist law countries. Importantly, insignificant findings further suggest that the results obtained in Column 1 are not driven by these two socialist law countries, which are usually classified as civil law countries in prior studies. Lastly, the findings on control variables are in line with those in Table 3 for the most part. Notably, the coefficient of Stock is significantly negative only in Column 1, indicating that stock market development has a negative effect on leverage for civil law countries. Hence, the observed negative effect of stock market development in Table 3 is driven by civil law countries.

CONCLUSION

The study results reveal that EP does influence leverage, and this finding is consistent with those of prior research. However, unlike prior studies that provide evidence indicating that EP has a single effect on leverage (i.e., either positive or negative based on the individual studies), this study shows that the effect of EP on leverage can be positive or negative depending on the types of legal system and financial system. More specifically, EP's effect on leverage generally proves to be positive (negative) for civil (common) law countries or for countries with bank-based (market-based) financial system. However, a more in-depth analysis based on subsamples classified by financial and legal systems suggest that the former plays a more important role than the latter in determining EP's effect on leverage. Specifically, when focusing on a country group with the same financial system, EP's effect on leverage is independent of legal system. By contrast, when focusing on a country group with the same legal system, financial system plays roles in determining EP's effect on leverage, which is negative (insignificant) for common law countries when financial system is market-based (bank-based). In addition, EP's effect on leverage for civil law countries that include China and Vietnam is positive and does not depend on the types of financial system. When China and Vietnam are excluded from the civil law country group though, EP's effect on leverage remains positive and strengthens when financial system is market-based. Given that EP's effect is insignificant for the subsample that consists of China and Vietnam only, the positive effect of EP on leverage for civil law countries gains further support. The results show that EP's positive effect on leverage for civil law countries is not driven by China and Vietnam.

Table 5. Financial system vs. EP's effect on leverage – sample partitions by legal system

Dependent variable: LEV	(1)	(2)	(3)	(4)
Independent variable	**Civil law**	**Common law**	**Civil law**	**Socialist law**
Tangibility	0.011	0.017	0.018	-0.023
	(0.010)	(0.023)	(0.012)	(0.018)
Size	0.041***	0.052***	0.049***	0.045***
	(0.002)	(0.006)	(0.003)	(0.003)
Growth	-0.003***	-0.001	-0.004***	-0.006***
	(0.001)	(0.003)	(0.001)	(0.001)
Profitability	-0.203***	-0.169***	-0.205***	-0.226***
	(0.011)	(0.024)	(0.012)	(0.024)
Liquidity	-0.307***	-0.304***	-0.333***	-0.279***
	(0.006)	(0.016)	(0.008)	(0.009)
Tax	-0.010***	-0.013***	-0.008***	-0.013***
	(0.001)	(0.005)	(0.001)	(0.003)
RGDPG	0.003***	0.000	0.004***	0.006*
	(0.000)	(0.001)	(0.000)	(0.004)
Stock	-0.004***	-0.004	-0.002	-0.008
	(0.001)	(0.007)	(0.002)	(0.005)
EP	0.019***	0.028	0.013***	-0.004
	(0.002)	(0.019)	(0.002)	(0.014)
FS×EP	-0.008	-0.039*	0.024*	
	(0.014)	(0.022)	(0.014)	
Constant	0.043***	0.082***	0.003	0.022
	(0.012)	(0.029)	(0.017)	(0.048)
N	99192	15652	70384	28808
n	10907	2307	7,049	3858
R^2	0.297	0.290	0.310	0.300

Notes: LEV is the ratio of book value of total debt to book value of total assets. Tangibility is the ratio of net fixed assets to book value of total assets. Size is the natural logarithm of book value of total sales. Growth is Tobin's q (i.e., the ratio of book value of total assets less book value of equity plus market value of equity to book value of total assets). Profitability is the ratio of operating income to book value of total assets. Liquidity is the ratio of working capital to book value of total assets. Tax is income tax expense divided by pretax income. RGDPG is real GDP growth rate. Stock is the ratio of stock market capitalization to GDP. EP is Environmental Performance Index (EPI) (Wendling *et al*. 2020). FS is a dummy variable that returns a value of one (zero) if a given country's financial system is market-based (bank-based). In all columns, year dummy variables are included to capture year-specific effects, but the results are saved for brevity. *N* and *n* represent the number of firm-year observations and that of firms, respectively. The numbers in the parentheses are robust standard errors. ***, **, and * stand for 1, 5 and 10% significant, respectively. In Column 3, China and Vietnam are excluded from the civil law countries.

The results provide important implications for researchers, practitioners, and policymakers. For researchers, future research related to EP's effect on leverage should consider country-specific variables such as financial and legal systems given that this study provides strong evidence indicating that these country variables indeed matter in explaining cross-country difference in EP's effect on leverage. In addition, given that the modifying effect of financial system varies between common law and civil law countries, future research can explore why this is the case.

For practitioners, given that the findings show that financial system plays a predominant role in modifying EP's effect on leverage, firms should be clear about the type of financial system adopted in a given country. Then, they should make the corresponding adjustment in leverage in response to EP improvement. For example, if they are located in a civil law (common law) country, they should consider holding more (less) debt as EP improves because study results suggest that doing so is optimal.

As for policymakers, given that country-level EP improvement influences the capital structure of firms, they should realize the potential effect of EP improvement on leverage of firms. For example, seeing that EP positively affects leverage in civil law countries, governments should know such a consequence and take measures to keep leverage from rising too much after EP improvement because high indebtedness increases the risk of financial crisis and destabilizes the economy. By contrast, given that EP negatively affects leverage for common law countries when financial system is market-based, the concern about high leverage due to EP improvement can be alleviated. More importantly, EP improvement is effective in reducing leverage under such circumstances.

DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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ENDNOTES

1 In this chapter, EP is measured by Environmental Performance Index (EPI), which is constructed by Wendling *et al*. (2020). According to Wendling *et al*. (2020), on the basis of data from 180 countries, the 2020 EPI summarizes the state of sustainability worldwide. Thirty-two performance indicators under 11 issue categories are used to rank the 180 countries in terms of environmental health and ecosystem vitality. Through these indicators, countries are graded on their degree of achievements with regard to established environmental policy targets at a national scale. For details, please visit the following website: https://epi.yale.edu/.

2 The effect of EP on leverage can also be analyzed from the perspectives of CG and financial constraint. However, this chapter focuses on the cost and risk for brevity. The other two channels will be considered in the future related studies.

3 Barros et al. (2021) find that shareholder activism has a negative effect on firms' performance.

4 Muslim majority countries are not considered in the present study because their legal system is unique and thus the determination of leverage is likely different from that for other countries.

[5] Total assets are also used to measure firm size for robustness check. The major results remain.

[6] Year dummies are included to capture year-specific effects, but the results are not reported for brevity. Industry dummies are not included because they are time-invariant and get dropped with the fixed-effects panel regression.

[7] The coefficient of LS2×EP is inestimable because there are only two kinds of legal systems (i.e., civil law and common law systems) in countries with market-based financial system.

Chapter 16
Environmental Policy and FDI Inflows:
Evidence From OECD Countries

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ABSTRACT

This chapter explores the impact of environmental policy stringency index (EPS) on FDI inflows in 26 OECD countries for the period 1995-2012. The study employed Durbin-Hausman panel cointegration and Emirmahmutoglu-Kose panel Granger causality tests to determine the long-run and the causal relationship between the relevant variables, respectively. According to findings, variables move together in the long run. On the one hand, in the long run, capital formation and economic globalization increase FDI inflows, while real effective exchange rate, EPS, and non-market EPS decrease these inflows. On the other hand, the coefficients of the parameters are estimated positively for capital formation and negatively for the real effective exchange rate. It was determined that environmental policies cause FDI inflows in 12 out of 26 countries. These empirical findings suggest several courses of action for policymakers.

INTRODUCTION

In the new global economy, Foreign Direct Investment (FDI) inflow has become a central issue for capital flows between developed and developing countries. FDI inflow is a form of cross-border investment, meaning direct investment equity flows to the recipient country. Besides, it combines equity capital, earnings reinvestment, and other capital (World Bank, 2020). FDI inflows can take three forms: a) greenfield investment (GI), b) joint ventures (JV), and c) mergers and acquisitions (M&A). An investment is named as GI when a foreign investor constructs a new facility in the host country. Furthermore, a JV is

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a contractual agreement between two or more economic agents to enter into a commercial partnership to achieve a common goal. In addition, an M&A encompasses changes in the ownership of existing assets (Hofmann, 2013). Besides, plant enlargements, an increase in equity stake, and real estate acquisitions can be regarded as the fourth form of FDI (Alba, Park, & Wang, 2010).

It has been conclusively shown that there is a positive relationship between FDI inflows and economic growth (Lee, 2013). Therefore, an increase in FDI inflows causes a rise in income level in the recipient country. At this stage, a crucial question comes to mind: Why do firms prefer to invest abroad? The most comprehensive answer to this question was given by Dunning (1977, 1981). According to Dunning (1977, 1981), companies choose to make investments abroad for three main reasons: ownership advantages (O), location advantages (L), and internalization advantages (I). These three factors that determine the investment decisions of companies are called as OLI paradigm in the literature. First, ownership advantages stand for management capabilities, knowledge-based advantages, or brand power of companies. Second, location advantages denote cultural, institutional, political, and economic factors of host countries. Hence, the country's characteristics of recipient economies determine the investment decisions of multinational companies (Gast & Herrmann, 2008; Aziz & Mishra, 2016). Last, internalization is based on the decision between producing abroad or offshore outsourcing. Moreover, internalization is relevant to decrease transaction costs, including monitoring, searching, contracting costs, and avoiding a principle-agent problem (Gast & Herrmann, 2008; Hofmann, 2013).

More recently, there has been an increased emphasis on the factors affecting FDI flows (Baskurt *et al.*, 2022). In the literature, there are a bunch of variables that affect foreign direct investment flows such as corporate tax rate, government expenditure, gross capital formation (CAF), human capital, inflation, infrastructure, institutional quality, labor cost, market size, political stability, the exchange rate (EXR), and trade openness (TO). In addition, some studies have asserted that environmental policies affect FDI flows, e.g., Mihci, Cagatay, and Koska (2005), Ljungwall and Linde-Rahr (2005), Zhang and Fu (2008), Kukenova and Monteiro (2008), Kalamova and Johnstone (2011), Naughton (2014), and Kim and Rhee (2019).

However, a limited study in the empirical literature uses the environmental policy stringency index (EPS) as a measure of the tightness of environmental regulations. This index was introduced by Botta and Koźluk (2014) and provided by the OECD (The Organization for Economic Cooperation and Development) database. It covers many environmental measures such as taxes on emission levels, trading schemes, feed-in tariffs, deposit and refund schemes, emission standards, and R&D subsidies. So far, several studies have utilized the environmental policy stringency index; however, to the best of our knowledge, only a few investigated its impact on FDI inflows. The empirical findings of Lundh (2017) suggest that EPS with one-lag increases FDI flows between OECD countries and host countries. Besides, Rahul and Viswanathan (2018) found that EPS increases FDI inflows in 33 developed and developing countries. However, these studies have failed to show a long-run link between EPS and FDI inflows. Also, they have not been able to show any causal relationship between these variables. Among the remaining studies, Ahmed and Ahmed (2018) used EPS to predict further values of CO_2 emissions in China. In addition, Andersson (2018) utilized EPS as a determinant of CO_2 emissions in China. Feng *et al*. (2019) and Martínez-Zarzoso, Bengochea-Morancho, and Morales-Lage (2019) examined the impact of EPS on the productivity level in OECD countries. Moreover, Malzi *et al*. (2020) investigated the impact of EPS on natural gas consumption in OECD countries.

The primary aim of this investigation has been to examine the impacts of environmental policy stringency indices on FDI inflows. Moreover, the study uses gross capital formation, real effective exchange rate, and economic globalization as control variables. For that purpose, 26 OECD countries were chosen as a sample for 1995-2012 for this study. The organization consists of high-income and upper-middle-income countries. Thus, one can say that OECD countries show similar but not the same economic characteristics. In addition, OECD countries have attracted research interest for a few decades since their share of world FDI inflows was around 82.4% for the period 1970-1989; 72.4% for the period 1990-2009; and above 50% for the period 2010-2018. Even if some emerging economies like Brazil, Russia, India, China, and South Africa (BRICS) have become the top FDI destinations among emerging economies in recent years, OECD countries still have a significant share of world FDI inflows.

The main contributions of this paper to the empirical literature can be listed as follows. First, the study chooses the environmental policy stringency index and its components (market-based and non-market policies) to assess the impacts of environmental regulations on FDI inflows. To the best of our knowledge, previous studies have failed to consider the effects of market-based and non-market environmental policies on FDI inflows in the long-run. Second, this study considers cross-section dependency (CD) in the testing procedure of panel data techniques. Thus, panel unit root, panel cointegration, and panel causality tests provide results that are more reliable. In detail, this study uses the Durbin-Hausman (DH) cointegration test developed by Westerlund (2008) and the Emirmahmutoglu-Kose (EK) Granger causality test introduced by Emirmahmutoglu and Kose (2011) in the panel setting.

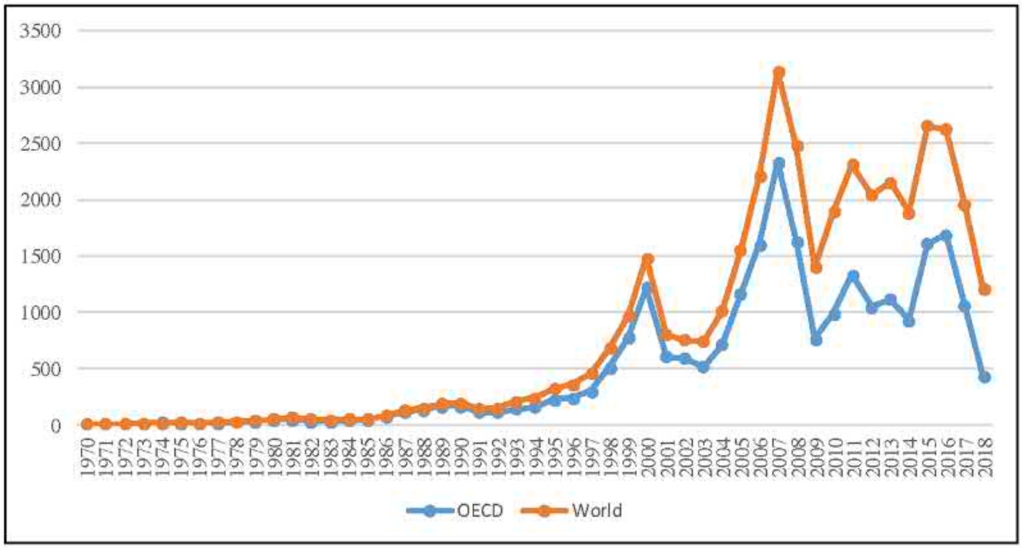
This paper has been divided into six sections. Section 2 provides a theoretical background for FDI inflow and its relationship with economic growth and environmental quality (Olayungbo *et al.,* 2022). Besides, Section 3 gives an extensive literature review, while Section 4 presents the data and methodology employed. The study's empirical findings are reported in Section 5, while Section 6 highlights the key empirical findings and concludes the study.

OVERVIEW OF FDI INFLOWS AND EPS IN OECD COUNTRIES

OECD countries mainly consist of high-income and upper-middle-income countries. They have attracted a significant amount of FDI inflows from the rest of the world for decades. Figure 1 displays the annual time-series graph of FDI inflows in OECD countries and the world. In the figure, there is a clear trend of increasing FDI inflows up to 2000, and then fluctuations in the series occur. Also, one can infer that these two series moved together for the period examined, and there was a strong positive correlation between these series. Figure 1 exhibits that FDI inflows were negatively affected by the 2001 recession and the 2007-2008 financial crisis. Notably, after the Great Recession, their share in global FDI inflows has decreased. In addition, the sharp decline in foreign direct investment inflows in 2018 can be explained by the changing tax regime in the US (UNCTAD, 2019). In recent decades, it is seen that foreign direct investment flows have started to shift from developed countries to developing countries such as BRICS, Asia Pacific, or MENA (the Middle East and North Africa) countries. However, FDI inflows to OECD countries still have a significant share in global FDI movements.

Among OECD countries, the United States has received the lion's share from FDI inflows with a value of 258.39 billion dollars. According to the graph, Germany, Ireland, Australia, France, and the United Kingdom have attracted 105.27, 64.53, 60.95, 59.84, and 58.65-billion-dollar value of FDI, respectively. Also, it is reported that disinvestments were higher than new investments in Hungary, Netherlands, and Switzerland in 2018.

Figure 1. Foreign direct investment, net inflows (billion current US$) in the period 1970-2018
Note: *The figure is constructed by using World Bank data.*



Overall, according to UNCTAD (United Nations Conference on Trade and Development) (2017), financial openness and liberalization have started at the beginning of the1980s. These developments cause an increase in FDI flows between economies. Also, it can be stated that FDI inflows can be affected by domestic and global crises negatively. Especially, OECD countries have attracted most FDI inflows for a few decades. However, developing countries such as BRICS countries have received a significant amount of FDI inflows in recent times.

Figure 2 displays the composite index for environmental standards for OECD countries in 2012. It shows that environmental standards were fragile in Mexico in 2012. Also, it is seen that the index value was relatively low in Greece, Ireland, Portugal, and Turkey compared to other members. On the other side, the highest values were observed in Denmark, Australia, Netherlands, and France.

Figure 3 represents country-specific market-based and non-market policies in OECD members. According to the figure, one can infer that the United Kingdom, Canada, France, and Australia focused on market-based environmental approaches in 2012. At the same time, they were not common policies in Turkey, Korea Republic, Ireland, and Mexico. Besides, it is seen that Finland, Denmark, and the Netherlands intervened in markets through non-market policies. However, the value of this index was relatively low in Greece and Mexico compared to other OECD members.

Overall, it can be concluded that developed countries prefer to implement more stringent environmental policies while developing economies tend to conduct weaker policies. It can be explained by the fact that the environmental consciousness of people increases with a rise in income level. So, high-income people demand higher ecological standards from governments. Therefore, ecological policies become tighter in developed countries compared to emerging economies. Besides, tight environmental policies in these countries can be explained by the common environmental policies conducted by both OECD and/or the European Union. Sustainability is an important consideration for environmental policy (Kiranmai *et al.,* 2022). For instance, European environmental policies try to focus on sustainable development. For this purpose, they have introduced several policy actions for decades to get high ecological quality and efficient use of natural resources and prevent climate change (European Parliament, 2020). Also, OECD has designed and implemented various environmental policies to fight against environmental issues for a long time. In addition, many of these countries play essential roles in intergovernmental actions to reduce environmental degradation in the world, such as the Kyoto Protocol and the Paris Agreement.

