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Green Finance: From Environmental Sustainability to Investment Vehicle – An Empirical Study

by

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This work is dedicated to my late father, who gave me confidence to keep aim high in life, my mother for her countless blessings, my dear husband who has been a constant support throughout the journey and my kids for their patience and understanding. I would like to thank Dr. Arshad Hassan for his guidance during the whole process.

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This is to certify that the research work presented in the dissertation, entitled "**Green Finance: From Environmental Sustainability to Investment Vehicle – An Empirical Study**" was conducted under the supervision of **Dr. Arshad Hassan**. No part of this dissertation has been submitted anywhere else for any other degree. This dissertation is submitted to the **Department of Management Sciences, Capital University of Science and Technology** in partial fulfillment of the requirements for the degree of Doctor in Philosophy in the field of **Management Sciences.** The open defence of the dissertation was conducted on **December 21, 2023**.

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List of Publications

It is certified that following publication(s) have been made out of the research work that has been carried out for this dissertation:-

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Abstract

This study aims to examine the role of green finance in mitigating the critical issue of climatic change and promoting green investment options for portfolio diversification. Environmental sustainability is one of the top priorities at international environmental and economic agendas such as sustainable development goals (SDGs) and the conference of parties (COP) 26. Policymakers, researchers and academicians are aware of the need to look for alternative ways to solve the imbalance in the environmental, social and economic ecosystem. Green finance is introduced with the goal to pursue a balanced financial activity that helps in environmental protection. This study aims to examine the functions of green finance in two ways. (a) The impact of green finance on environmental quality (b) green finance as an investment vehicle. This study extensively analyzes the impact of green finance (GF), renewable energy, environmental regulations, and carbon finance towards environmental sustainability using panel dataset of 70 countries from 2012-2022. Generalized method of moments (GMM) is used to sidestep the matter of endogeneity. First, a novel index is developed by combining several indicators of green finance to measure its impact on environmental sustainability by lowering CO_2 emissions. The results show a significant impact of green finance as well as renewable energy on environmental sustainability, whereas the effect of carbon finance is insignificant. Second, the moderating role of environmental regulations, devised by Nationally Determined Contributions (NDC) policies, between GF and CO_2 emissions shows the importance of these regulations in moving towards a sustainable environment. Finally, this study examined the Environmental Kuznets Curve (EKC) of 70 countries and confirmed the presence of an inverted U-shape curve. The results confirm the significance of green finance as an indicator in EKC fitting, thus, supporting its importance. This study recommends long-term green finance projects and implications of environmental regulations to ensure environmental sustainability.

Furthermore, this study examines the dynamic connectedness between green finance, socially responsible investments, Islamic investments and gold is taken as a safe haven. Time-varying parameters, vector autoregressions (TVP-VAR) along with network connectedness approach based on generalized forecast error variance decomposition (GEVD) are used. The dynamic connectedness results show a time-varying pattern in return spillovers indicating a high connectedness in COVID-19 pandemic (early 2020). An interesting net pairwise connectedness between green bonds-sustainable investments, green bonds-clean energy stocks, green bond-Islamic investments, green bond-gold is detected. The results of time-varying returns transmission and net pairwise connectedness suggest that investors and policymakers can uses these findings to formulate regulatory decisions, improve portfolio diversification and net pairwise hedging strategies. Furthermore, the investment options investigated in this study focus on social and ethical interests in the background but they respond differently to market shocks. Hence proving to be better investment options for investors regarding optimal portfolio construction.

Keywords: Green finance, environmental sustainability, environmental regulations, renewable energy, sustainable development goals (SDGs), EKC curve, Islamic investments, TVP-VAR, spillover.