Figure 2. Index for environmental policy stringency in OECD countries, 2012

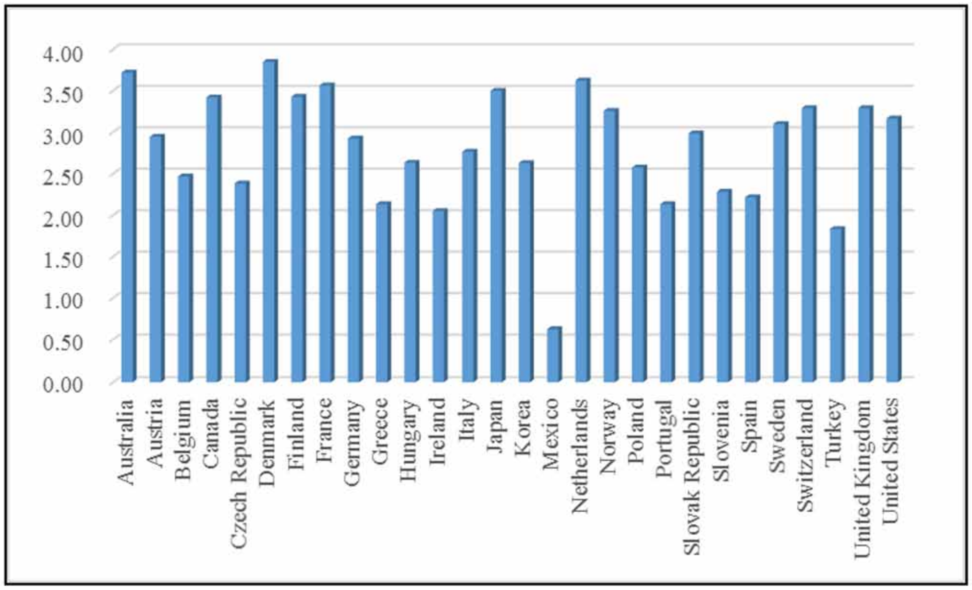
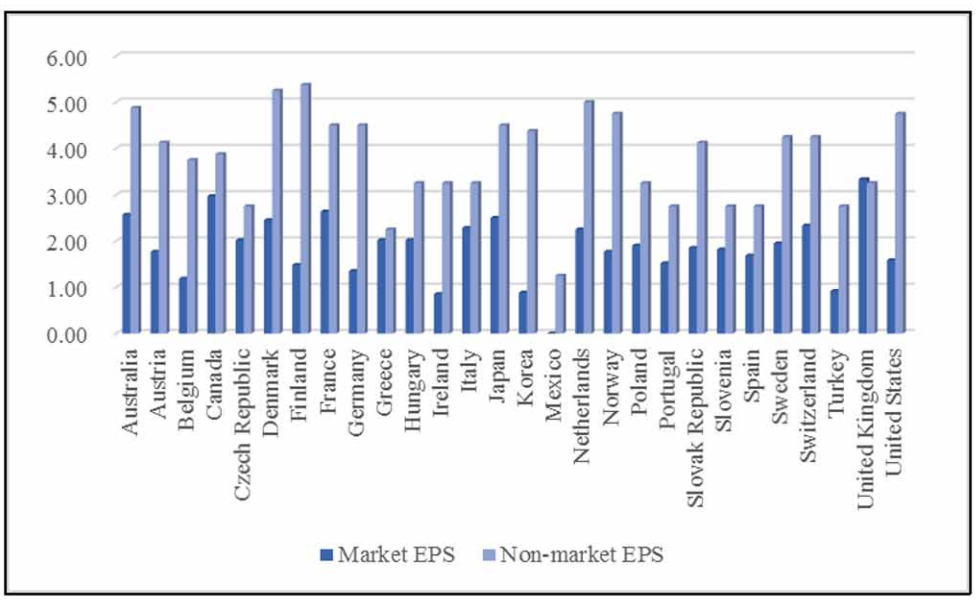


Figure 3. Index for market-based and non-market policies in OECD countries, 2012



THEORETICAL BACKGROUND

It is a common idea that FDI inflows increase productivity and cause economic growth in host countries. Even if there is a positive impact of FDI inflows on microeconomic or macroeconomic variables, in some cases, it might damage the environmental quality in the receiving countries. In developed countries, governments impose tight environmental regulations on pollutive activities of firms through policy tools (including taxes on emission levels and emission limits) due to high environmental consciousness and demand by citizens. Thus, firms' production costs increase, and they start to look for new investment opportunities in developing countries with lax environmental standards. Besides, foreign investors may change investment decisions in developed countries because of their strict environmental policies. Therefore, stringent environmental policies may cause an increase in FDI outflows from developed countries and decrease FDI inflows to developed countries through disinvestment. Mostly, pollutive industries (paper, textile, metal-plating, or pharmaceutical industries) (Keleş, Hamamcı, & Çoban, 2015) prefer to invest in developing countries due to their loose environmental policies. As a result, the pollution level and environmental deterioration increase in developing countries. In the literature, it is called the Pollution Haven Hypothesis (Cole, 2004). Shorty, the PHH reveals that pollution-intensive production moves from developed countries with tight environmental control to developing countries with lax environmental regulations (Copeland, 2010). In the empirical literature, the PHH has been mostly tested through the effect of TO, FDI inflows, and FDI outflows on the pollution level.

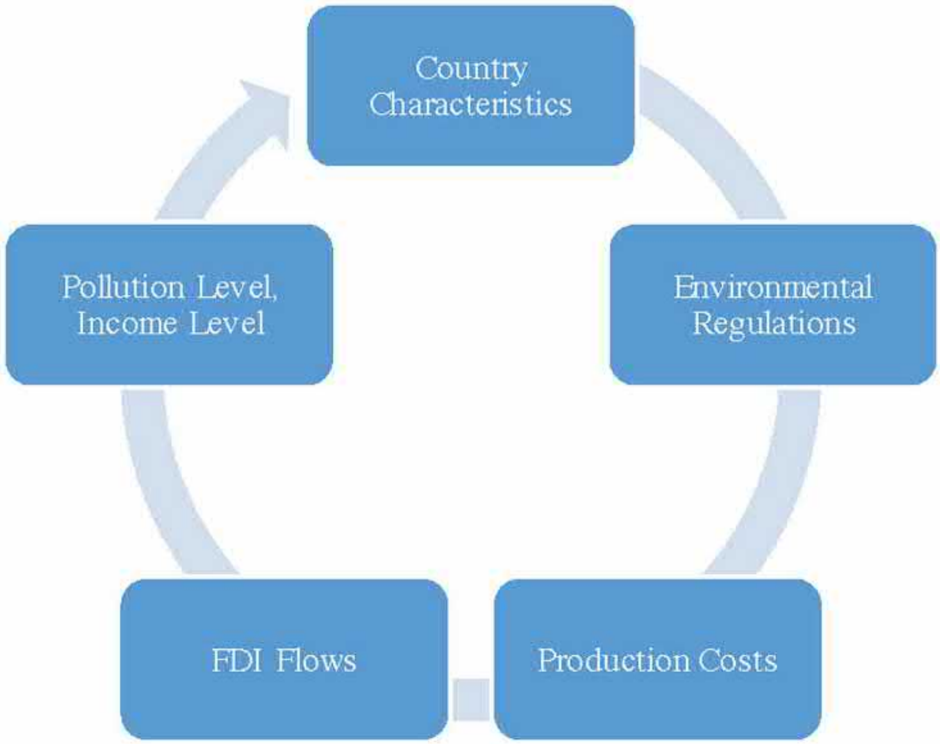
According to Taylor (2004), production technology level, abatements in taxes and debts, and having production factors like natural resources form the characteristics of an economy. These factors affect the income level of a country, and then national environmental policies are designed. An increase in environmental taxes regarding manufacturing causes higher production costs and decreases the profits of companies. Therefore, firms shift their operations from countries with high environmental taxes to countries with low environmental taxes. These movements affect foreign direct investment flows, and they change the production patterns of countries. These investment movements directly affect environmental quality and per capita income levels. Eventually, all these factors cause a change in country characteristics. One can see the unbundling the Pollution Haven Hypothesis in Figure 4.

On the other side, the effects of FDI inflows on environmental degradation sometimes may not be detrimental in the receiving countries. Domestic companies in host countries may take advantage of foreign firms' eco-friendly technologies and environmental management systems. Therefore, they can change their old-fashioned pollutive production systems, and their environmental damage decreases gradually. The positive impact of foreign direct investments on the host country's environmental quality is called the Pollution Halo Hypothesis (Zarsky, 1999).

LITERATURE REVIEW

This section summarizes the empirical literature on FDI inflows and environmental quality. In the first strand, the study focuses on the impact of FDI inflows on the environmental quality. In the second part of this section, the study reviews the literature on the effects of environmental policies on FDI flows.

Figure 4. Unbundling the Pollution Haven Hypothesis
Note: *The figure is constructed by the authors based on the work of Taylor (2004).*



FDI Inflows-Environmental Quality Nexus

In the empirical literature, both the PHH and the pollution halo hypothesis are tested via the impacts of FDI inflows or trade variables on environmental quality.

On the one hand, among the first studies on the PHH, Grimes and Kentor (2003) found that an increase in FDI inflows caused environmental degradation in 66 less-developed countries covering the period 1980-1996. He (2006) discovered that FDI inflows had a positive but small impact on the sulfur dioxide emissions in Chinese cities for the period 1994-2001. Later, the empirical findings of Aliyu (2005) suggested that lagged values of FDI inflows deteriorated environmental quality (according to the GLS results) in emerging countries for the period 1990-2000. Koçak and Şarkgüneşi (2018) explored the determinants of environmental pollution in Turkey for the period 1974-2013. For this purpose, the study used the Maki cointegration test, which allows sharp structural breaks in the long-run relationship between the variables. The findings exhibit that FDI inflows have a positive but small impact on the pollution level that supports the PHH in Turkey. In addition, Sapkota and Bastola (2017) tested the significance of FDI inflows and income levels on pollution levels in 14 Latin American countries during the period 1980-2010. Empirical findings demonstrate that FDI inflows trigger pollution levels in this set of countries. Also, Solarin *et al.* (2017) found evidence supporting the PHH in Ghana for the period 1980-2012.

Moreover, Ansari, Khan, and Ganaie (2019) tested the validity of the pollution haven hypothesis in 29 selected countries covering the period 1994-2014. The study's empirical findings show that CO_2 emissions, energy consumption, per capita income, TO, and FDI inflows are cointegrated. In the long-run, it is estimated that the coefficient of FDI inflows is positive in East Asian countries. Ganda (2019) explored the effects of financial development variables on the environment for 23 OECD countries during the period 2001-2012. The empirical results display that FDI inflows trigger environmental pollution. Gorus and Aslan (2019) examined the effects of per capita income, energy consumption, and FDI inflows on CO_2 emissions in nine MENA countries in the period 1980-2013. According to the empirical findings, the PHH is valid in Algeria, Iran, Jordan, Morocco, and Turkey. Also, Hanif *et al.* (2019) analyzed the link between fossil fuels, FDI inflows, income level, and pollution level for the 15 Asian countries during the period 1990-2013. The authors conducted a panel ARDL methodology to find both short-term and long-term relationships among these indicators. The empirical results support that the PHH is confirmed in these countries.

Furthermore, Ansari, Haider, and Khan (2020) investigated the effect of the TO on environmental degradation in ten global economies during the period 1971-2013. The study used time-series techniques, including a unit root test—allowing a structural break in the series—and an ARDL bound test. According to the empirical results, TO deteriorates the environment in Canada and Saudi Arabia in the long-run. Assamoi *et al*. (2020) found that the PHH is valid in Ivory Coast for the period 1980-2014 both in the short-term and long-term. Recently, Yilanci, Bozoklu, and Gorus (2020) studied the effects of FDI inflows on ecological footprint and its components in BRICS countries during the period 1982-2014. The study employed a bootstrap ARDL bounds testing approach with a Fourier function to reveal the long-run relationship between the abovementioned variables. Empirical results exhibit that FDI inflows are pollutive in China regarding ecological footprint. The remaining components of the ecological footprint provide mixed results. On the other hand, most of the studies test the pollution halo hypothesis in the empirical literature. Among them, Tamazian, Chousa, and Vadlamannati (2009) analyzed the impacts of financial variables on the pollution level in BRIC countries during the period 1992-2004. The empirical results gathered from the study show that FDI stocks have a positive impact on environmental quality. In addition, Kirkulak, Qui, and Yin (2011) investigated the relationship between environmental pollution, per capita income, FDI inflows, population, technology level, and industry structure in China using provincial data for the period 2001-2007. According to the findings, it is supported that an increase in FDI inflows causes a decrease in environmental degradation in China.

Kohler (2013) examined the relationship between environmental pollution, income level, energy consumption, and TO in South Africa for the period running from 1960 to 2009. For this purpose, the study conducted an ARDL bound test method and Granger causality test. According to the empirical results, TO decreases the emission level in the country both in the short-run and in the long-run. Dogan and Turkeku (2016) utilized an ARDL bound test to exhibit the long-run impact of the TO on the pollution level in the United States. It was found that TO decreases environmental degradation in the period 1960-2010. Zhang and Zhou (2016) employed several panel data estimation techniques to determine the effects of FDI inflows on the environmental quality in China for the period 1995-2010. The empirical findings demonstrate that FDI inflows decrease environmental pollution in national case. Shahbaz, Destek, and Polamis (2018) found that FDI inflows led to a decrease in carbon emissions (in the cubic model) in 11 emerging countries covering the period 1992-2016. Yilanci, Bozoklu, and Gorus (2020) discovered that FDI inflows decrease crop land footprint in India, China, and South Africa. They also led to a decrease in grazing land footprint in Brazil, China, and South Africa. Besides, the pollution halo hypothesis is valid in Russia regarding forest land footprint. In South Africa, FDI inflows cause a better environmental standard regarding fishing ground footprint. In addition, an increase in international investment inflows leads to a rise in built up land footprint in Russia and South Africa. Finally, it was found that these flows mitigate the carbon footprint in Brazil.

Balsalobre-Lorente *et al*. (2019) examined the nonlinear relationship between ecological footprint and foreign direct investment inflows in Mexico, Indonesia, Nigeria, and Turkey in the panel setting over the period 1990-2013. The paper provides evidence that there is an inverted U-shaped relationship between the aforementioned variables. After a threshold point, FDI inflows improve environmental quality in the countries examined. Recently, Huynh and Hoang (2019) explored the impacts of the interaction between FDI and institutional quality on environmental degradation in 19 Asian countries for the period 2002-2015. It was found that, after a specific point of the institutional quality, FDI inflows increase environmental standards in this set of countries. Lastly, Waqih *et al*. (2019) conducted a panel ARDL test to find the effect of FDI inflows on the pollution level in the South Asian countries during the period 1986-2014. They found that international investment flows decrease the pollution level in the long-run.

Environmental Policies-FDI Flows Nexus

In the literature, several empirical studies have asserted that environmental policies affect FDI flows significantly. Among these studies, Mihci, Cagatay, and Koska (2005) found that a rise in environmental regulations increases FDI outflows in OECD countries. They stated that Japan, Netherlands, and Denmark show better environmental performance compared to the other member states. Besides, Ljungwall and Linde-Rahr (2005) exhibited that environmental policies have a negative impact on FDI inflows only in the Central Region in China. Similarly, Zhang and Fu (2008) found that policies on the environment decrease FDI inflows in China. They conducted a feasible generalized least square method for the period 1999-2003. Furthermore, Kukenova and Monteiro (2008) found a negative relationship between environmental stringency and FDI inflows in OECD countries for the period 1981-2005 according to the random effect model. Besides, an inverted U-shaped relationship was found between environmental stringency differentials and FDI inflows in OECD members to developing countries sample by Kalamova and Johnstone (2011).

Naughton (2014) examined the effects of environmental regulations in the host and home countries on FDI inflows in OECD countries covering the period 1990-2000. The author utilized a gravity model to reveal the link between the aforementioned variables. According to the findings, an increase in the tightness of the environmental policies in the host country causes a decrease in FDI inflows. Besides, Ridzuan *et al*. (2014) aimed to investigate the impact of environmental regulatory stringency on FDI inflows for 110 countries during the period 2006-2010. For this purpose, they carried out the Generalized Method of Moments for their analysis. The paper's empirical results suggested that an increase in the tightness of the environmental policies leads to a decrease in FDI inflows for the countries examined. Lundh's (2017) empirical findings suggested that EPS with one-lag increases FDI flows between OECD countries and host countries.

Yoon and Heshmati (2017) studied the impact of the environmental regulations on the FDI outflows for South Korea, 2009-2015. According to the findings, an increase in the environmental standards led to a rise in the FDI outflows in the host countries. These standards primarily affected the production side of the economy. In addition, Rahul and Viswanathan (2018) revealed that EPS increases FDI inflows in 33 developed and developing countries. Kim and Rhee (2019) demonstrated that an increase in the environmental performance index attracts FDI inflows in 120 emerging economies. The authors employed the panel fixed effects model covering the period 2000-2014. Recently, Cansino *et al*. (2020) investigated the impact of environmental regulations on the investment flows from Spain to abroad for the period 2008-2018. The authors employed the gravity model for this purpose. The study's empirical findings demonstrated that high environmental standards cause Spanish firms to move their operations abroad. Besides, Ge *et al*. (2020) found that the emission reduction policies of the Chinese government mitigate FDI inflows for the period 2001-2005, according to the "difference-in-difference-in-differences" model.

DATA, MODEL, AND METHODOLOGY

In this section, this study presents the dataset utilized and gives brief information on the methodology employed.

Data and Model

In this section, the study presents the dataset examined. The study employs an annual dataset covering the period 1995-2012 for 26 OECD countries. This dataset is chosen because of working with balanced panel data. Notably, EPS and its components are not available for most of the OECD countries after 2012. Countries examined in this study can be seen in Table 4-6. The dependent variable of the study is FDI inflows, while independent variables are gross capital formation, real effective exchange rate (REER), economic globalization index, EPS, market-based environmental policy stringency index (MEPS), and non-market environmental policy stringency index (NMEPS).

FDI inflow data is in terms of billion current U.S. dollars, and it is taken from the World Development Indicators Database. Among the independent variables, CAF (in terms of current U.S. dollars) covers outlays on additions to the fixed assets of the economy. Also, it includes net changes in the level of inventories. CAF data is gathered from the World Development Indicators Database. This study uses the consumer price index (2010=100) to deflate nominal FDI inflows and gross capital formation data. In addition, REER data is based on consumer price indices (2015=100) is taken from Thompson Reuters Eikon. An increase in REER means appreciation of the currency and leads to a decrease in competitiveness. Besides, the study uses the KOF Economic Globalization Index as a proxy for economic globalization. The index includes plenty of indicators ranging from current economic activities to regulations on trade and finance. KOF Globalisation Index is developed by Dreher (2006), and the revised version is provided by Gygli *et al*. (2019). An increase in the index means a more global economy. This index is retrieved from the KOF Swiss Economic Institute database. Lastly, this paper uses the environmental policy stringency index and its components—market-based and non-market environmental policy stringency indices—for exploring the effects of strict environmental policies on FDI inflows. The range of the index is between 0 and 6, and higher values show more stringent policies regarding the environment. The MEPS includes taxes on emission levels, trading schemes, feed-in tariffs, and deposit and refund schemes, while NMEPS covers emission standards and R&D subsidies. This data is taken from the OECD database for 26 member countries.

This study constructs three main models to evaluate the impacts of environmental policy stringency on FDI inflows. Besides, this paper includes three control variables in the models—CAF, REER, and economic globalization. These three models can be presented as follows:

Model 1. *FDI=f*(ln*CAF*, ln*REER,* ln*EGLOB,* ln*EPS*)
Model 2. *FDI=f*(ln*CAF,* ln*REER,* ln*EGLOB, MEPS*)
Model 3. *FDI=f*(ln*CAF*, ln*REER*, ln*EGLOB*, ln*NMEPS*)

Overall, one can summarize the research hypotheses of this paper as follows:

Hypothesis 1: Countries with higher gross capital formation receive more FDI inflows.
Hypothesis 2: Countries with higher real effective exchange rates receive less FDI inflows.
Hypothesis 3: Countries with a more global economy receive more FDI inflows.
Hypothesis 4: Countries with more stringent environmental policies receive less FDI inflows.

Methodology

Recent advances in econometric techniques have facilitated the investigation of panel data methods considering cross-section dependency. Thus, in this study, this paper employs second-generation panel data techniques to get more reliable results than conventional techniques.

In the empirical literature, it is suggested that second-generation panel cointegration tests should be utilized to reveal the long-term relationship between variables in the case of CD in the residuals of the model. In this study, this paper conducts a panel cointegration test proposed by Westerlund (2008). The benefit of this approach is that it allows investigating the cointegration relationship between variables when the dependent variable is stationary at the first difference, while independent variables can be either I(0) or I(1). Westerlund proposes two panel cointegration tests—DH_g and DH_p—that have the null hypothesis of no cointegration. In the first one (group mean test), the rejection of the null means that there is a cointegration relationship for at least some of the cross-sectional units. Besides, the second one (panel test) indicates that there is a cointegration relationship for all the cross-sectional units in the case of the rejection of the null hypothesis (Westerlund, 2008). In addition, this study employs a PMG ARDL estimation method to estimate the models' long-run and short-run parameters. The PMG estimator provides homogeneous long-run parameters while it allows different intercepts, error variances, and short-run coefficients across the cross-sectional units (Pesaran, Shin, & Smith, 1999).

After, the presence of the cointegration relationship between variables indicates that there is a unidirectional causality between variables at least one direction. Thus, the causal linkages between variables should be investigated in the panel setting. This study employs a panel Granger causality test introduced by Emirmahmutoglu and Kose (2011). EK panel Granger causality approach has a number of attractive features as follows: a) it considers the CD in the residuals of the model; b) it takes heterogeneity into consideration. Thus, this test provides robust and reliable results in the case of both CD and heterogeneity since it uses bootstrap techniques. The null hypothesis of this test is that there is no causality between variables for the panel. Contrarily, the rejection of the null hypothesis means that there is a causal relationship between variables for at least one of the cross-sectional units. In the analysis, it is not necessary to make stationary the variables; however, the maximal number of the integration level ($d_{\max}$) should be determined (Emirmahmutoglu & Kose, 2011; Fang & Chang, 2016).

EMPIRICAL RESULTS AND DISCUSSION

In this section, the study reports empirical findings obtained and discusses these results. At first, this study conducts CD tests for the series to determine which generation panel unit root test should be used. This study takes into consideration the empirical results of the bias-corrected scaled LM test. According to the empirical findings, there is cross-section dependency in the series examined[1]. Thus, the paper conducts a second-generation panel unit root test—CIPS test. Besides, the authors also report the first-generation panel unit root test—IPS test—to enrich the study.

The empirical results of the CIPS panel unit root tests suggest that FDI, lnCAF, lnEGLOB, lines, and MEPS are stationary at the first difference while lnREER and lnNMEPS are stationary at level. In addition, IPS unit root test results indicate that FDI, lnREER, and lnEGLOB stationary at level, while the remaining series are stationary at the first-difference (see Table 1).

Table 1. Panel unit root tests results

Variables	**IPS Unit Root Test Level**	**First Difference (Δ)**	**Result**
FDI	-7.273***	—	*I(0)*
ln*CAF*	-0.333	-7.004***	*I(1)*
ln*REER*	-1.457*	—	*I(0)*
ln*EGLOB*	-7.300***	—	*I(0)*
ln*EPS*	3.326	-13.112***	*I(1)*
MEPS	3.094	-12.256***	*I(1)*
ln*NMEPS*	2.956	-18.185***	*I(1)*
Variables	**CIPS Unit Root Test Level**	**First Difference (Δ)**	**Result**
FDI	-1.833	-3.244***	*I(1)*
ln*CAF*	-1.536	-2.175**	*I(1)*
ln*REER*	-2.284**	—	*I(0)*
ln*EGLOB*	-1.782	-2.639***	*I(1)*
ln*EPS*	-1.841	-2.427***	*I(1)*
MEPS	-1.762	-2.071*	*I(1)*
ln*NMEPS*	-2.173**	—	*I(0)*

Note: ***, **, and * are the significance levels at the p=0.01, p=0.05, p=0.10, respectively.

It is found that independent variables are the mixture of I(0) and I(1), while the unit root property of the dependent variable is I(1). This paper also investigates the CD in the residuals of the models through the bias-adjusted LM test developed by Pesaran, Ullah, and Yamagata (2008). Empirical results of the study exhibit that there is a cross-sectional dependence in all three models (see Table 2, second column). Thus, this study utilizes the DH cointegration test—considering CD in the model—to find the long-term relationship between variables. This study sets up three main models, and the empirical results indicate that these variables move together in the long-run. All the related findings are reported in Table 2.

Table 2. DH cointegration test results

Models	Bias-Adj. LM Test Statistics	DH_g	DH_p
1) *FDI*=*f*(ln*CAF*, ln*REER*, ln*EGLOB*, ln*EPS*)	7.145***	45.902***	3.393***
2) *FDI*=*f*(ln*CAF*, ln*REER*, ln*EGLOB*, *MEPS*)	8.678***	124.082***	3.240***
3)*FDI*=*f*(ln*CAF*, ln*REER*, ln*EGLOB*, ln*NMEPS*)	8.225***	140.490***	7.271***

Note: *** is the significance level at the p=0.01. DH_g denotes Durbin-Hausman group mean statistics while DH_p shows Durbin-Hausman panel statistics.

The short-run and the long-run coefficients of the models can be estimated through PMG ARDL estimators. Firstly, this study considers the long-run estimation results of the study that is reported in Table 3. The empirical findings exhibit that an increase in CAF causes FDI inflows in the host countries in all three models. According to Ranjan and Agraval (2011), high CAF indicates that there is a potential of the economy for spending. Besides, capital formation plays a significant role in the attraction of international investment flows since it includes land improvements, plant, machinery, and equipment spending, construction of roads and railways. Hence, the sign of the coefficient is estimated as expected. In addition, the impact of the REER on FDI inflows is found as negative in Model 1 and Model 2, while its impact is estimated positive in Model 3. These results are significant at the p=0.01 level. An increase in the real effective exchange rate causes an appreciation of the domestic currency and leads to a decline in price or cost competitiveness of the host country. Moreover, foreign investors cannot compete with local investors in terms of taking overs and mergers because of the appreciation of the host country's currency (depreciation of the source country's currency) (Takagi & Shi, 2011). Therefore, the sign of the coefficient of the REER in Model 1 and Model 2 is in line with the expectations. Contrarily, the coefficient of the real effective exchange rate is positive in Model 3. This result seems somewhat economically counterintuitive. However, the appreciation of the domestic currency might signal for foreign investors that there will be better economic conditions in the economy. Therefore, multinational companies may invest in the host country (Aziz & Mishra, 2016).

Moreover, the empirical findings of this study demonstrate that a rise in the economic globalization triggers FDI inflows in OECD countries in all three models. In detail, the economic globalization index takes into consideration many variables such as trade in goods and services, trade partner diversity, portfolio investments, international reserves, tariffs and taxes, and investment restrictions. Positive developments in this indicator provide a better trade and investment environment for host countries. Lastly, this paper examines the impacts of environmental policy stringency on the FDI inflows. In Model 1, it is found that the effect of the environmental policy stringency index (composite index) on the FDI inflows is negative in 26 OECD countries. Besides, non-market policies covering emission limit values affect international inflows negatively in Model 3. Thus, it can be said that stricter environmental policies deter FDI inflows to these countries.

On the contrary, a rise in the stringency index regarding market-based policies covering taxes on emissions causes an increase in the FDI inflows in Model 2. This contradictory result can be attributed to low tax rates (or no tax) on CO_2, NO_x, and SO_x emissions in most of the OECD countries. Even if taxes on the emission increase the production cost of foreign investors slightly, they may bear these low costs. In addition, Elliot and Zhou (2013) assert that tighter environmental standards may increase FDI inflows in the host country, depending on the market structure. A tax increase may deter the entry of domestic firm and leads inflow of foreign direct investment. Therefore, the foreign firm becomes an

FDI monopolist because the domestic firm is excluded from the market. Thus, the profit of the foreign firm increases with the rise in environmental standards.

Secondly, this study also reports the short-run coefficients and the error correction terms (ECT) of the models in Table 3. The short-run relationship between variables partially supports the long-run estimation results regarding CAF and REER. It is found that gross capital formation increases FDI inflows, while an appreciation of domestic currency causes a decrease in FDI inflows in OECD countries. Furthermore, no statistically significant correlation between the remaining variables is evident. Thus, economic globalization and environmental stringency do not affect the FDI inflows in the short-run. In the light of this information, one can conclude that foreign investors choose their investment decisions according to the economic criteria—CAF and REER—in the short-run. In addition, it is found that ECT is negative and statistically significant in all three models. Any deviation from the long-run equilibrium between FDI inflows, CAF, REER, economic globalization, and environmental stringency is corrected about one year later in Model 1 and Model 2. In contrast, it is corrected about 1.5 years later in Model 3.

Table 3. PMG ARDL estimation results

	Model 1 ARDL(1, 1, 1, 1, 1)	**Model 2 ARDL(1, 2, 2, 2, 2)**	**Model 3 ARDL(2, 2, 2, 2, 2)**
Variables / Models	***Long-Run Coefficients***		
ln*CAF*	24.852***	26.121***	17.737***
ln*REER*	-86.528***	-111.018***	86.926***
ln*EGLOB*	188.323***	236.743***	97.453***
ln*EPS*	-9.285***	—	—
MEPS	—	9.254***	—
ln*NMEPS*	—	—	-11.629***
Variables / Models	***Short-Run Coefficients***		
ECT	-0.890***	-0.824***	-0.642***
CONSTANT TERM	-906.716***	-955.304***	-796.556***
Δ*FDI*(-1)	—	-0.129	—
Δln*CAF*	104.867*	105.913*	110.091**
Δln*CAF*(-1)	49.947	8.817	—
Δln*REER*	-263.928**	-168.908	-276.358**
Δln*REER*(-1)	-201.154	-118.330	—
Δln*EGLOB*	-77.840	193.182	77.511
Δln*EGLOB*(-1)	87.088	-40.620	—
Δln*EPS*	11.811	—	—
Δln*EPS*(-1)	-10.180	—	—
Δ*MEPS*	—	25.128	—
Δ*MEPS*(-1)	—	7.395	—
Δln*NMEPS*	—	—	15.765
Δln*NMEPS*(-1)	—	—	—
TREND	0.837	-0.972	—

Note: ***, **, and * are the significance levels at the p=0.01, p=0.05, p=0.10, respectively. ECT denotes the error-correction term.

This study also examines the impact of market size on FDI inflows for OECD countries in the Appendix. This study uses the economic growth rate as a proxy for market size[2]. In the long-run, an increase in the economic growth rate causes a rise in FDI inflows, while there is no statistically significant effect in the short-run (see Table 4).

Table 4. Panel causality test results between FDI and lnEPS

Individual / Direction	**ln*EPS* → *FDI***	***FDI* → ln*EPS***	**Conclusion**
	Wald statistics		
Australia	0.134	0.495	No Causality
Austria	1.934	0.571	No Causality
Canada	0.035	0.977	No Causality
Czech Republic	0.020	3.270*	One-Way Causality
Denmark	0.073	0.138	No Causality
Finland	0.021	0.008	No Causality
France	1.522	0.538	No Causality
Germany	0.009	2.774*	One-Way Causality
Greece	0.094	3.633*	One-Way Causality
Hungary	0.461	0.135	No Causality
Ireland	1.492	0.228	No Causality
Italy	17.013***	0.919	One-Way Causality
Japan	0.377	0.315	No Causality
Korea, Rep.	3.381*	0.403	One-Way Causality
Mexico	1.896	1.711	No Causality
Netherlands	1.460	0.000	No Causality
Norway	0.210	0.185	No Causality
Poland	7.153***	0.728	One-Way Causality
Portugal	1.801	8.147**	One-Way Causality
Slovak Republic	0.028	0.006	No Causality
Spain	0.218	1.078	No Causality
Sweden	0.293	8.274**	One-Way Causality
Switzerland	5.388**	0.126	One-Way Causality
Turkey	1.505	0.156	No Causality
United Kingdom	2.438	0.411	No Causality
United States	1.686	0.209	One-Way Causality
Panel Fisher statistics			
Panel	74.590	55.268	No Causality

Note: ***, **, and * are the significance levels at the p=0.01, p=0.05, p=0.10, respectively.

In addition to estimating the long-run and the short-run coefficients of the models, this study also employs a Granger causality analysis between FDI inflows and environmental policy stringency variables. For that purpose, the study uses a bias-adjusted LM test to determine which kind of causality test is proper for our models. The empirical results state that there is a cross-sectional dependence in the residuals of the models[3]. Thus, this paper utilizes a Granger causality test developed by Emirmahmutoglu and Kose (2011)—considering CD in the model—to find the causal nexus between the variables. This test provides both panel and country-specific Granger causality test results.

The empirical findings are provided from Table 4 to Table 6. In this paper, the authors are only interested in the causal link between FDI inflow and environmental policy stringency indices[4]. The causal relationship among the independent variables is not the scope of this study. Table 4 shows that the past values of the environmental policy stringency index can be used to estimate the future values of FDI inflows in Italy, the Korea Republic, Poland, and Switzerland. Besides, it is found that there is a one-way causality running from FDI inflows to EPS in the Czech Republic, Germany, Greece, Portugal, and Sweden for the period examined.

Table 5 presents the Granger causality results between FDI inflows and market-based environmental policy stringency index in OECD countries. According to the empirical findings, there is a one-way causality running from *MEPS* to FDI inflows in Canada, Finland, Ireland, Korea Republic, Mexico, Netherlands, Poland, Spain, and Switzerland. It was also found that there is a unidirectional Granger causality from FDI inflows to *MEPS* in Australia, the Czech Republic, Greece, Spain, and Turkey. Lastly, there is no causal link between the variables as mentioned above in the remaining countries.

Finally, this study examines the causal relationship between FDI inflows and non-market-based environmental policy stringency index in OECD countries during the period 1995-2012. According to the empirical findings, ln*NMEPS* Granger causes FDI inflows in Austria, France, Ireland, Italy, and Poland. Also, it is found that the previous values of the FDI inflows include valuable information for predicting further values of ln*NMEPS* in Austria, Germany, Sweden, and Turkey. Therefore, there is a bidirectional relationship between these variables in Austria. Furthermore, the empirical findings support that there is no causal relationship between the variables above in the remaining countries.

Overall, this study shows that forms of environmental policy stringencies have a predictor power on FDI inflows for a variety of countries. It was found that environmental policies Granger cause FDI inflows in 12 out of 26 countries. Among these countries, eight of them is EU member (Austria, Finland, France, Ireland, Italy, Netherlands, Poland, and Spain), while only four of them is non-EU members (Canada, Korea Republic, Mexico, and Switzerland). Therefore, one can infer that being an EU member can affect the impact of environmental policies on FDI inflows slightly.

This study summarizes the empirical findings derived from the cointegration and causality analyses as below:

- FDI inflows, CAF, REER, economic globalization, and environmental policy stringency indices are cointegrated in the long-run in OECD countries for the period 1995-2012.
- CAF and economic globalization increase FDI inflows in the long-run, while REER, EPS, and NMEPS decrease these flows.
- In the short-run, the coefficients of the parameters are estimated positive for CAF and negative for the real effective exchange rate.
- The ECT is negative and statistically significant in all three models.

Table 5. Panel causality test results between FDI and MEPS

Individual / Direction	*MEPS → FDI*	*FDI → MEPS*	Conclusion
	Wald statistics		
Australia	0.731	4.995**	One-Way Causality
Austria	0.008	0.105	No Causality
Canada	3.064*	0.003	One-Way Causality
Czech Republic	2.484	4.654**	One-Way Causality
Denmark	0.007	0.163	No Causality
Finland	7.038***	1.208	One-Way Causality
France	0.205	1.729	No Causality
Germany	0.126	1.632	No Causality
Greece	0.624	8.643***	One-Way Causality
Hungary	0.241	0.058	No Causality
Ireland	3.094*	0.020	One-Way Causality
Italy	2.458	0.023	No Causality
Japan	2.613	0.592	No Causality
Korea, Rep.	5.731*	0.642	One-Way Causality
Mexico	2.971*	0.781	One-Way Causality
Netherlands	4.189**	0.098	One-Way Causality
Norway	0.042	1.745	No Causality
Poland	5.028**	0.060	One-Way Causality
Portugal	0.080	0.000	No Causality
Slovak Republic	0.045	0.483	No Causality
Spain	2.922*	3.872**	Two-Way Causality
Sweden	0.069	0.330	No Causality
Switzerland	7.851***	0.111	One-Way Causality
Turkey	0.052	2.918*	One-Way Causality
United Kingdom	1.605	2.547	No Causality
United States	0.012	2.294	No Causality
Panel Fisher statistics			
Panel	82.657	67.352	No Causality

Note: ***, **, and * are the significance levels at the p=0.01, p=0.05, p=0.10, respectively.

Our findings show some similarities with the existing literature for OECD countries. Since the economic globalization index covers a part of trade activities and regulations, it can be compared with trade openness variable. Agiomirgianakis, Asteriou, and Papathoma (2004) (2004), Wisniewski and Pathan (2014), Dellis, Sondermann, and Vansteenkiste (2017), Economou *et al*. (2017), and Baltas, Tsionas, and Baltas (2018) find that an increase in trade openness causes more FDI inflows in the host country. Thus, the results of this paper support the empirical findings of the above studies. Besides, the positive impact of gross capital formation on FDI inflows is in line with the empirical results of Economou *et* *al*. (2017) and Baltas, Tsionas, and Baltas (2018). Furthermore, the long-run coefficient of MEPS in Model 2 is similar to studies of Lundh (2017) and Rahul and Viswanathan (2018). However, the signs of the parameters of EPS and NMEPS differ from the aforementioned studies in the long-term. Moreover, Kukenova and Monteiro (2008) and Naughton's (2014) findings for OECD countries are compatible with our empirical results obtained from Model 1 and Model 3.

Table 6. Panel causality test results between FDI and lnNMEPS

Individual / Direction	**ln*NMEPS* → *FDI***	***FDI* → ln*NMEPS***	**Conclusion**
	Wald statistics		
Australia	0.115	0.034	No Causality
Austria	4.090**	4.296**	Two-Way Causality
Canada	0.655	0.174	No Causality
Czech Republic	1.502	0.750	No Causality
Denmark	0.761	0.817	No Causality
Finland	0.329	0.030	No Causality
France	4.501**	0.068	One-Way Causality
Germany	1.113	8.787**	One-Way Causality
Greece	0.803	0.301	No Causality
Hungary	0.084	0.013	No Causality
Ireland	5.271*	0.457	One-Way Causality
Italy	4.934*	3.484	One-Way Causality
Japan	0.125	0.304	No Causality
Korea, Rep.	0.638	1.214	No Causality
Mexico	0.120	0.313	No Causality
Netherlands	0.381	0.106	No Causality
Norway	0.724	0.007	No Causality
Poland	8.298***	0.791	One-Way Causality
Portugal	0.016	1.813	No Causality
Slovak Republic	0.047	0.174	No Causality
Spain	0.117	0.180	No Causality
Sweden	0.002	6.182**	One-Way Causality
Switzerland	0.224	1.873	No Causality
Turkey	1.352	3.004*	One-Way Causality
United Kingdom	0.428	0.163	No Causality
United States	1.733	0.022	No Causality
Panel Fisher statistics			
Panel	62.165	57.032	No Causality

Note: ***, **, and * are the significance levels at the p=0.01, p=0.05, p=0.10, respectively.

CONCLUSION

This study sets out to explore the influence of environmental policy stringency indices on FDI inflows in 26 OECD countries covering the period 1995-2012. This study also uses CAF, REER, and economic globalization index as control variables. In accordance with the purpose of this research, recent panel data techniques were employed. In the first step, stationarity properties of the variables were examined through the CIPS panel unit root test because of the presence of the CD in the series. Empirical findings revealed that independent variables of the models consist of a mixture of I(0) and I(1). Therefore, the long-run relationship between variables was examined through the DH panel cointegration test. DH test allows for the CD in the residual of the models and the cointegration relationship between stationary and non-stationary variables. DH test results support that all the variables move together in the long-run.

The results of this investigation show that, on the one side, it was found that CAF and economic globalization increase FDI inflows in OECD countries in the long-run. Besides, an increase in the REER, in other words, an appreciation of the domestic currency, leads to a decrease in FDI inflows because of the competitiveness effect. Lastly, the empirical findings show that an increase in EPS and non-market environmental policy stringency index deters FDI inflows. The empirical results of this study are in line with prior expectations and provide a shred of evidence for the validity of the PHH in OECD countries in the long-run. However, it was found that the impact of market-based environmental policy stringency index has a positive effect on FDI inflows in OECD countries. On the other side, the ECT is negative and statistically significant in all models. In the short-run, the impact of CAF on FDI inflows is positive, while the coefficient of the real effective exchange rate is negative. These findings support the long-run results regarding CAF and REER. Overall, this study strengthens the idea that tight environmental policies decrease FDI inflows in the host country in the long-run.

This study also examines the causal relationship between variables through the EK panel Granger causality test. The country-specific results indicate that EPS has predictive power on FDI only in Italy, Poland, and Switzerland during the period examined. Besides, market-based environmental policies Granger causes FDI inflows in nine countries, while non-market policies have predictive power on FDI inflows in five OECD countries. Taken together, this result suggests that there is a one-way causality from subcomponents of EPS to foreign direct investment flows only in Ireland and Poland.

These findings suggest several courses of action for policymakers. First, policymakers should be careful when they design environmental policies. They should be aware of the consequences of tight environmental policies because their effects on FDI inflows can be harmful. Second, CAF and REER are useful tools to manage FDI inflows both in the short and long-run. Thus, they should focus on the policies increasing gross capital formation and preventing domestic currency appreciation. Third, a more global economy leads to a rise in FDI inflows in the host country in the long-run. Therefore, policymakers should put required regulations into action on trade and finance to provide a better trade and investment environment. Policymakers should also focus on market-based environmental regulations to avert a decrease in FDI inflows. Further investigations are needed to evaluate the impact of environmental policy stringency index on FDI inflows in emerging markets using recent analyzing tools.

DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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KEY TERMS AND DEFINITIONS

Causality: The method that is used to whether an independent variable predicts the dependent variable's further values or not.

Cointegration: The method that is used to whether the dependent and independent variables move together in the long-run or not.

Economic Globalization: A concept that shows the economic interaction between a country and the world.

Environmental Policy Stringency Index: A measure to determine the stringency level of environmental policies in a country.

Foreign Direct Investment Inflows: They are direct investment flows from the home country to the host country.

Gross Capital Formation: It shows the potential of the economy for spending, including land improvements, plant, machinery, and equipment spending, construction of roads and railways.

Real Effective Exchange Rate: The weighted average of a domestic currency in relation to an index or basket of major foreign currencies such as the dollar or euro.

ENDNOTES

1. CD test results can be provided upon request.
2. This study uses economic growth rate as a proxy for market size since GDP per capita and GDP are not stationary at I(0) or I(1). Thus, this study could not investigate the long-run relationship between these variables and FDI inflows. Economic growth rate data is taken from the OECD database.
3. CD dependency test results for the residuals of the models can be provided upon request.
4. All the causal linkages between variables can be provided upon request.

APPENDIX

Table 7. PMG ARDL estimation results (considering economic growth)

ARDL(1, 1, 1, 1, 1)	
Variables / Models	***Long-Run Coefficients***
ln*GROWTH*	0.385**
ln*CAF*	10.635***
ln*EGLOB*	70.923***
ln*EPS*	-6.173***
Variables / Models	***Short-Run Coefficients***
ECT	-0.783***
CONSTANT TERMS	-444.208***
Δln*GROWTH*	-0.422
Δln*CAF*	73.412*
Δln*EGLOB*	388.443**
Δln*EPS*	0.195
TREND	1.444**

Note: ***, **, and * are the significance levels at the p=0.01, p=0.05, p=0.10, respectively.

Chapter 17
Carbon Financial Market:
The Case of the EU Trading Scheme

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ABSTRACT

This chapter explains the drivers for carbon prices related to institutional decisions, energy prices, and weather events. The study focuses on price changes in the EU as being the most liquid carbon asset. In this regard, the daily spot price of the EU is highlighted to demonstrate the daily changes, given the high volatility in this carbon financial market. The CO2 prices depend on several determinants. This chapter constitutes an introduction to emission trading and an overview of the regulations of carbon financial markets. First, the price changes in the EU and primary energy prices are discussed. Second, the characteristics of emissions trading are introduced in terms of spatial and temporal limits, clean dark spread, and switch price. Third, a global analysis of atmospheric variables, structural variations, the subprime crisis, and the COVID-19 crisis is presented.

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INTRODUCTION

Managers have recently been highly interested and engaged in issues of renewable finance from the perspective of an effective style of management. Yet, among the many studies concerned with this field (Rafay, 2022), only few works have particularly investigated the performance of the adoption of Sustainable Finance (El Amri, Boutti & Rodhain, 2020).

Since the seventies of the last century, when the scientific community has shown tremendous interest in Climate Change (CC), there has emerged a global agreement on the responsibility for producing greenhouse gas emissions (GHG)(Bunyamminu & Yakubu, 2022). As such, there is now a global consensus on taking immediate measures to help reduce these emissions to curb the scale of future consequences on climate change, bearing in mind that the global average temperature could reach higher levels ranging from 1.1 C to 6.4 C° towards the end of the 21st century.

It is deemed very decisive at this stage to bring about a significant reorientation of these methodologies and approaches in order to better face up to the challenges posed by climate change. One important aspect is that these strategies effect a reallocation of CO_2 emissions- a fact, which tends to drive industrial companies to evaluate the intensity and rate of their emissions, and which also gives paramount importance to the resultant priorities (taking into consideration the recommendations for limiting carbon). In this context, the EU ETS deeply consider the hazards related to Climate Change (CC) and define the financial development prospects as regards GHG emissions (Alberola, Chevallier and Cheze, 2008); this in turn helps demonstrate existing CO_2 pricing practices (EUA) through the econometric analysis of the two phases of the EU ETS. Given this, it makes sense then to state that the real objectives of EU ETS are to offer financial opportunities to manufacturing companies so that they can limit their CO_2 emissions and thus help foster the adoption of technologies, which produce less carbon and develop Efficiency Energy (EE) and Renewable Energies (RE).

Of the most significant objectives that characterize management research are the attempts at describing, understanding, explaining, or predicting various phenomena pertaining to organizations. Similarly, complexity is what characterizes the world of organizations to the extent that it becomes impossible for researchers to delineate all the details of the phenomena he or she is studying. Modeling represents an effective way to represent these complex phenomena in an understandable and conceivable manner.

To better account for this statement, the objective in this chapter is to examine and study the impact of the explanatory variables (primary energy, atmospheric, fuel modification, structural movement, CO_2 emissions information and the Sanitary Covid-19 crisis variables) on EUA price variable so that the researchers can detect and better explain the practices of the Responsible Management of companies involved in the European Union Emissions Trading Scheme (EU ETS).

Chevallier (2012), following the seminal work of Christiansen *et al*. (2005), came up with the first literature review on carbon price development, which was later developed by Lebatt and White (2007). Given the economic analysis (particularly demand and supply fundamentals), Christiansen *et al*. (2005) and Alberola *et al*. (2008) did a pioneering work in terms of laying bare economically the relationship between energy markets and the price of CO_2. Taking into consideration Phase I spot and future data, these researchers have stressed that these relations vary depending on the period of time in concern and the institutional events taking place (Phase I, Phase II, Phase III). Furthermore, Bunn and Fezzi (2007) have investigated the close ties between CO_2 and electricity variables such as Clean Dark, Clean Spark Spreads, and the switch price during the first phases of EU ETS. As such, Christiansen *et al*. (2005)

have defined the following factors as decisive in the EU ETS: strategy and regulatory issues, market fundamentals, the role of fuel-switching, and weather/ production situations.

After the pioneering work by Christiansen *et al.* (2005), Chevallier (2012) produced the first literature reviews on the carbon price development in their respective publications. This work was further elaborated by Lebatt and White (2007).

Considering the economic analysis (essentially demand and supply fundamentals), Christiansen *et al*. (2005) have defined the following aspects as being very influential in terms of price in the EU ETS: strategy and regulatory issues, market fundamentals, the role of fuel-switching, weather and production levels. Christiansen *et al*. (2005) and Alberola *et al*. (2008) were pioneers in econometrically accounting for the relations between energy markets and the CO_2 price.

Based on Phase I spot and futures data, the former group of authors emphasizes that the nature of this relationship between energy and carbon prices varies depending on the period under consideration (Phase I, Phase II or Phase III) and the major influence of institutional events.

In addition, Bunn and Fezzi (2007) have examined the causalities between CO_2 and electricity variables (such as Clean Dark and Clean Spark Spreads, and switch price) during the first phases of the EU ETS.

Lebatt and White (2007) underscore a primordial element in functioning of EU ETS to know the incorporation of two of three mechanisms of suppleness of Kyoto even in the first stage (2005-2007) and before the second stage (2008-2010), particularly, the Negotiable Emissions Permits (PEN) and the Mechanisms of Clean Development (MDP).

Faced with this official report, these last two mechanisms are established to help industrial companies to achieve their discounts allocated by programs CO_2; even if there is a space of clarity, the use of which is made of these mechanisms as percentage of the complete objective of discount of programs.

Finally, it is worth highlighting the work by Boutti, El Amri and Rodhain (2019) whose structural model of allowance price under the assumption of the performance of the Carbon Finance Strategy for Sustainable Finance is based on the reaction of the fundamentals of quota prices of the European Union Emissions Trading Scheme (EU ETS).

The former group of authors using multiple econometrically show regression that changes in the price of carbon (EUA) react to changes in primary energy prices (mainly natural gas). Last but not least, macroeconomic fundamentals of carbon prices respond to the impact of the COVID-19 crisis during the phase III: 2013-2019.

CARBON FINANCE

Policy Aspects

The UNFCCC estimates very high annual adaptation costs for infrastructure as shown in the table of estimates above. Indeed, it is found that the upper bound of climate change adaptation costs for infrastructure is ten (10) times higher than other sectors such as agriculture, coastal protection and water supply. The Kyoto Protocol (KP) has been supplemented by several Conferences of the Parties (COP), the main ones being Bonn (COP 5 (1999) & COP 6 (2001)) and Marrakech (COP 7 (2001)), in the context of sustainable development initiatives in the South. However, the procedures for formalizing a CDM strategy are complex, involving multiple stakeholders as well as the costs of adaptation to climate change (CC).

A positioning of the CDM strategy within the strategies and mechanisms advocated by the Kyoto Protocol is presented as follows:

Table 1. A look at the flexibility applications of the Kyoto Protocol

Strategies and Mechanisms	Parties Involved	Consistent
Emissions Trading	Between industrialized countries	An industrialized country with GHG emission reduction margins sells all or part of its surplus to another industrialized country that is having difficulty meeting its quantified target under the Protocol.
Joint Implementation (JI)	Between industrialized countries and countries in transition	An industrialized country invests in a project that reduces GHG emissions in a country with a transition economy and in exchange receives emission credits that it can count as assets.
Clean Development Mechanism (CDM)	Between industrialized and developing countries	An industrialized country invests in a project that reduces GHG emissions in a developing country (DC) and in exchange receives emission credits that it can count as assets.

Source: (El Amri *et al*., 2020)

According to El Amri *et al.* (2021), the de-carbonization of the capitalist mode of production requires a transformation. This makes sense if the productive, technological and consumption model is considered as well as the ways of living and working on a global scale.

It is therefore useful to specify how the carbon constraint is applied today in the countries of the South. If it is evident in industrialized countries, it is more, without a doubt, an economic opportunity thanks to the implementation of GHG emission reduction projects on their own territory. Favoring this analysis would therefore restrict the understanding of Sustainable Development and Environmental Responsibility practices.

In this perspective, El Amri, Boutti & Rodhain (2020) draw up a « short list » of negotiation themes defined in Bali (COP 13 took place in Bali in 2007). Among the advances made is an action plan for a post-Kyoto agreement (Post 2012) at COP 15 (Copenhagen)). The debate concerned the negotiation themes that are at the heart of the climate negotiations on the post-2012 regime. The vernacular axes of these themes are briefly presented:

- Adaptation: the adaptation support funds are now operational, namely the Least Developed Countries Fund (LDCF), the Special Climate Change Fund (SCCF), the Adaptation Fund (AF), (these funds are developed in the following) ;
- Technology transfer: DCs are asking for an exemption on intellectual property rights for climate-friendly (low-carbon) technologies ;
- Financing: the focus was on the financial assistance that industrialized countries must provide to Least Developed Countries (LDCs) and Small Island Developing States (SIDS) to help them adapt to Climate Change (CC) ;
- Deforestation: the urgency to act quickly through ad-hoc actions, to strengthen the capacities of developing countries and to have these actions financed by developed countries was recognized.

It must be recognized that the evaluations of the costs of adaptation to climate change for developing countries (DCs) are based on the same methodological basis. According to El Amri, Boutti & Rodhain (2020), these evaluations are based on the unified methodology of the World Bank, the Stern Review, Oxfam and the United Nations Development Programme (UNDP). Following this principle, it can be stated that these evaluations are based on three financial flows received by developing countries, namely:

Financial Flow 1: Official Development Assistance (ODA),
Financial Flow 2: Foreign Direct Investment (FDI) and
Financial Flow 3: Gross Domestic Investment (GDI) (This notion, otherwise known as Gross Fixed Capital Formation (GFCF), accounts for the expenditures allocated to the increase of the fixed capital of the economy, considering variations in the levels of the stocks).

These three financial flows received by developing countries highlight potential investment amounts that are sensitive to the impacts of climate change (El Amri, Boutti & Rodhain, 2020). In this respect, making these investments climate resilient implies the use of a climate sensitivity factor and a mark-up factor reflecting the additional cost of improving resilience to climate change impacts (WC, 2006).

Indeed, other methodologies exist. The Stern Review adopted a mark-up factor of 5-20% and further reduced the fraction of ODA (financial flow 1) sensitive to climate change (CC) to 20%. Oxfam adopted the WC (2006) figures but added some additional costs such as the costs of the work of non-governmental organizations (NGOs) at the community level in developing countries (DCs) and the implementation of NAPAs. UNEP FI (2013) also adopted the WC (2006) approach.

Means of Carbon Finance

Carbon markets are defined as the environmental markets created to regulate the emissions of greenhouse gases (including CO_2) such as the European Union Emissions Trading Scheme (EU ETS) and the Kyoto Protocol (more precisely the Clean Development Mechanism).

Through the analysis of the EU ETS and the CDM, the chapter shows how to use a variety of econometric techniques to analyze an evolving and expanding carbon market sphere worldwide.

This chapter offers a mix knowledge on emissions trading with practical applications to carbon markets. It covers the stylized actions on carbon markets from an economics perspective as well as key aspects on pricing strategies, fundamental and technical analysis.

This work deals with carbon price drivers (institutional decisions, energy prices and extreme weather events) in the context of the linear regression model.

The use of dummy variables contains the relevant price fundamentals on carbon markets. In terms of applications use, this chapter may be appealing to fundamentals in finance such as principles of financial markets, financial economics and finance econometrics.

The EU ETS has been created by the Directive 2003/87/CE. Across its 27 Member States, it covers large plants from CO_2-intensive emitting industrial sectors with a rated thermal input exceeding 20 MW. The European market covers approximately half of European CO_2 emissions.

Since 2005, the EUETS has operated independently from the Kyoto Protocol, but it has been linked to International Emissions Trading (IET) in 2008. In this context, the sectors covered include power generation, mineral oil refineries, coke ovens, iron and steel and factories producing cement, glass, lime, brick, ceramics, pulp and paper.

The price track of CO_2 allowances under the EU ETS is deeply affected by institutional decisions. Indeed, the EU ETS is an environmental market which has been created by the Directive 2003/87/EC. According to this environmental regulation tool, the EU Commission, and more particularly Directorate-General for Climate Action, can intervene to amend the functioning of the scheme. As market participants fully react to new arrival, any policy intervention from regulator has an immediate impact on the carbon price. The influence of institutional decisions is classically captured in regression model by using dummy variables. To illustrate how to use dummy variables, it is hoped to evaluate the impact of COVID-19 crisis about Phase III National Allocation Plans (NAPs) by the European Commission on the price of carbon. In this context, the news announcements of COVID-19 crisis have been identified. The dummy variables refer to news information disclosure concerning NAPs Phase III (NAPsPhaseIII).

The main sources for the news events recorded may be cited as being the United Nations Framework Convention on Climate Change (UNFCCC), the European Commission, the European Parliament, the European Economic and Social Committee, European Climate Exchange (ECX), European Energy Exchange (EEX), Bleunext, European emission allowances on the Intercontinental Exchange (ICE) and Point Carbon.

A vivid industry has developed with hundreds of participating firms, asset management firms, brokers, consultants, verifications agencies or other institutions.

FUNDAMENTAL ANALYSIS OF THE EU ETS

The former group of authors whose drivers a structural model of allowance price under the assumption of the performance of the Carbon Finance Strategy for Sustainable Finance is based on the reaction of the fundamentals of quota prices of the European Union Emissions Trading Scheme (EU ETS). It is worth highlighting the work by Boutti, El Amri and Rodhain (2019); it establishes to show econometrically using multiple regression that changes in the price of carbon (EUA) react to changes in primary energy prices (mainly natural gas) during the Phase I: 2005-2007 test period. Last but not least, macroeconomic fundamentals of carbon prices respond to the impact of the subprime crisis during the phase II: 2008-2010.

The Price of Carbon

This study engages with the price variations of the EUA as being the most liquid carbon asset. The daily spot price of the EUA is shed light on to foreground the daily changes that influence its price taking into consideration the intensity of volatility in this market (Chevallier, 2012). Given this, it is focused on the spot price of the EUA on the most liquid regulated spot markets.

The exchange is established in the French register for the USA and Swiss for the RECs. The buyer's cash account is debited to the BlueNext transit account then the seller's cash account. According to El Amri *et al.* (2020) the BlueNext scholarship proposes decreasing costs (tariffs) which are presented below according to the volumes of transactions carried out.

In this regard, since the buyers of allowances can turn either to the market or to auctions, the two prices should thus be very close. After dealing with the price of carbon, the focus will be on the prices of primary energies: price of oil, price of natural gas and price of coal.

Table 2. Characteristics of transactions on the stock exchange spot and future markets BlueNext

Spot Market	USA	CER	SpreadCER-EUA
Contract	BlueNext Spot EUA	BlueNext Spot CER	NC
Min volume	1000 tons	1000 tons	1000 tons
Register	French	Swiss	French (EUA) Switzerland (CER)
Future Market	**USA**	**CER**	
Contract	BlueNext Futures EUA	BlueNext Futures CER	
Underlying asset	USA 2008-2012	CERs issued by the CDP steering committee and accepted by BlueNext	
Min volume	1000 tons	1000 tons	
Register	French	Swiss	

Source: El Amri *et al.*, 2020

Primary Energy Prices: Oil, Natural Gas and Coal

The prices of allowances are clearly influenced by the price of primary energy. As a consequence, when the price of oil and gas are up, coal consumption also goes up. Given this principle, it is stated that CO_2 emissions go up, thus leading to an increase in the price of allowances (El Amri, Boutti, Rodhain, 2020). To realize this, potential future prices of primary energies are analyzed to demonstrate the price variations of the EUA (European Union Allowance) as related to the needs of industrial firms once the carbon is launched. Thus, the future markets for these energies are the most liquid. The data was taken from Reuters in Chevallier (2012).

The brent price (expressed in Euro/BBL) is the brent crude futures Month Ahead price negotiated on ICE. The brent is a North Sea deposit: its oil is representative of crudes produced in this region. Hence, it offers the best attributes to face up to the other energy variables traded in continental Europe, which enter in the determination of carbon price.

The natural gas price used (expressed in Euro/Therm) is the futures Month Ahead natural gas price negotiated on Zeebrugge Hub. It is the best liquid gas trading market in Europe and has a major influence on the price that European consumers pay for this gas. As such, the Zeebrugge price represents the best proxy of the European gas market price determined close to end-users.

The coal price is the Atntwerp/Rotherdam/Amsterdam (ARA) coal futures Month Ahead price, which is the major imported coal in northwest Europe. The ARA coal is expressed in Euro/ton.

The Clean Dark Spread, Spark Spread and Switch Price

Power operators pay close attention to the Dark and Spark spreads as well as to the difference between them. The Dark spread represents the theoretical profit that a coal-fired power plant makes from selling a unit of electricity, having purchased the fuel required to produce that unit of electricity.

The operators of electricity production can modify the fuel used for this purpose. In this sense, it is a sine qua non to take into consideration a few variables. To qualify this statement, the researchers can detail this as follows:

First Variable

The Clean Dark Spread: (expressed in € / MWh) represents the difference between the price of electricity during peak hours (note elec) and the price of coal (noted coal) used to generate and produce electricity, corrected for energy output from coal in the plant and CO_2 costs (noted), as follows:

$$\text{Clean dark} = \text{elec} - \left(\text{coal} \times \frac{1}{\rho_{\text{coal}}} \times EF_{\text{coal}} \right) \tag{1}$$

With ρ_{coal} is the thermal efficiency of a conventional coal-fired plant, and EF_{coal} the CO_2 emissions factor of a conventional coal-fired power plant.

Second Variable

The Clean Spark Spread: (expressed in € / MWh) represents the difference between the price of electricity in peak hours and the price of natural gas (noted ngas) used to generate and produce electricity, corrected for the energy output from fuel gas in the plant and CO_2 costs, as follows:

$$\text{Clean spark} = \text{elec} - \left(\text{ngas} \times \frac{1}{\rho_{\text{ngas}}} + p_t \times EF_{\text{ngas}} \right) \tag{2}$$

With ρ_{ngas} is the thermal efficiency of the fuel gas in the approved plant, and EF_{ngas} is the factor of CO2 emissions factor of conventional coal-fired power plant.

Third Variable

The Switch Price: (expressed in € / MWh) represents the competitive price to equalize the *Clean Dark* and the *Clean Spark*, as following:

$$\text{Switch} = \frac{\text{cost}_{\text{ngas}} / MWh - \text{cost}_{\text{coal}} / MWh}{tCO2_{\text{coal}} / MWh - tCO2_{\text{ngas}} / MWh} \tag{3}$$

With $cost_{ngas}$ is the cost to produce a unit of MWh of electricity based on the net CO_2 emissions of gas (expressed in € / MWh), $cost_{coal}$ is the cost to produce a unit of MWh of electricity based on the net CO_2 emissions of coal (expressed in € / MWh), $tCO2_{coal}$ is the emission factor (expressed in $t\mathrm{CO}_2$ / MWh) of fuel coal in the approved plant and $tCO2_{ngas}$ is the emission factor (expressed in $t\mathrm{CO}_2$ / MWh) of fuel gas in the contracted plant.

Atmospheric Variables

No doubt, atmospheric conditions affect the amount of CO_2 emissions. As this is considered, it can be posited that more energy produced will certainly be concluded by more oil consumed in relation with CO_2 emissions, and as a result, CO_2 allocations on the carbon market will be needed in relation to a positive effect on CO_2 prices. Carbon prices (EUA prices) are also influenced by temperature of each region using an index called the NBCI "National Business-Climate Index". The latter is defined by an average daily temperature of the region of the country, produced by the population of this region (Chevallier, 2012). This index is expressed in "Celsius Degree (C°)" concerning eighteen (18) countries[1] as following:

$$\theta = \frac{\sum_{i=1}^{N} pi \times \theta_i}{\sum_{i=1}^{N} pi} \quad (4)$$

With N the number of regions in the country under consideration, pi the population of region i, and θi the average temperature of region i during the month in question. Moreover, this methodology has been extended by CDC Climate to consider the specificities of the carbon market. The European temperature index is equal to the average of the national temperature indices forecast for the eighteen countries, weighted by the weight of each country in the total volume of allowances distributed. The researchers present the formula for this index as follows:

$$T = \frac{\sum_{j}^{4} Q_j \times \theta_j}{\sum_{j=1}^{4} Q_j} \quad (5)$$

With T the monthly index, Q_j the number of quotas allocated by country j in its National Quota Allocation Plan (PNAQ), and θ_j the country's national temperature index j.

French Stock Exchange Companies and Subprime Crisis

It is highly decisive that the weight of economic activity on electricity production and the price of the EUA (Boutti *et al.,* 2019) is considered. As such, it is intended to highlight the effect of the subprime crisis on companies of the EU Emissions Trading Scheme (EU ETS) for Responsible Management.

Given this, it can be argued that this analysis does suggest the SBF 250 variable, which is listed on NYSE Euronext. The following Table highlights the members of BlueNext by categories.

It is important to notice that the economic activity influences electricity producers (representing 37% in the carbon market) and companies subject to ETS (41% share in BlueNext).

Table 3. BlueNext members by categories

Categories	Share of Members (%)
Companies subject to ETS	41
… Of which electricity producers	37
Bank and market participants	32
Brokers	20
Credit issuers	07

Source: El Amri *et al.*, 2020

TECHNICAL ANALYSIS OF THE EU ETS

At the outset, the explained variable and the explanatory variables in the framework of this econometric work will be highlighted so as to test the research hypothesis. The research hypothesis is as follows: the performance of the Carbon Finance strategy for Responsible Management is influenced by the Sanitary Covid-19 crisis during phase IIII of the EU ETS.

Specification of the Variable to Be Explained

This explained variable (endogenous variable) is evaluated and measured by the change in EUA spot prices. It is used to express the return from the point of view of allocation on the carbon market: the European Union Emissions Trading Scheme (EU ETS).

Specification of Explanatory Variables

The goal is to demonstrate the link between the performance of the strategies of industrial players subject to the European Union Emissions Trading Scheme (EU ETS) for both periods via the variation of the EUA spot price and the primary energy variables, atmospheric variables, CO_2 emissions information variables, fuel modification variables, structural movement variables and the Sanitary COVID-19 crisis variable (exogenous variables).

Variables for the Third Period EU ETS 2013-2021

The variables for the third period, known as the Kyoto Protocol commitment phase (KP) of the European Union Emissions Trading Scheme (EU ETS) are also presented in four groups (A - B - C and D) in Table 4.

As is shown in the table above, ten variables have been opted for as the first period for the third period of the EU ETS. However, it is to be noted that the variable Structural movement dummy is substituted with the Sanitary Covid-19 crisis dummy. As a result, six (06) explanatory variables have a positive expected sign and four (04) explanatory variables have a negative expected sign.

Table 4. Presentation of explanatory variables for the third period of the EU ETS

Explanatory Variables	Predicted Signs	
Group A: Primary Energy Variables		
Variations in the price of Brent	+	**Var. 01**
Variations in the price of gas	-	**Var. 02**
Coal Price Variations	-	**Var. 03**
Group B: Fuel Modification Variables in Power Generation		
Clean Spark Spread	-	**Var. 04**
Clean Dark Spread	+	**Var. 05**
Group C: Structural Movement Variables		
Dummy Sanitary crisis COVID-19	+	**Var. 07**
The impact of economic activity and the Sanitary COVID-19 crisis on electricity production - SBF 250 variations	-	**Var. 08**
Group D: Atmospheric variables		
Extremely Cold Dummy	+	**Var. 09**
Extremely Hot Dummy	+	**Var. 10**
Normal Seasonal Variations	+	**Var. 11**

Source: El Amri *et al*., 2021

EU ETS Model Specification

The general linear model is a generalization of the simple regression model in which several explanatory variables are included.

$$Y_t = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + \ldots + \beta_k X_{kt} + \varepsilon_t \text{ of } t = 1, \ldots., n \tag{6}$$

The parameter βi is called the partial regression coefficient; it measures the variation of Y when Xi increases by one unit and the other explanatory variables are kept constant. ε represents the random error; it is unobservable and includes both the measurement errors on the observed values of Y and all other explanatory factors not considered in the model.

Multiple regression aims to explain a dependent variable Y and p explanatory variables X1, X2, X3, ..., Xp (p>1). Then, if this relation is confirmed, evaluate its intensity.

To determine the variables that influence the performance of EU ETS actors' strategies via the EUA price, the following formulation is adopted:

$$PERF\ EUA_{i,t} = \alpha W_{i,t} + \beta X_{i,t} + \chi Z_{i,t} + \delta Y_{i,t} + \varepsilon_{i,t} \tag{7}$$

To get to the heart of the matter, the above table includes four groups of addressable action variables on the performance of the strategies of EU ETS actors via the EUA award.

Table 5. The four groups of variables in the econometric study of the EU ETS time series

$PERF\ EUA_{i,t}$	**Performance of EU ETS Actors' Strategies via the EUA Price**	**Groups Variables**
$W_{i,t}$	**Primary energy variables**	**Group A**
Brent $_{i,t}$	Variations in the price of Brent	(**Var. 01**)
Gas $_{i,t}$	Changes in the price of gas	(**Var. 02**)
Coal $_{i,t}$	Coal price changes	(**Var. 03**)
$X_{i,t}$	**Fuel modification variables of energy production**	**Group B**
CSS $_{i,t}$	Clean Spark Spread	(**Var. 04**)
CDS $_{i,t}$	Clean Dark Spread	(**Var. 05**)
$Z_{i,t}$	**Structural movement variables**	**Group C**
DMS $_{i,t}$	Structural Dummy Movement for Phase II	(**Var. 06**)
DCS $_{i,t}$	Dummy Sanitary crisis COVID-19 for phase IIII	(**Var. 07**)
SBF $_{i,t}$	The impact of economic activity and the Sanitary COVID-19 crisis on electricity production - SBF 250 variations	(**Var. 08**)
$Y_{i,t}$	**Atmospheric variables**	**Group D**
DEF $_{i,t}$	Extremely Cold Dummy	(**Var. 09**)
DEC $_{i,t}$	Extremely Hot Dummy	(**Var. 10**)
VNS $_{i,t}$	Normal Seasonal Variations	(**Var. 11**)
$\varepsilon i_{,t}$	**Random variable (error term), following a normal law N=(0,δ2)**	**Error Term**

Source: Boutti *et al.*, 2019

First, group A of primary energy variables ($W_{i,t}$) contains three addressable action variables, namely, changes in the price of Brent (Brent i,t) [Var. 01], changes in the price of gas (Gas i,t) [Var. 02], and changes in the price of coal (Coal i,t) [Var. 03]. Second, group B of the variables of modification of the fuel of energy production shows in force two addressable action variables; the Clean Spark Spread (CSS i,t) [Var. 04] and the Clean Dark Spread (CDS i,t) [Var. 05]. Thirdly, group C of structural movement variables involve three variables; the Structural Movement Dummy for phase II (DMS i,t) [Var. 06], the Sanitary COVID-19 crisis Dummy for phase III (DCS i,t) [Var. 07] and the impact of economic activity and the financial crisis on electricity production - SBF 250 Variations (SBF i,t) [Var. 08].

Finally, group D of atmospheric variables highlight Extremely Cold Dummy (DEF i,t) [Var. 09], Extremely Hot Dummy (DEC i,t) [Var. 10], and Normal Seasonal Variations (VNS i,t) [Var. 11].

Phase III EU ETS Model Validation

The Fisher statistic (F-test) enables us to validate this model. By consulting F tabulated (theoretical or critical) with the degrees of freedom of 5% and the number of observations, the authors find the F tabulated (theoretical or critical)[2] which is equal to 2,01. Then this tabulated F (theoretical or critical) is compared with the calculated F (F-statistic) which is 36.93663; it is found that F (F-statistic) > F tabulated (theoretical); it is concluded that the model is validated.

The calculated value of F is compared to its critical value read from the Fisher table at a threshold (1-α). A high value of F shows that the regression model is globally significant, which leads to and results in the rejection of H0; therefore, at least one of the coefficients *β*i is different from zero. In accordance with the above statement, this model is validated because the model according to the above table confirms a value Prob (F-statistic) = 0,000000 which is lower than the threshold α =0,05. At the 5% significance threshold; it can be affirmed that there is a significant relationship between the performance of the Carbon Finance strategy for Responsible Management and the performance of the Carbon Finance strategy as Responsible Management is influenced by the Sanitary COVID-19 crisis during phase III. Ultimately, this analysis indicates that this research Hypothesis is therefore verified.

RESULTS, DISCUSSIONS AND CRITICAL ISSUES

To minimize the electricity production cost, power producers can capitalize on the fact that they switch from coal to gas depending on the share of coal and gas in their electricity mix.

The switching between coal and gas is focused on to produce one unit of electricity. As oil is mostly consumed to meet high peak demand, particularly in winter, it is most likely that it will not interfere with coal and gas switching in the European system. In addition, oil has known an intensity and rise in volatility during the recent period while gas and coal are considered the cheapest alternatives.

Switching offers good solutions to power to decrease and lessen their emissions at low costs. Electricity generators have to compare the CO_2 price and marginal abatement costs in order to exploit and benefit from these cheap abatement offers.

It seems less demanding to switch for a less carbon-intensive fuel (such as gas) in lieu of using coal and buying permits. This explains why electricity prices are conditioned by the marginal generation technology in power sector. Variant generation units are evaluated and ranked by marginal costs from the cheapest technology to the most expensive one. This is called ‘merit order’ ranking and it is conditioned by several parameters like fuel prices, plant efficiencies, and carbon intensity.

The intensity of power generation technologies is changed and the competitiveness of power plants is modified once the introduction of a carbon cost is affected through tradable permits. The expensive gas-fired power plants, yet less CO_2 intensive than coal fired power plants, may become more profitable than coal-fired power plants as the authors introduce the high carbon costs. This is called ‘switching point’ and it is made up when the two technologies are rendered equally attractive.

Without carbon costs, the marginal cost of producing electricity is given by the ratio between fuel costs and the efficiency of the plant.

The switch can only occur if coal-plants are running while some gas plants are available to replace them. The best opportunities occur when the load is relatively low and mostly met by coal-fired plants (during weekends, nights and summers).

Then, with adequate economic incentives, available gas-fired units may be switched. Consequently, the possibility of fuel-switching varies throughout the year depending on the season (winter or summer), the time of the week (day-of-week or week-end effects), and the period of the day (day or night).

As shown in this chapter, the influence of such drivers (mainly energy variables and extreme temperatures events) varies depending on the period under consideration and the influence of institutional decisions.

Last but not the least, concerning spatial limits, it is worth emphasizing scaling issues. Indeed, increasing the scale of the cap-and-trade system increases economic efficiency, but also decreases trade security.

In addition, when setting a tradable permits market, the regulator needs to consider deposition constraints, by avoiding exceedance of critical loads in specific geographical zones. Another concern lies in the proper design of national emission ceilings. In this analysis, the authors aim to investigate the important and unimportant variables for this model. The probability column "Prob." 3 is considered in the table above. This table of results from the EU ETS Phase III multiple regression summarizes the results of the correlation analysis. It forcefully demonstrates the significant and non-significant variables with their correlations in this sense of the EU ETS Phase III correlation analysis results.

Table 6. Significant and non-significant variables in Phase III of the EU ETS

Five (05) Significant Variables From Phase III of the EU ETS		
Analysis variables	**Correlations (hind signs)**	
Variations in the price of Brent crude oil	→ Positive correlation	**Var. 01**
Coal Price Variations (Coal)	→ Negative correlation	**Var. 03**
The impact of economic activity and the Sanitary COVID-19 crisis on electricity production (SBF)	→ Positive correlation	**Var. 08**
Extremely Hot Dummy (DEC)	→ Negative correlation	**Var. 10**
Variations in Seasonal Standards (VNS)	→ Negative correlation	**Var. 11**
Four (04) non-significant EU ETS Phase III variables		
Analysis variables	**Correlations (hind signs)**	
Changes in gas prices (Gas)	→ Positive correlation	**Var. 02**
Clean Spark Spread (CSS)	→ Positive correlation	**Var. 04**
Clean Dark Spread (CDS)	→ Positive correlation	**Var. 05**
Extremely Cold Dummy (DEF)	→ Negative correlation	**Var. 09**

Source: Boutti *et al.*, 2019

As shown in the table above, the five significant variables in the EU ETS Phase III that are:

- [Var. 01] Variations in the price of Brent (Brent): predicted sign (+) and hind sign (+) ;
- [Var. 03] Variations in the price of coal (coal): predicted sign (-) and hind sign (-) ;
- [Var. 08] The impact of economic activity and the Sanitary COVID-19 crisis on electricity production (SBF): predicted sign (-) and hind sign (+) ;
- [Var. 10] Extremely Hot Dummy (DEC): predicted sign (+) and hind sign (-) ;
- [Var. 11] Normal Seasonal Variations: predicted sign (+) and hind sign (-).

The following table highlights the impact of the increase in the cost of the carbon constraint on the profits of firms listed on the EU ETS market according to the state of competition on the markets (upstream and downstream).

Table 7. Significant impact of the rising cost of carbon

Elasticity to Changes in the Price of Quotas	Supply of Production Factor	Request Addressed to the Company
Inelastic	Downward trend in earnings	Trend towards sustained earnings
Elastic	Trend towards sustained earnings	Downward trend in the deficit

Source: Boutti *et al.*, 2019

The table above highlighted the following four situations with respect to the price elasticity of quotas:

1. If the company cannot reduce the use of a production factor: downward trend in profit. Example: aluminum production if the supply of electricity is uncompetitive.
2. Customers cannot forego purchasing the company's product and the company is not experiencing an exacerbated competitive intensity: tendency to maintain profit. Example: Electricity supply in countries with monopoly and pricing freedom.
3. If the market for a production factor is highly competitive: tendency to maintain profits. Example: Aluminum production if the supply of electricity is competitive.
4. If there are substitutes with a relative advantage for their costs in carbon constraint: tendency to decrease the deficit. Example: short-haul air transport subject to competition from rail and road networks.

RECOMMENDATIONS

In this chapter, it is examined and shown how energy costs related to fuel use (Brent, natural gas, coal) and power producers' fuel–switching behavior (Clean dark spread, clean spark spread, switch price) affect carbon price changes through various regression models. Also, it has been emphasized the impact of extreme weather events on carbon prices, based on unexpected changes in temperature. Carbon Finance will have consequences for the various economic actors, directly for industrial activities and indirectly for the rest of the socio-economic system. According to the literature, market mechanisms have led to the emergence of a carbon price signal, which companies must incorporate into their strategies in order to optimize their reductions in GHG emissions (Nordhaus, 1991). The interest for the company is to understand the ins and outs of Carbon Finance and to make the best use of allocated quotas in order to optimize their economic, financial and environmental performance. Thus, the central question of this research was formulated in the following way: "*What are the responsible issues and sustainable opportunities for the adoption of carbon finance for EU ETS companies for the development of a "2 ° C Finance*"?. In practice, several determinants of CO_2 prices (EUA) exist to promote the resilience of Carbon Finance, which can be characterized by the price of carbon, primary energy prices: oil, natural gas and coal, Clean Dark Spread, The Clean Spark Spread and the Switch Price, the atmospheric variables and the SBF250 and the Subprime crisis. Unlike solutions that are inflexible or irreversible, that increase Climate Change or reduce the incentive to adapt to Carbon Finance would be poorly adopted (Springer, 2003).

The mechanisms of Carbon Finance have a prominent place for the realization of the Sustainable Development (SD) agendas for Carbon Finance to become “Finance 2 ° C”. In these circumstances, not including the anticipation of Climate Change (CC) and the adoption of Carbon Finance (especially the CO_2 exchange system) will increase the risk of making the existence vulnerable to uncertainties while eliminating the actions and carbon transactions available to Sustainable Finance and Sustainable Development (SD). It seems very useful to inject less GHGs in absolute terms, but the real challenge is to reduce the GHGs to a threshold that limits the rise in temperature to 2°C (Toth, 1995). To carry out this study, it is decided to treat each period of the EU ETS in a different way according to their specificities and the academic work already carried out. In addition to the results of the econometric tool itself and their analysis, the process of sensitizing the industrial players and refocusing reflection on their own interest, that maximizing profitability (or avoid reducing profitability) a project to exchange EU ETS CO_2 allowances for current and future climate change.

FUTURE RESEARCH DIRECTIONS

As is shown in these econometric analyses, it is noticed that a number of levels of interpretation of Carbon Finance in the test of Responsible Management. The five (05) significant variables are identified as follows:

- The variable **“**Variations in the price of Brent (Brent)” [Var. 01], is the determinant of the price of a ton of carbon are very different from those of the EU ETS test period. First, the probabilities are much lower. Indeed, one of the main determinants of the EU ETS period I had a probability of 7% with a correlation coefficient of 8%. Secondly, the Variations in the price of Brent, had a probability of 0.81% with a correlation coefficient higher than that of gas, namely 19%.
- The variable “Variations in the price of coal (Coal)” [Var. 03], is a significant variable with a negative backward sign. Coal was used more than natural gas in power plants during the Sanitary COVID-19 crisis. The statistical test applied allows us to pay particular attention to the negative (-) hind sign. In this respect, the use of coal, compared to other energies and particularly gas, for energy production, increases CO_2 emissions. In the same vein, carbon market companies were facing a crisis situation (Sanitary COVID-19 crisis). In this respect, in order to obtain liquidity, sales of allowances contributed to an increase in activity in the carbon market during this crisis period (Chevallier, 2012).
- The variable “The impact of economic activity and the Sanitary COVID-19 crisis on electricity production (SBF)” [Var. 08] is significant in the model. In this respect, this variable has a positive sign (+) after the fact, as does the variable “Variations in the price of Brent (Brent)” [Var. 01]. The researchers can argue that the variable [Var. 08] has a positive influence on EUA prices. The authors can conclude that industrial actors were motivated to reduce the use of natural gas on behalf of coal (in the short term to face the Sanitary COVID-19 crisis and as part of a long-term Responsible Management strategy, at the end of the period).
- The “Extremely Hot Dummy (DEC)” [Var. 10], is a significant variable. That said, when temperatures are extremely high, the authors are faced with a situation of increasing energy requirements for air conditioning, which increases CO_2 emissions.

- The variable “Variations in Seasonal Standards (VNS)” [Var. 11], is a significant variable. This said, when temperatures are extremely low, the researchers are faced with a situation of increasing heating energy needs. According to the above, energy consumption increases and, in turn, increases CO_2 emissions. On the other hand, when the temperature is very hot in summer, the authors are faced with a situation of increasing energy needs for air conditioning. In these circumstances, EUA prices have been increased on the market. This analysis is very relevant with that of Chevallier (2012). A colder than usual temperature in winter increases energy generation and, in particular, the need for heating fuel. A very hot temperature in summer increases energy consumption for air conditioning. In the case of cold winters and hot summers, emissions are, all other things being equal, higher, which leads to an increase in the price of allowances on the market.

To sum up, five (5) types of determinants of the EUA price for the third phase of the EU ETS have been identified: the first determinant being « Variations in the price of Brent crude oil » [Var. 01], the second determinant being « Coal Price Variations (Coal) » [Var. 03], the third determinant being « The impact of economic activity and the Sanitary COVID-19 crisis on power generation (SBF) » [Var. 08], the fourth determinant being « Extremely Hot Dummy (DEC) » [Var. 10], and finally « Variations in Seasonal Standards (VNS) » [Var. 11].

In this respect, it is tried to show using multiple regression that carbon price variations react to economic activity and the Sanitary COVID-19 crisis during period III of the EU ETS. According to Chevallier’s (2012) financial analysis, the EUA market had six (6) fundamental disconnections during period III of the EU ETS, as follows:

- 1st fundamental disconnection in 2008: Subprime Financial Crisis
- 2nd fundamental disconnection in 2009: New equilibrium in the soft recovery
- 3rd fundamental disconnection in 2010: Fukushima incident
- 4th fundamental disconnection in 2010: Debt crisis and further deterioration of growth prospects
- 5th fundamental disconnection in 2011: Energy Efficiency (EE) discussions
- 6th fundamental disconnection in 2019: Sanitary COVID-19 crisis and further deterioration of growth prospects

It is concluded with the idea that the results are in perfect symbiosis with the literature reviews. The interest for the company is to understand the ins and outs of Carbon Finance and to make the best use of the allocated quotas in order to optimize their financial and economic performance. Ultimately, carbon finance will help us find a way to meet the climate change challenge only when all elements of the economy—consumers, producers, and regulators—have to factor GHGs into their bottom line.

CONCLUSION

Many decades after the economic work of Coase (1960) on negative externalities, the European carbon market has grown significantly and has become the main market for environmental instruments in the world. In the introduction to this chapter, the authors mentioned the significance of the recent development of carbon finance and its relevance in the fight against climate change.

Carbon Finance encompasses the versatile market mechanisms included in the Kyoto Protocol and it includes all the activities that contribute to making GHGs a tradable good. Market mechanisms have created a carbon price signal—a fact which makes companies forced to adopt and integrate into their strategies in order to optimize their GHG emission reductions.

In the analysis, it was able to highlight key concepts and theories relating to carbon finance which led us to consider two main themes: determining the price of carbon and the impact of its accounting treatment on the assets of the Business and its financial profitability. These themes are closely linked to each other insofar as the carbon price is subject to several influencing factors (regulatory decisions, primary energy prices, macroeconomic factors, etc.) and itself has a direct impact on the valuation of the market.

To set out on the analysis, it was decided to treat each topic in a different way depending on their specificities and the academic work already done. The authors studied the determinants of the price per ton of carbon using a quantitative methodology. An econometric study was performed based on a linear regression model in order to test the research hypothesis.

This information is decisive for companies to integrate carbon risk into their long-term strategies and adapt their sales and purchasing strategies to the carbon market. These studies have enabled us - quite modestly - to enrich the existing literature and make managerial recommendations, mainly based on the need for legal, financial and informational monitoring of the carbon market. Clear identification of carbon risks is essential. Some of the challenges and opportunities of Carbon Finance have thus been highlighted; although the subject being very broad to deal with, it is important to conclude this part by setting in perspective the implications and suggest the need for a better supervision of the carbon market so as to bring about a robust long-term price signal in Europe and on all current and future carbon markets.

As for the pedagogical possibilities, this chapter may be appealing to courses in finance such as principles of financial markets, financial economics and financial econometrics. It will also be relevant to courses in energy, environmental and resource economics as it covers the EU ETS and the Kyoto Protocol which constitute a new commodity; it will also be eligible to courses on commodity markets and risk management on these markets. Finally, the measure of risk in climate change in CO_2 spot and a future market is detailed based on commodity markets models and linear regressions. Besides, carbon price risk management strategies are described by the means of an econometric analysis of the factors influencing fuel-switching in the power sector.

DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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KEY TERMS AND DEFINITIONS

Activities Carried Out Jointly: Pilot Stage of the joint implementation (MOC), such as it is defined in the Article 4.2 (a) of CCNUCC and which favors the implementation of activities of plans between developed countries (and their firms) as well as between country developed and developing country (and their firms). Activities carried out jointly should allow Parties in CCNUCC to acquire experience in this domain. It is not planned to validate the activities of this type during pilot stage. One still decides on nothing as for the future of the plans of activities carried out jointly and, in the manner, they can be linked to the mechanisms of Kyoto. Under the simple form of negotiable licenses, activities carried out jointly and other expressions founded on the market represent mechanisms which could greatly contribute to the draft of additional means for the preservation of total environment.

Annex B (Kyoto Protocol ([PK]): The countries of the annex B are principally the same that the countries of the annex I of CCNUCC with some difference. For instance, Belarus and Turkey are not included in the annex B. These countries have objectives of discount of programs of GES. The countries of the annex B are 37 countries as follows: Germany, Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Denmark, Spain, Estonia, the United States, Finland, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, New Zealand, Norway, Netherlands, Poland, Portugal, Republic Czech, Romania, United Kingdom, Russia, Slovakia, Slovenia, Sweden, Switzerland, Ukraine.

Carbon Dioxide (CO_2): Artificial or natural Gas of origin in case it results from fossil fuels (oil, gas, coal, etc.), of biomass and changes of allocation of lands, as well as other industrial techniques. It is main gas with anthropogenic greenhouse effect and reference gas for the measure of other gases with greenhouse effect. It is a gas which occurs of course, and that is also a product diverted from the combustion of fossil fuels and from biomass, as well as of the changes of allocation of lands and other industrial processes. It is main gas with anthropogenic greenhouse effect which has an influence on the radiatif balance sheet of the Earth. Gas acting as reference for the measure of other Gases with Greenhouse effect (GES); his Potential of Worldwide Warming is equal to 1.

Clean Dark Spread (CDS): Expressed as € / MWh, represents difference between the selling price of electricity and its production cost, inserting the purchase of fuel (coal) and the possible purchase of the corresponding licences of program. Other expenses (functioning and maintenance and other interest charges) are excluded from counting. For the producer of electricity, one Clean positive Dark Spread means that the production of electricity is lucrative for considered period.

Clean Sark Spread (CSS): Expressed as € / MWh, represents difference between the selling price of electricity and its production cost, inserting the purchase of fuel (gas) and the possible purchase of the corresponding licences of program. Other expenses (functioning and maintenance and other interest charges) are excluded from counting. For the producer of electricity, one Clean positive Spark Spread means that the production of electricity is lucrative for considered period.

Climatic Change (CC): Detectable and persistent Variation of climate (modifications of the average of temperatures). Climatic Changes indicate a statistically significant variation of the medium state of climate or its changeability persisting during long periods, in general during decades or more. Climatic changes can be owed to natural internal processes or to external forcings, or to changes anthropiques persistent of the composition of the atmosphere or the allocation of lands.

Kyoto Protocol (PK): The Kyoto protocol is signed in 1997 has as objective to force industrial countries to reduce their programs of six (6) Gases to Greenhouse effect (GES): CO_2, CH_4, N_2O, HFC, PFC, SF6. Agreement envisages for the period 2008-2012 that greenhouse gas emissions (GES) regress of 5,2% on average in comparison with the year of 1990. The European Union (EU) and other numerous countries ratified aforementioned protocol in 2002. To come into force, this protocol must be ratified by more than 55 countries totaling more than 55% of programs GES. Further to ratification by Russia at the end of 2014, the Kyoto protocol came into force on February 16th, 2005. Several big countries did not sign PK, notably the United States of America and China. Developing countries (PED) are exempted from ciphered commitments so that their development is not called into question.

Price of Carbon: Commands who must be poured (in a public authority in form of tax or in license of exchange of programs) for the program 1 ton of CO_2 in the atmosphere. In models, as well as in the present Report, the price of carbon represents the social expense to avoid the program of an additional unit of Équivalent - CO_2. In certain models the price of carbon is represented by the informal price of an additional unit of issued CO_2, in others – by the rates of taxes on carbon or price of the license of programs. In the present Report it is also used as limit rate for the marginal expenses of depressions during the valuation of the economic possibilities of alleviation.

Transfer of Programs of Carbon: Fraction of the discounts of programs in the purposeful countries/parties in the Annex B which can be compensated, in countries exempt from obligations, by an increase of programs above basic conditions. This transfer can be linked (1) to a relocation of the activities of production with strong energy intensity in regions exempt from obligations; (2) in an augmented consumption of fossil fuels in regions exempt from obligations due to fall of the international prices of oil and gas following from a reduction of the request of these forms of energy; and (3) in an evolution of incomes (and as a result of the request of energy) owed to an improvement of the terms of exchange. The transfer of programs also corresponds to the effects of the discount of the programs of GES or the plan of activities of stocking of CO_2 which can happen beyond the borders of plan and that are measurable and attributable to activity. Nevertheless, it happens that effects attributable to an activity not being part of plan, can entrained a reduction of the programs of GES. It is what they call commonly an effect of entrainment. If a (negative) transfer of programs can entrain a delivery on the discounts of proved programs, an effect of positive entrainment will not be reason there out of necessity.

Unit of Discount Certified by Programs (URE) – Program Reduction Unit (ERU): Corresponds to a ton of programs in Equivalent-CO_2 reduced or trapped thanks to a plan of the Mechanism for a clean development, calculated with the aid of the Potential of worldwide warming. To reflect possibility that a plan of afforestation or reforestation is not competitive, the 9th Conference of Parties decided to use temporary certificates for the net elimination of gases with greenhouse effect anthropogenic. See also Units of discount of programs. It is a credit carbon generated by the discount of a ton of greenhouse gas emission (GES) emanating from a plan MOC, expressed in tons CO_2 (teqCO_2) is equivalent.

ENDNOTES

1. Austria, Belgium, Germany, Denmark, Spain, Finland, France, United Kingdom, Hungary, Ireland, Italy, The Netherlands, Norway, Poland, Portugal, Sweden, Slovenia and Slovenia.
2. To find the theoretical value on the Fisher table the authors need dl1 and dl2. In this respect, [dl1 = 9 (the variables) - 1 = 8] and [dl2 = 122 (the observations) - 9 = 113].
3. This column indicates the percentage chance that the correlation between the variable and the EUA spot price is zero. In this respect, the authors take the variables that have the lowest probability (value less than 0.05).

Chapter 18
FDI and Environmental Degradation:
Evidence From a Developed Country

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ABSTRACT

The factors affecting environmental quality are examined in this chapter. Along with the support of relevant literature, Environmental Kuznets Curve (EKC) hypothesis is explained in detail to examine the impact of economic growth. In order to understand the linkage between foreign direct investments (FDI) and environmental degradation, pollution haven hypothesis (PHH) and pollution halo hypothesis (P-HH) are scrutinized. Using data of Sweden for the period 1971-2015, impacts of economic growth, FDI inflows, and energy consumption on the ecological footprint are measured. Results show that there exists a U-shaped relationship between gross domestic product per capita and ecological footprint. In the long run, the EKC hypothesis is contradicted. Additionally, FDI inflows are found to affect ecological footprint negatively, meaning that it decreases the environmental deterioration, in the long run, affirming P-HH. This study could be extended by using different econometric models, countries, and larger datasets.

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INTRODUCTION

Economic activities like foreign investments, global trade and transportation are essential for economic growth, which is the main goal to achieve for many countries around the world. However, rapid economic growth accompanied by excessive levels of such activities, industrialization, and higher population, result not only in increased levels of energy consumption by ongoing economic activities (Wang, Li, Fang, & Zhou, 2016), but also negative environmental impacts, especially the increased emissions and gradual gathering of Greenhouse Gases (GHG) in the atmosphere (Ahmad *et al.*, 2016). The accumulation of GHGs is among the root causes of global warming, climate change and other factors that cause environmental degradation. All these factors have serious implications to the whole ecosystem and may roll back the development progress.

Due to significant pace of growth, global warming, climate change and environmental degradation draws more attention and awareness (Apergis & Ozturk, 2015; Destek & Sarkodie, 2019). Industrialization became more prominent in last few decades which resulted in an increase in energy demand. As this demand is usually met by non-renewable fossil fuels causing GHG accumulation, managing the trade-off between economic growth and environmental deterioration gets harder day by day (Uddin, Salahuddin, Alam, & Gow, 2017; Majeed & Mazhar, 2019). Economic growth usually brings in industrialization that adds value to the extracted resources and increases agricultural output which raises consumption of natural resources. Consequently, regenerative capacity of natural resources is exceeded, creating ecological deficits in more countries (Sarkodie & Strezov, 2019). The people all over the globe create ecological footprint that is 60% higher than ecosystems can renew (Global Footprint Network, 2020) as a result of which the human-induced pressures on the environment have become an important threat.

The major global challenges that the humanity must face is continuing economic development while preserving the environment simultaneously. This challenge forms the notion of "sustainable development." Significant steps must be taken to prevent an environmental catastrophe while ensuring global sustainable development. The Sustainable Development Goals (SDG), two of which are fighting against climate change and creating access to affordable and clean energy for more people, were adopted in 2015 as a development guide for all the UN member states with the aim of forming their principles and activities to reach these objectives by the end of 2030 (UN, 2020). The success in achieving sustainable development requires staying under world's average bio-capacity which is the capability of natural resources to renew (Global Footprint Network, n.d.b). However, many countries involve in excessive economic activities to achieve rapid economic growth, resulting in over-exploitation of natural resources and/or accumulation of GHGs. The ultimate outcome is unsustainable environment.

The relationship between the quality of environment and economic growth is explained by Environmental Kuznets Curve (EKC) hypothesis whereas Pollution Halo Hypothesis (P-HH) theorizes the relationship linkage between degradation of environment and inflows of foreign direct investment. In general both these hypotheses show the relationships for a developing country. EKC hypothesis defends that for a developing country, priorities are constructed upon economic growth instead of protection of the nature, while the latter two hypotheses investigate the impact of FDIs on the environmental deterioration in a developing country which depends on the attitudes of foreign investors. That is why, researching the validity of these hypotheses for a developed country case might be informative and pathfinder. It may pave the way for theories explaining better the relations mentioned above for the developed cases and may be insightful for policymakers.

The aim this chapter is to scrutinize the factors affecting environmental degradation with an empirical application for Sweden, a developed country. Examining and understanding these factors properly may result in efficient policy suggestions with the aim of creating a sustainable environment not only for this generation but also for the next ones. Economic growth, FDI inflows and environmental degradation are discussed. Hypotheses are constructed, and empirical analysis is made by using econometric techniques to test the hypotheses. In the last part, results are discussed and suggestions for future research are made.

BACKGROUND

Indicators of Environmental Quality

The carrying capacity of environment is its "maximum persistently supportable load" (Catton, 1986). In our context, the prosperity of increasing human population depends on the viability of scarce energy and material resources the nature provides. Hence, allowing these sources to regenerate and preventing them from depleting are the keys to reach environmental sustainability. Considering this, Rees (1996) defined human carrying capacity as "*the maximum rates of resource harvesting and waste generation (the maximum load) that can be sustained indefinitely without progressively impairing the productivity and functional integrity of relevant ecosystems wherever the latter may be located*" (p. 203). Because all resource materials eventually turn into waste as the degraded form, waste generation has significant importance in this cycle, too.

Various indicators have been used as proxies for environmental deterioration. For example, Salahuddin *et al.* (2015), Ahmad *et al.* (2016), and Wang *et al.* (2016) used carbon dioxide (CO_2), Cole *et al.* (1997) used nitrogen dioxide (NO_2) while others used other chemicals as environmental degradation indicators in their studies. CO_2 emission is the most prominently used one among these which is probably because it has the biggest share in GHGs (Zafar *et al.*, 2019). The effect of economic development on environmental deterioration comprises of several dimensions. Single indicator cannot give a full picture of environmental degradation as it is only a part of the deterioration resulting from large scale energy consumption (Solarin & Al-Mulali, 2018; Uddin *et al.*, 2017). Carbon footprint (CAR_t) comprises the productive surface areas' use but excludes other productive surface areas such as cropland, forests, fishing lands, built-up lands, forests, and grazing lands (Solarin & Al-Mulali, 2018).

Ecological footprint is more appropriate to augment previously used separate indicators of degradation with a composite global indicator. It points out the per capita demand for bio-capacity (Mrabet, AlSamara, & Jarallah, 2017). William Rees and Mathis Wackernagel introduced ecological footprint concept in 1990's initially. It was defined by Rees (1996) as "*the corresponding area of productive land and aquatic ecosystems required to produce the resources used, to assimilate the wastes produced, by a defined population at a specified material standard of living, wherever on Earth that land may be located*" (p. 205). This indicator reveals the impact on the environmental deterioration in terms of soil, water, and air (Al-Mulali, Weng-Wai, Sheau-Ting, & Mohammed, 2015) for individuals, companies, cities, nations, and the world (Charfeddine & Mrabet, 2017). Ecological footprint comprises carbon demand on land and biologically productive areas like forest, built-up and grazing lands, crop lands and fishing grounds that are required for regeneration of the resources for consumption, waste assimilation and economic growth (Destek & Okumus, 2019; Majeed & Mazhar, 2019). It depends on the population, income, consumption patterns, living standards and ecosystem efficiency (Wackernagel *et al.*, 1999).

There are sub-categories of ecological footprint like carbon footprint, water footprint that can be used for various measurements and comparisons. The carbon footprint usually constitutes the largest part of ecological footprint (Verhofstadt *et al.*, 2016).

In this chapter, ecological footprint is used as a proxy for environmental deterioration (Bello *et al.*, 2018; Destek *et al.*, 2018). Ecological footprint combines all the data about environment into a single number, which makes it easier to compare regenerative capacity of the ecosystem with human consumption of natural resources and to make sure the natural resources are used sustainably. Rees (1996) defined ecological deficit as "*the level of resource consumption and waste discharge by a defined economy or population in excess of locally/regionally sustainable natural production and assimilative capacity*" (p. 205). Ecological footprint provides information about ecological deficit or surplus. In this way, ecological footprint tells if the resources are used sustainably, or if the pace of consumption is higher than the regeneration capacity of biosphere. The rapid pace of increase in the human demand for ecosystem resources may create a danger for biological capacity available. Measurement of ecological footprint is done in global hectares (GHA) per person. In its calculation, first step is to estimate land area appropriated (aa) per capita for each important consumption item production. Then, all appropriate ecosystem areas are summed to find total ecological footprint per capita. At the last step, this number is multiplied by the population size to get total ecological footprint (Rees, 1996).

In view of the foregoing, it is better to use ecological footprint as a proxy of human pressure on the environment (Destek, Ulucak, & Dogan, 2018; Uddin *et al.*, 2017; Bello, Solarin, & Yen, 2018; Ozcan, Apergis, & Shahbaz, 2018; Majeed & Mazhar, 2019).

Factors Effecting Environmental Quality

Numerous studies consider different factors as effectors of ecological footprint and scrutinizes causality relations between ecological footprint and these variables. In their pioneering study, Grossman and Krueger (1995) examined the relationship between per capita income representing economic development and the environmental pollution level measured by various indicators. The researchers pointed out that this relationship could be represented by an inverted U-shaped curve. A U-shaped relationship is found if a dependent variable decreases due to an increase in an independent variable at a decreasing rate until it reaches a minimum turning point, after which the dependent variable rises at an increasing rate as the independent one continues to increase. In the opposite side, an inverted U-shaped relationship is found if the dependent variable first rises with the increase of the independent variable at a decreasing rate until the maximum turning point, after which it falls at an increasing rate (Haans, Pieters, & He, 2016). The researchers claimed that during the early stages of economic development, environmental awareness is usually limited, and the policy makers' focus is the material output. That is why, the environmental degradation gets higher with high emission and pollution levels. Over extraction of natural resources result in higher waste generation. As the countries' development and income per capita levels rise; the importance of the environment increases and institutions protecting environment get much more attention (Grossman & Krueger, 1995; Sarkodie, 2018; Sarkodie & Strezov, 2019; Zafar *et al.*, 2019). Additionally, the technology improves and economy's development path changes from pollution intensive industries to service industries resulting in increased quality of the environment (Sarkodie & Strezov, 2019). Panayotou (1993) labelled this pattern as Environment Kuznets Curve (EKC) hypothesis as it is named after Kuznets who stated that the relationship between the inequality and income level can be defined by an inverted U-shape curve. The hypothesis asserts that the economic growth is not a threat but a requirement for the environmental quality in the long-term. If EKC hypothesis truly reflects the linkage between economic growth and deterioration of the environment, then levels of environmental degradation would be predicted according to countries predicted gross domestic product (GDP) levels in future years (Charfeddine & Mrabet, 2017). The theoretical equation of EKC can be written as,

$$EFP_{it} = a_{it} + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + \beta_3 Z_{it} + \varepsilon_{it} \tag{1}$$

In this equation, EFP represents ecological footprint, while GDP represents GDP per capita of the country. GDP squared is also added to the equation and all other possible effectors of ecological footprint are represented by Z.

For different signs of parameter β, shape of the EKC would change (Lorente & Álvarez-Herranz, 2016). If all β parameters are 0, then there is no significant relationship between economic growth and environmental deterioration. If only $\beta_1>0$ and other parameters are zero, then an increase in economic growth causes a linear increase in the environmental degradation. If $\beta_1<0$ and all other parameters are zero, then an increase in economic growth causes a linear decrease in the environmental degradation. If $\beta_1>0$ and $\beta_2<0$ and the other parameter β is zero, there exists an inverted U-shaped EKC. In the opposite way, if $\beta_1<0$, $\beta_2>0$ and other parameter β is zero, there exists a U-shaped EKC as explained above. If $\beta_1>0$, $\beta_2<0$ and $\beta_3>0$, there exists an N-shaped relationship between economic growth and environmental deterioration and for the opposite signs of the parameters; there will be an inverted N-shaped linkage between environmental degradation and economic growth (Allard, Takman, Uddin, & Ahmed, 2018).

Total energy use is one of the variables that is studied often and may have a relation with ecological footprint. It is defined by Charfeddine and Mrabet (2017) as "*the use of primary energy before transformation to other end-use fuels (such as electricity and refined petroleum products)*" (p. 144). It is usually represented by energy consumption or logarithm of energy consumption per capita. Impact of energy consumption on the environment may differ according to the way and the purpose of energy usage. If non-renewable energy sources are used creating higher demand for oil, gas, and coal; than this consumption probably increases GHG emissions and deteriorate environmental quality (Mirza & Kanwal, 2017). If the utilization of "green technologies" exists, then it may not increase environmental degradation.

Energy use affects environmental quality that impacts the economic growth. There are different hypotheses about energy use and economic growth relationship. "Growth hypothesis" states that as energy consumption positive bidirectional relationship with economic growth (Shahbaz, Farhani, & Ozturk, 2015). "Feedback hypothesis" asserts causality and reverse causality for economic growth and consumption of energy. Whereas conservation hypothesis defines the one way causality between these two variables. No causality is depicted by "Neutrality hypothesis" (Ahmad *et al.*, 2016). Additionally, it is claimed that energy use contributes economic growth that results in environmental deterioration (Charfeddine & Mrabet, 2017).

The influence of urbanization on ecological footprint is also studied by many researchers. Urban population is represented by the percentage of the people living in urban areas out of the total population (Charfeddine & Mrabet, 2017). Process of urbanization is contributed by the transition of the economy from agriculture to industry. This transition usually accompanied by rapid economic development and higher earnings. The effect of urbanisation on the environment may differ. If the urbanization process is planned properly and the people living in urban areas use green technology, then it may decrease the deterioration of the environment (Arouri, Shahbaz, Onchang, Islam, & Teulon, 2013). Additionally, according to ecological modernization theory, environmental deterioration may decrease with the help of efficient use of space and transportation, ecologically rational institutions and technologies (Majeed & Mazhar, 2019). Urbanization and rapid industrialization enhance the production of goods and services which ultimately increases the environmental degradation (Ulucak & Khan, 2020).

Political factors like political freedom or democracy may affect sustainable environmental quality in the long-term. Charfeddine and Mrabet (2017) claimed that the political institutions are critical in ensuring compliance with the regulations and laws protecting the environment. Usually, developments in law, regulations and institutional quality are seen among the political factors that are effectors of the environment. Deacon and Mueller (2006) defended that political system and institutional mechanisms of a country are important in making people and producers adapt more environmentally friendly attitudes and production mechanisms.

The fertility rate may affect the environmental degradation in many ways. High fertility rate is usually accompanied by higher population growth rate that fastens the rate of depletion for limited natural resources. Naturally, this impact depends on the consumption patterns of population, agricultural practices, urbanization pace, changes in land-use, energy consumption patterns and many other factors. Charfeddine and Mrabet (2017) considered fertility rate as a crucial factor affecting the environmental quality. According to them, as the population grows, degradation of the environment caused by the people also increases.

Human capital also has the potential to impact environmental quality, especially in the long run. As the society becomes more educated, human capital is accumulated. This helps efficient use of natural resources. By the increase in human capital, efficiency in production processes and energy consumption may advance, causing less GHG emissions and more tendency to adopt cleaner technologies, not only in industrial sectors but also in daily routine (Zafar *et al.*, 2019).

There are different views about the effect of trade openness on the environment. One view defends that for production, environmental control costs are generally not very high and developing countries with stricter environmental laws may focus on less-polluting industries to get competitive advantage (Asghari, 2013). Depending on the pollution the production process creates the income gain from trade may be outbalanced by the environmental degradation in the exporting country.

FDI is among prospective determinants of environmental deterioration. It may be measured by FDI inflows as a percentage of GDP. Compliance of environmental protection laws attract FDIs for green technologies. This promotes research and development in cleaner technologies, decreasing the environmental degradation in turn (Asghari, 2013). On the other hand, FDIs benefit from loose/weak environmental regulations and the weak infrastructure in the countries (Majeed & Mazhar, 2019), that results in the decreased quality of the environment by the accumulation of GHGs and pollution.

Environmental Deterioration and Economic Growth: EKC Curve

Economic growth is represented usually by GDP, logarithm of GDP or real GDP per capita (Majeed & Mazhar, 2019). Through different channels environment is affected by economic growth like Scale, composite and technique effect.

Scale effect represents the increased degradation of the environment due to “the economies of scale production”, i.e. better utilization of inputs for higher production. Hence, rising output requires more inputs, resulting in higher environmental degradation. This impact asserts a monotonically increasing relation between income and environmental deterioration (Charfeddine & Mrabet, 2017). Composite effect means that the negative effect on the environment increases as the growth path changes from agriculture to industrialization with heavy manufacturing industries and then declines afterwards as the path goes towards the service sector. Lastly, economic growth may decrease environmental deterioration by the development of green technology and decreasing pollutant emissions, which is defined as technique effect (Stern, 1998). Countries with higher income tend to make the environment cleaner (Asghari, 2013). Environmental quality can be developed only if the technological effect dominates both the composite and scale effects. Hence, the EKC hypothesis is important and provides policy makers a roadmap on how the sustainable growth may be achieved (Mrabet *et al.*, 2017). It is notable to mention that GDP comprises only official economic activities. Hence, given the presence of informal economic activities and the informal economy, studying the relation between economic growth and environmental degradation using GDP may give misleading results (Imamoglu, 2018).

The standard practice is to analyse the impacts of economic growth on the environmental deterioration to test EKC hypothesis. However, considering their direct and indirect influences on the environment, a few other variables are incorporated into the framework, for example, financial development. There are different channels through which the financial development affects the environment. First, it would attract FDI, which may contribute to economic growth. Also, just like the economic growth, financial development may bring easier access to clean technologies, which would increase efficient use of energy (Zhang, 2011). It also attracts more projects using green technology and facilitate investments in such technologies like renewable energy (Majeed & Mazhar, 2019). On the other hand, financial development may motivate the credit facilities that help the investors for purchasing machinery, devices and such which increases the GHG accumulation and environmental degradation (Zhang and Zhang, 2018).

LITERATURE REVIEW

Environmental Degradation and Economic Growth

Numerous studies have scrutinized the linkage between environmental degradation and economic growth by investigating the EKC hypothesis. Differing results have been witnessed.

First strand of studies confirms the EKC hypothesis for which CO_2 emission is considered as an indicator for degradation of environment. The inverted U shape EKC hypothesis is confirmed for Malaysia by investigating the relationship between real GDP and the environmental deterioration (Saboori *et al.*, 2012). Using time series data of twenty-one countries, Boulatoff and Jenkins (2010) proved the negative relationship between CO_2 emissions and income.

EKC hypothesis integrates the influence of other variables on the environment. Jalil and Mahmud (2009) supported the EKC hypothesis where the inverted U-shaped linkage is found between income and CO_2 emissions. The study also confirmed the increasing influence of energy consumption on CO_2 emissions. Twenty-four transition economies Using panel data for twenty four economies, Tamazian and Rao (2010) approved the EKC hypothesis. The study revealed the significance of institutional quality and financial developments to decrease environmental degradation. Jalil and Feridun (2011) confirmed EKC hypothesis and pointed out that financial development decreases environmental deterioration in China. Omri (2013) considered 14 MENA countries and found that energy consumption and economic growth increase environmental deterioration, confirming EKC hypothesis. Through an inverted U-shaped relationship, Ahmad *et al.* (2016) found that the GDP per capita in linear form has an increasing impact on CO_2 emissions, while GDP per capita squared affects it negatively in India. Similarly the EKC hypothesis holds for China (Zhang and Zhang, 2018). In addition, trade and exchange rate affect the environmental quality negatively according to the results. Sarkodie and Strezov (2019) also confirmed the validity of EKC hypothesis in China.

There are opposite findings in some studies which do not confirm the EKC hypothesis. Tamazian *et al.* (2009) investigated the impacts of economic growth and financial development on the environment for the BRIC economies and emphasized that the higher levels of financial development and economic growth would bring technological innovations creating energy efficiency, resulting in decreased environmental degradation in turn. Hence, results of the study oppose EKC hypothesis. Ozturk and Al-Mulali (2015) showed that GDP, urbanization, energy consumption, and trade openness increase CO_2 emissions, hence intensify environmental degradation in Cambodia so EKC hypothesis is not confirmed in the study. Bakirtas and Cetin (2017) could not find any evidence supporting EKC hypothesis for Mexico, Indonesia, the Republic of Korea, Turkey, and Australia (MIKTA) countries, whose focus is not on environmental quality but on material output, while FDI has a positive influence on the environmental degradation. Dar and Asif (2018) concluded that, in Turkey, financial development affects environmental quality positively while economic growth and higher energy usage deteriorates. Thus, the study challenges the validity of EKC hypothesis.

In view of the foregoing literature, CO_2 emissions are considered as an indicator for environmental degradation although CO_2 emissions are just a part of environmental deterioration (Al-Mulali, Weng-Wai, *et al.*, 2015). Available bio-capacity is not considered while testing EKC hypothesis. Ecological footprint would be a better and more comprehensive proxy for the environmental quality regarding its specifications. Charfeddine and Mrabet (2017) investigated EKC hypothesis for 15 MENA countries using ecological footprint as an environmental indicator and found that while the EKC hypothesis is confirmed for the whole sample, for the non-oil-exporting sub-sample, U-shaped behaviour of EKC curve is witnessed. The researchers also found that while the increases in energy consumption and political institutions index scale up ecological footprint, urbanization decreases it. The researchers also added that fertility rate and the life expectancy at birth decrease ecological footprint, benefiting the environment. Uddin *et al.* (2017) found that considering the highest emitting countries, real income has significant positive effect on ecological footprint per capita, while financial development and trade openness decrease it. Bello *et al.* (2018) showed that hydroelectricity usage as renewable energy consumption significantly decreases the ecological footprint in Malaysia and EKC hypothesis is supported by the inverted U-shaped relationship. It is concluded that urbanization increases CO_2 emissions. For the period 1980-2013, Destek *et al.* (2018) confirmed EKC hypothesis for the countries of European Union EU countries using data from 1980 to 2013. There exists U-shaped relationship between the real income and ecological footprint, hence EKC hypothesis is supported. Also, the findings revealed that the non-renewable energy consumption increases the ecological footprint while renewable energy consumption and trade openness affected it negatively in EU. Imamoglu (2018) considered formal and informal economic activities separately and found that formal income, informal income and energy consumption increase the ecological footprint in Turkey. Using the panel data of twenty countries, Solarin and Al-Mulali (2018) found that the real GDP and energy consumption have an increasing effect on ecological footprint, intensifying the environmental degradation. At the country level analyses, with a few exceptions, the same results persist. It is also observed that the urbanization scales up carbon footprint, ecological footprint and CO_2 emissions by using the panel data, while individual country level results differ. Udemba (2020) found a positive relationship between ecological footprint and GDP per capita in Turkey, supporting EKC hypothesis.

Al-Mulali, Tang, and Ozturk (2015) studied 129 countries and found that while the urbanization increases CO_2 emissions in the long run in lower-middle, upper-middle, and high-income countries, it does not affect low-income countries significantly. According to the findings, GDP growth also increases CO_2 emissions in upper-middle and high-income countries, but no significant effect is witnessed in lower-middle-income countries. It is also found that the financial development has a significant negative impact on CO_2 emissions, meaning that financial development may develop the environment. Apergis and Ozturk (2015) used data from 14 Asian countries and the analyses conducted show that there exists an inverted U-shaped linkage between emissions and income, confirming EKC hypothesis. The finding of Charfeddine (2017) confirmed the U-shaped curve for ecological footprint. It is found that trade openness and urbanization increase ecological footprint. Ulucak and Bilgili (2018) studied the effect of human capital on the ecological footprint by dividing countries into categories of low, middle, and high-income countries. According to the results, the human capital index lowers ecological footprint for all country groups, confirming the EKC hypothesis. Ahmed and Wang (2019) researched the effect of human capital and energy usage on ecological footprint in India and show that human capital decreases environmental deterioration by lowering ecological footprint, while energy consumption increases ecological footprint. Baloch *et al.* (2019) evaluated data from 59 Belt and Road Initiative (BRI) countries and found that financial development, economic growth, energy consumption, FDI inflows, and urbanization increase ecological footprint, intensifying the environmental degradation. Ulucak and Khan (2020) found an inverted U-shaped relationship between income and ecological footprint for all BRICS countries.

Caviglia-Harris *et al.* (2009) investigated the linkage between ecological footprint and economic growth for 146 countries for the period of 1961-2000 and the findings pointed out that there was a relationship between the ecological footprint and economic development supporting the EKC hypothesis. Salahuddin *et al.* (2015) explained that economic growth and electricity consumption caused a rise in CO_2 emissions in the Gulf Cooperation Council (GCC) countries, while for financial development no significant impact was found. Mrabet *et al.* (2017) found that as the long run influence of income on the ecological footprint is higher than its short run effect, there exists a monotonic relationship between income and the ecological footprint. Hence, the EKC hypothesis is not valid in Qatar. Additionally, the findings show that the influence of trade openness on the ecological footprint is decreasing in the long run. Ozcan *et al.* (2018) analysed EKC hypothesis for Turkey and the findings show that for some periods there were feedback relationships between ecological footprint and economic growth. In addition, it is found that the economic growth influenced ecological footprint in the positive way by an effect which is slowly increasing. Thus, the EKC hypothesis is not confirmed for Turkey. Zafar *et al.* (2019) found that, in the long run, the natural resources and human capital decrease the ecological footprint, thus improve environmental quality. U-shaped relationship is found for OECD countries (Destek and Sinha, 2020).

The mixed nature of the empirical findings in the literature may be attributed to various reasons. Researchers prefer different econometric methodologies for the investigations depending on the datasets. Sample size and frequency may result in different conclusions. Environmental deterioration indicators are various which include $CO_{2,}$ CH_4, and NO_2 emissions, ecological footprint, water pollution, deforestation. Preferring one among these indicators affects the research results. As the ecological footprint is the most comprehensive one among all, it is widely used in the current literature as the indicator of environmental deterioration. In addition, researchers integrate divergent variables to the models used in research. Some researchers tested the basic EKC equation while others used broader models which may provide more comprehensive results if the variables are chosen properly. Lastly, sample of countries and the period examined have an impact on the findings of the study because of that individual peculiarities and development levels of the countries. Investigating the same country for different periods generate different results. If a group of countries are analysed, these should be chosen as homogenous as possible (Wang *et al.*, 2016; Charfeddine & Mrabet, 2017; Mrabet *et al.*, 2017).

ENVIRONMENTAL DEGRADATION AND FOREIGN DIRECT INVESTMENT

Exactly like the economic growth, FDI inflows may affect the environmental quality of host countries through three channels: the scale effect, composition effect and the technique effect (Grossman & Krueger, 1991). The scale effect suggests that during the first stages of economic development, the countries require additional natural resources and inputs which would affect the environment negatively through increased emissions, resource consumption or dangerous by-products. Hence, more FDIs would trigger economic growth while deteriorating the environment at the same time. The composition effect points out the fact that FDI inflows may affect composition of the industries in the host country, which may create differing effects on the ecology depending on the sectors' composition (Nathaniel *et al*, 2020). Through technique effect FDI inflows channelize the relocation and diffusion of modern technology which is accompanied by new environmental regulations. This relocation would lower the environmental degradation while creating positive spill overs to local firms (Abdo *et al*., 2020; Nathaniel *et al.*, 2020).

FDI inflows affect the host country negatively in terms of the environment when technique effect is dominated by scale and composition effects. Pollution haven hypothesis (PHH) is the degrading effect of FDI inflows on the environment (Asghari, 2013; Udemba, 2020). This hypothesis defends that loose environmental regulations, which are usually seen in less developed countries, attract opportunist and pollution-intensive multinational companies (MNC) who want to outsource pollution-intensive productions to benefit from lower costs of adapting to the regulations, lower negative externality costs, abundant natural resources and labour force without regarding the negative impacts on the environment in the host countries (Grossman & Krueger, 1991; Copeland & Taylor, 1994; Cole & Elliot, 2005; Bakirtas & Cetin, 2017; Sarkodie & Strezov, 2019; Mert & Caglar, 2020). That is why, these less developed countries which do not have the resources required for development, may provide legislative incentives in order to gain comparative advantage in pollution-intensive industries to attract FDIs by producing pollution-intensive products (Solarin & Al-Mulali, 2018; Mert & Caglar, 2020). In this chain, dirty industries of developed countries migrate to less developed ones and the latter exports these pollution-intensive goods while these goods are imported by the former (Destek & Okumus, 2019).

There are some supporting explanations of this hypothesis. Initially, environmental consciousness is higher in developed countries thanks to high income level and increased demand for better environmental quality, while extra earnings are valued more in less developed countries due to the poverty. In addition, as the qualified and trained personnel and the equipment required for environment-friendly production are scarce in less developed countries, costs of enforcing environmental regulations are higher in less developed countries. Thirdly, the development in developed and less developed countries are accompanied by a shift from manufacturing to service sector and a shift from agriculture to industrialization, respectively. The former decreases environmental degradation while the latter intensifies it (Asghari, 2013).

Pollution Halo Hypothesis (P-HH) is the favourable effect of FDI inflows on both the economy and the environment. In this case, the scale effect is outweighed by the composition and technique effects. This hypothesis defends that if the MNCs perform activities in the host countries in an environment-friendly and cleaner manner using innovative production approaches, the environment is not degraded (Alfaro, Chanda, Kalemli-Ozcan, & Sayek, 2010; Al-Mulali & Tang, 2013; Udemba, 2020). As the investments in the less developed host countries increases, pollution in these countries decreases because FDI inflows promote the use of advanced environment-friendly technologies and management skills by obeying the environmental regulations. As the domestic industries adopt these freshly learned methods, environmental degradation in the host countries diminish (Destek & Okumus, 2019; Abdo *et al.*, 2020; Mert & Caglar, 2020; Nathaniel *et al.*, 2020). Supporters of this hypothesis posit that as the country attracts more FDIs, new training opportunities in the host country provide the workers with opportunity of learning new skills and know-how (Alfaro *et al.*, 2010). Secondly, MNCs do not risk their reputation, goodwill, and business in the long-term by deteriorating the environment (Nathaniel *et al.*, 2020). Lastly, the less developed host countries get latest technology and new inputs with the help of FDIs (Zafar *et al.*, 2019).

The relationship between FDI inflows and environmental indicators is discussed widely in the literature. In the long run FDI inflows have a small but positive effect on CO_2 emissions (Seker *et al.,* 2015). PHH is confirmed in BRICs countries (Zakarya *et al.*, 2015) and ASEAN-5 (Baek, 2016) as FDI inflows have a positive influence on CO_2 emissions. Bakirtas and Cetin (2017) found that with a positive shock on FDI inflows, CO_2 emissions increase by 0.4% in MIKTA countries, confirming PHH. FDI inflows increase CO_2 emissions in the top five emitter developing countries as suggested by Sarkodie and Strezov (2019). Solarin *et al.* (2017) validated PHH for Ghana using CO_2 emissions as an environmental indicator and concluded that PHH is confirmed for the country. For China, during the period 1980-2012, the results revealed the validity of PHH (Sun *et al.*, 2017). Baloch *et al.* (2019) examined the impact of FDI inflows on the ecological footprint for 59 BRI countries and conclusion was an affirmation of PHH for these countries.

Shahbaz *et al.* (2019) researched the linkage between FDI inflows and CO_2 emissions for the MENA. The N-shaped relationship is found between FDI inflows and CO_2 emissions which confirms PHH. Abdo *et al.* (2020) researched the influence of FDIs on ecological footprint in 12 Arab countries and found that FDI inflows increase CO_2 emissions, supporting PHH. Udemba (2020) investigated the linkage between FDIs and ecological footprint and showed that FDI inflows increase ecological footprint. Thus, PHH is confirmed. Tamazian and Rao (2010) analysed the effects of various variables on CO_2 emissions in twenty-four transitional countries. The results pointed out that FDI inflows reduce CO_2 emissions per capita in these countries so P-HH is valid. Asghari (2013) studied the linkage between FDI inflows and the quality of the environment in MENA region and found that FDI inflows support environmental quality, confirming P-HH for the region. Mert and Boluk (2016) examined the effect of FDI inflows on CO_2 emissions in 21 Kyoto countries. Their results confirm the P-HH meaning that FDI inflows improve the environment. It is also concluded that the renewable energy consumption reduces CO_2 emissions. In twenty nine provinces of China Zhang and Zhou (2016) found that FDI inflows help CO_2 emissions to decrease, hence their findings support the P-HH. For countries of ASEAN, Zhu *et al.* (2016) reached at the conclusion that FDI inflows reduced CO_2 emissions except for first quintile, approving the validity of the P-HH for high emission countries. Zafar *et al.* (2019) found that FDI inflows decrease ecological footprint in the US. Mert and Caglar (2020) applied hidden co-integration analyses and concluded that increase in FDI inflows decrease the emission growth rate in the long run in Turkey as an affirmation of P-HH. Kivyiro and Arminen (2014) researched the relationships between CO_2 emissions, energy usage, and economic development and FDI inflows in six Sub Saharan African countries. The results concluded that FDI inflows raise CO_2 emissions in Kenya and Zimbabwe, while decrease it in the other ones.

Solarin and Al-Mulali (2018) found that FDI inflows diminish carbon footprint using data of twenty countries. Results are mixed at the individual country level. It is also concluded that FDI inflows have no significant impact on the ecological footprint at the panel level while results at individual country level are different. As most of the results show that FDI inflows have a negative impact on the environmental deterioration in the developed countries in accordance with P-HH, there is an increasing impact on the environmental deterioration in the developing countries. Destek and Okumus (2019) rejected both PHH and P-HH 10 newly industrialized countries.

Mixed results of the above said studies depend on the contexts and research subjects. Additionally, research designs, econometric methods used for analyses, research periods and variables may also affect the results (Wang *et al.*, 2016).

EMPIRICAL ANALYSIS

While the relevant literature provides a theoretical base, real data analysis is useful to contribute to the existing literature. That is why, theories explained and argued are tested using real-life data of Sweden. Sweden is a country in North Europe whose population has reached to 10.38 million as of 2020. It represents an interesting case as, in 2017, its ecological footprint is 22nd highest one among all countries. Still, its bio-capacity deficit has been positive since 1961, which means it has bio-capacity reserve (Global Footprint Network, n.d.b). Being a developed country, investigating the influences of the variables (which are defined as ecological footprint effectors in the relevant literature) on the environmental degradation would result in useful inferences. Following two hypotheses are tested.

Hypothesis One: Ecological footprint and economic growth of the Sweden has a relationship represented by an inverted U-shape, as EKC suggests.

Alternative Hypothesis: Hypothesis one does not hold.

Hypothesis Two: Ecological footprint and FDI inflows to the Sweden have a negative relationship, as P-HH suggests.

Alternative Hypothesis: Hypothesis Two does not hold.

Data

The relationships between the ecological footprint (production per capita), energy consumption (in per capita of kg of oil equivalent), GDP per capita, GDP square and net FDI inflows are analysed using annual frequency time series data for the period 1971–2015. Details about the variables are given in Table 1. GDP, GDP square, energy consumption and net FDI inflows data are obtained from World Bank online database, while ecological footprint data is acquired from Global Footprint Network.

All variables are included in the form of natural logarithm forms to prevent heteroskedasticity. To get the natural logarithm of the FDI series, negative values must be fixed. That is why, a constant value is added to all values in this series to make them all non-negative. Descriptive statistics of the variables are presented in Table 2. The standard deviation values reveal that the instabilities of economic growth, ecological footprint and the FDI are greater than that of energy consumption.

Table 1. Variables and data sources

Variables	Description	Data Sources
Ecological footprint of production (lnEFP)	In global hectares per capita	Global Footprint Network
Foreign direct investments net inflow (lnFDI)	Measured in net FDI inflows per capita current US $	World Bank online dataset
Economic growth (lnGDP)	Measured in GDP per capita current US $	World Bank online dataset
Quadratic term of GDP (lnGDPsq)	To check non-linear relations	
Energy consumption (lnenergy)	Measured in per capita of kg of oil equivalent	World Bank online dataset

Unit Root Tests

A combination of unit root tests is employed to determine the integration order of the variables. DF-GLS unit root test which found by Elliot, Rothenberg, and Stock and KPSS (Kwiatkowski, Phillips, Schmidt, & Shin, 1992) test are applied to examine the stationarity of the series. The null hypotheses of DF-GLS and KPSS tests show non-stationarity and stationarity, respectively. The results of the KPSS test in Table 3 show that the variables are at non-stationary levels because the null hypothesis of stationarity is rejected at 1% significance level for all variables. All variables included in the study become stationary at the first difference according to KPSS test outcomes.

When DF-GLS test results are considered, null hypothesis of non-stationarity could not be rejected for the level variables. However, when the first differences are used for the test, all become stationary and the null hypothesis is rejected at 5% and 1% levels for lnFDI and others, respectively. Hence, the test results disclose that all the variables employed in the study are non-stationary at the level and stationary at the first difference, showing that these are integrated of order one, I(1). Test results are shown in Table 3.

Table 2. Descriptive statistics

	lnEFP	lnGDP	lnFDI	lnEnergy
Mean	22.480	10.097	23.432	8.578
Median	22.839	10.296	23.193	8.588
Maximum	23.003	11.012	25.013	8.679
Minimum	20.533	8.543	21.050	8.401
SD	0.817	0.668	0.648	0.076
Skewness	-1.677	-0.325	-0.489	-0.620
Kurtosis	3.859	6.079	2.354	2.472
Obs	45.000	45.000	45.000	45.000

Co-Integration Tests

Next important step is to decide the optimal lag length. Table 4 shows lag order selection criteria results. As both Hannah-Quinn (HQIC) and Schwarz Bayesian Information Criterion (SBIC) gave the optimal lag length of 1, lag length is determined as 1.

Table 3. Unit-root test results

	DF-GLS	KPSS
lnEFP	-2.390	0.447***
ΔlnEFP	-10.730***	0.021
lnFDI	-1.970	0.0313***
ΔlnFDI	-3.356**	0.021
lnGDP	-2.484	0.382***
ΔlnGDP	-4.127***	0.066
ln (GDPsq)	-0.951	0.805***
ΔlnGDPsq	-4.316***	0.037
lnenergy	-1.006	0.774***
Δlnenergy	-4.778***	0.018

The models with trend and intercept are used. ** and *** shows significance at 5% and 1% levels, respectively.

Table 4. Lag order selection criteria

Lag	LogL	LR	FPE	AIC	HQIC	SBIC
0	-132.356	NA	NA	6.700	6.776	6.909
1	-16.392	231.930	0.001	3.263	2.720*	3.517*
2	1.164	35.113	0.000	2.626	3.463	4.925
3	23.020	43.711	0.000	2.780	3.997	6.123
4	69.793	93.547*	0.000*	1.717*	3.315	6.105

* shows the chosen lag order according to the criteria.

As the outcomes of the DF-GLS and KPSS tests indicate that the variables analysed in the study are integrated of order one, Engle-Granger and Johansen cointegration tests may be employed to investigate the existence of any cointegrating relationship.

Table 5 shows the outcomes of both cointegration test results. In the Panel A, results are shown for the Engle-Granger test and the null hypothesis has no cointegration. As the null is rejected at 5% significance level, it is concluded that there exists a cointegrating relationship between the series. This test is useful as it is easy to implement. However, this test is based on the assumption of existence of one cointegrating factor so one should be careful while using this test in models having more than two variables. The Johansen cointegration test is more appropriate is such situations as it can test the existence of multiple cointegrating vectors. Ulucak & Bilgili (2018) found that the Johansen procedure outperforms both single equation and multivariate methods. So, Johansen cointegration test is applied for double check. Panel B of Table 5 shows the results of the Johansen cointegration test for which the null hypothesis is no cointegrating relationships. The H_0 is rejected at rank 0 and 1, and it cannot be rejected at rank 2. Hence, it can be concluded that there are two cointegrating equations.

Table 5. Cointegration test results

A. Engle-Granger Cointegration Test	Test Statistic	5% Critical Value	Cointegration
z (t)	-5.231	-4.741	√
B. Johansen Cointegration Test	**Trace Test**	**5% Critical Value**	**Cointegration**
R = 0	79.521	68.520	x
R ≤ 1	49.336	47.210	x
R ≤ 2	25.632*	29.680	√

* shows significance at 1% levels.

VECM – Causality Relations

Vector Error Correction Model (VECM) could be constructed to investigate short run and long run causal relationships between the variables.

$$\Delta LEFP_t = \alpha + \sum_{i=1}^{k-1} \beta_i \Delta LFDI_{t-i} + \sum_{i=1}^{k-1} \beta_i \Delta LGDP_{t-i} + \sum_{i=1}^{k-1} \beta_i \Delta LGDP_{t-i}^2 + \sum_{i=1}^{k-1} \beta_i \Delta LENERGY_{t-i} + \lambda ECT_{t-1} + u_t \quad (2)$$

Δ shows differenced operator and lag length is denoted by k-1. u_t is the residual which is assumed to be i.i.d. ECT_{t-1} shows the lagged error correction term whose significance points out the long run linkages among the variables. Once the series are known to be cointegrated, the VECM is superior in differentiating between short run and long run causal relationships (Shahbaz, Loganathan, Zeshan, & Zaman, 2015).

Here, as the optimal lag length is 1, no short run dynamics among the variables is observed. In VECM models, one less lag than the optimal lag is employed. The coefficient of the error correction term is examined to detect long-term causal linkages. If the term is statistically significant, then there exists a causal relationship in the long run (Seker, Ertugrul, & Cetin, 2015).

Long-term relationship outcomes are presented in Table 6. These coefficients must be interpreted in their negative forms. Hence, FDI inflows have a decreasing impact on the ecological footprint and every increase of 1% in FDI inflows results in a decrease of 0.51% in the ecological footprint at the significance level of 10%. This result proves the existence of P-HH for Sweden. Evidence of P-HH is confirmed for GCC countries (Tang, 2013), Vietnam (Tang and Tan, 2015), and Turkey Mert and Caglar, 2020) respectively.

GDP and GDP^2 have asymmetric impacts on the ecological footprint, ceteris paribus. Every increase of 1% in GDP and GDP^2 results in a decrease of 0.63% and an increase of 0.20% on the ecological footprint, respectively. The coefficients are significant at 5% and 1% levels. As the GDP decreases the ecological footprint until the point at which it starts to increase it, a U-shaped linkage is observed between the economic growth and the quality of the environment. Lindmark (2002) applied structural time-series approach and found no proof of EKC hypothesis. However, this may be a result of the period he examined (1870-1997). U-shaped relation is also found by Charfeddine (2017), Destek *et al.* (2018), and Destek and Sinha (2020) for Qatar, EU countries and 24 OECD countries, respectively.

Table 6. Long run estimations

	Coefficient	Std. Error	t-Stat.	Prob.
lnFDI	0.510*	0.276	1.850	0.065
lnGDP	0.627**	0.300	2.090	0.036
$lnGDP^2$	-0.199**	0.080	-2.490	0.013
lnEnergy	-17.892***	3.079	-5.810	0.000

*, **, and *** show the significance levels of 10%, 5% and 1%, respectively.

Last line of Table 6 shows the relationship between the energy consumption and ecological footprint. It is observed that an increase of 1% in the total energy consumption results in an increase of 17.89% in the ecological footprint. The impact is significant at 1%. Increasing effect of energy consumption is confirmed for the environmental is confirmed for China (Jalil and Mahmud, 2009), 14 MENA countries (Omri, 2013) and five countries (Sarkodie and Strezov, 2019).

Diagnostic Tests

Table 7 shows results of the diagnostic tests applied after VECM calculations. First line of the table shows the results of the autocorrelation test. Here, the null hypothesis states that the errors are not auto-correlated and as the p-value is 0.37, the null hypothesis cannot be rejected. Errors are not serially correlated. Second part of the table demonstrates the results of the normality tests. Skewness, kurtosis and Jarque-Bera tests are employed to check for normality. For tests, small sample adjustments are done. While skewness test affirms the normality, kurtosis test results and Jarque-Bera statistic reject it. Last part of the table indicates stability test results confirming stability of the system.

Table 7. Diagnostic tests

		F-Statistics	P-Value
Autocorrelation test	LM	29.680	0.237
Normality tests	Skewness test	5.830	0.323
	Kurtosis test	15.574***	0.008
	Jarque-Bera test	21.404**	0.018
Stability test		**Eigenvalue**	**Modulus**
		0.288	0.278

*, **, and *** show the significance levels of 10%, 5% and 1%, respectively.

DISCUSSION OF RESULTS

Empirical analysis results show that there exists a U-shaped relationship between the GDP and ecological footprint in Sweden. EKC hypothesis defends that especially in developing countries, GDP increases the pressure on the environment until the turning point at which the country becomes more developed, and the people become more sensitive about environmental issues. Sweden was among the developed countries in 1971 where the dataset initiates (UN, 1971), which may be the reason of U-shaped EKC. For the developing countries, financial development has the priority over environmental quality especially at the early stages of the development, as suggested by the EKC hypothesis. However, as Sweden was already a developed country, results must be evaluated accordingly. For Sweden, as the GDP per capita rises, environmental degradation decreases until the turning point, after which the ecological footprint starts to increase. As Sweden has the 21st place among all countries according to the GDP per capita value of 2019 (World Bank, n.d.), highest priority of the nation was not the financial concerns. As the GDP per capita of Sweden increases, environmental degradation decreases until the turning point. This situation may be explained by the environment being one of the highest priorities of the nation.

Developments and investments to make the environment better and to protect it are probably supported in the country. However, after a certain point, decreasing the deterioration of the environment would be impossible even if the highest technologies are adopted, due to the limited capacity of environmental development and the increasing population, which may explain the U-shaped relationship. In the study, Sweden analysis results point out a pattern affirming P-HH. In other words, FDI inflows decrease the degradation of the environment. This may result from the well-designed and strictly enforced environmental regulations forbidding FDIs' activities causing harm on the environment. Especially in the developed countries in which environmental policies are a priority for the nation and FDIs are expected to follow strict environmental regulations, P-HH affirmation would be more probable.

POLICY RECOMMENDATIONS AND CONCLUDING REMARKS

In this study, ecological footprint and the variables affecting it are examined. After the review of the relevant literature, most widely analysed effectors of the ecological footprint are found to be the economic growth, FDI inflows, and energy consumption. The EKC hypothesis, which supports the existence of an inverted U-shaped relationship, is commonly used to explain the relationship between the economic growth and ecological footprint. The linkage between FDI inflows and ecological footprint is also analysed often and clarified by two opposite hypotheses: PHH and P-HH. While the former one defends that FDI inflows increase the environmental degradation, the latter one claims the opposite as it defends that the environmental deterioration decreases by FDI inflows. The results of various empirical work affirm different hypotheses probably because of different econometric techniques, periods of datasets, countries/country groups, or the same country in different phases of the development are included in the empirical analyses.

For this study, Sweden is considered and dataset comprising from 1971 to 2015 is used. After the implementation of KPSS and DF-GLS unit-root tests, Engle-Granger and Johansen cointegration tests are applied to check for unit-roots in the series and cointegration among the series, respectively. With the help of VECM, short run and long run causal relations between the ecological footprint and other variables are checked. Result of empirical analysis indicate that there exists a U-shaped relationship between the GDP and ecological footprint in Sweden, rejecting the Hypothesis One. EKC hypothesis defends just the opposite that the GDP increases the pressure on the environment until the turning point at which the country becomes more developed, and people become more sensitive about environmental issues. Sweden was among the developed countries in 1971 where the dataset initiates (UN, 1971), which may be the reason of U-shaped EKC. Hence, the linkage between the environmental degradation and economic growth must be validated in accordance with the peculiarities of the countries.

Results of analysis demonstrate that the FDI inflows in Sweden decrease the ecological footprint helping the environmental quality to increase. This result affirms P-HH, and the Hypothesis Two could not be rejected. Policymakers may benefit from this result as an insight. This may be a result of well-designed and strictly enforced environmental laws that prevent FDIs from creating negative environmental results like over-pollution, accumulation of GHG emissions or dangerous waste material. Hence, especially the countries in which the environmental quality indicators are in a rising trend, must reconsider their regulations and laws about FDI activities and the environment. Policymakers need to enforce stricter environmental regulations not only in developing countries but also in the developed ones. Foreign investors need to follow regulations preventing them from creating environmental deterioration in the host country.

Based on the results of the empirical analysis, the most important recommendation would be to have solid and clear environmental laws and regulations. As the investors may try to benefit from the lax environmental regulations in the prospective host countries, their investments would benefit the financial development process while degrading the environmental quality of the host country at the same time. That is why, to prevent investment facilities from creating pollution, depleting the sources, and harming the nature; laws regulating the FDIs must be designed accordingly. In this way, host countries would benefit from FDI inflows while avoiding increased environmental deterioration. EKC curve would be useful in showing the linkage between the economic growth and the deterioration of the environment for many countries. However, as can be seen in the results of the analysis, the linkage may be in the opposite way. That is why, all nations must be careful in designing the policies for balancing the financial growth and environmental outcomes.

Policy recommendations may become more target-specific. Energy consumption trends are critical for the environmental sustainability in the long run. As the development levels of the countries affect the study results significantly, such empirical analyses should be made for countries at different development levels. In this way, tailored policies may be created. Additionally, better indicators for the environmental degradation are needed in the long-term. Ecological footprint has been used as an environmental indicator for nearly 30 years. A more comprehensive indicator would provide the people with healthier results.

DISCLAIMER

The contents and views of this chapter are expressed by the authors in their personal capacities. It is not necessary for the Editor and the Publisher to agree with these viewpoints and they are not responsible for any duty of care in this regard.

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KEY TERMS AND DEFINITIONS

Bio-Capacity: Forecast of an ecosystem's production capacity mainly for natural resources.

Ecological Deficit/Surplus: Difference between a nation's bio-capacity and the footprint.

Ecological Footprint: The amount of ecological assets required to create the items the people need to consume and to dispose the waste.

Foreign Direct Investment: An investment as a controlling ownership in a business in a country other than the business is based on.

Greenhouse Gases: A gas whose emission causes the greenhouse effect.

Pollution: All kinds of waste material created after production and consumption activities, which deteriorates the environment and must be absorbed.

Renewable Energy: Energy coming from renewable resources that renews in a certain period.

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