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Abbreviations

CE	Clean Energy Focused
CF	Carbon emissions futures
CH4	Methane
CO_2	Carbon dioxide
COP	Conference of the Parties
EBI	European Investment Bank
ER	Environmental Regulations
EKC	Environmental Kuznets Curve
GBI	Green Bond Index
GBL	Green Building
GCEI	S&P Global Clean Energy Index
GHGs	Greenhouse gases emissions
Gold	S&P GSCI Gold
GT	Green Transportation
GWL	Global Water
HFCs	Hydrofluorocarbons
IMWI	DJ Islamic Market World Index
MDGs	Millennium development goals
MPT	Modern Portfolio Theory
NDC	Nationally Determined Contributions policies
NO	Nitrous oxide (NO)
PFCs	Perfluorocarbonse
SDGs	Sustainable development goals
SF6	Sulfur hexafluoride
STRI	DJ Sukuk Total Return Index

SWI DJ Sustainability World Index

UN United Nations

UNFCCC United Nations Framework Convention on Climate Change

Chapter 1

Introduction

1.1 Introduction

Climatic change has been a global concern for the past few decades, which is a threat to environmental sustainability (Jiang et al., 2021).In the recent era, humanity is facing multiple crises regarding environmental sustainability such as climate change, surge in environmental pollution, acidification of oceans and loss of biodiversity due to deforestation. All these problems are the result of greenhouse gases emissions (GHGs), massive CO_2 emissions, use of heavy nitrogen-based and phosphorus-based fertilizers in agriculture (Sachs, 2012). These climatic changes and environmental damages are a global concern which are being addressed by policymakers, researchers, academicians worldwide.

To address the environmental sustainability issues, United Nations (UN) developed eight Millennium development goals (MDGs) for the time period 2000-2015 which appeared to be an efficient strategy to focus on important social priorities worldwide. In the list of eight millennium development goals, sustainable environment was listed at seven. The global need for sustainable development further led to the establishment of 17 Sustainable development goals (SDGs) for 2015-2030.In this list, affordable and clean energy is listed number at number 7 and climate action is at number 13. The inclusion of "environmental sustainability" in Millennium development goals (MDGs) and addition of goals like "climate action" and "affordable and clean energy" in Sustainable development goals (SDGs) highlights the importance of actions needed to be taken at every level to address climate change.

The initiation of pacts like Kyoto protocols, Paris agreement, Nationally Determined Contributions policies (NDC) and SDGs are a step toward addressing this global threat. Similarly, the agenda of Glasgow Climate Pact (COP26) held in November 2021 also emphasized the reduction of CO_2 emissions to accelerate the transition towards non-zero emissions by 2050. Additionally, these international forums have provided platforms for global agreement upon limiting harmful emissions reductions and promoting the shift towards renewable energy (WHO, 2021). This has caused an increased demand for renewable energy globally. By 2040, the share of renewable energy is predicted to increase by 40% (Tolliver, 2020). By 2050, two-thirds of the energy supply is supposed to be sourced through renewable energy (IRENA, 2020).

United Nations Framework Convention on Climate Change (UNFCCC) which is a pact agreed upon in 1994 and has 197 signatories have initiated various protocols and agreements to address the climate change issues. Conference of the Parties (COP) are the signatories of the UNFCCC and in its recent meeting held in Glasgow shows the significance of financial markets towards climate change and environmental sustainability is extensively studied. Kyoto protocols also emphasizes on the objective of UNFCCC to reduce seven greenhouse emission gases: nitrous oxide (NO), hydrofluorocarbons (HFCs), carbon dioxide (CO_2), Methane (CH4), perfluorocarbons (PFCs), sulfur hexafluoride (SF6), Nitrogen trifluoride (NF3). All these goals and agreements defined by United Nations confirm the dire need to focus on environmental sustainability and low CO_2 emissions while making investment decisions.

As per stakeholder theory (Freeman, 2010) the firms should create value for all the stake holders. Climate change is a global concern and society at large is a stake holder hence its sustainability should be one of the agendas for all organizations. The companies and investors are also becoming aware of the financial implications of being responsible towards climatic change (Lee et al., 2021). Hence the financial ecosystems need to incorporate environmental sustainability. Finance is a diverse ecosystem where financial markets act as a signal to direct investments and economic activities. The flow of capital controlled by financial sector is manifold as compared to that available with governments for sustainable development or that associated with other philanthropist activities (Bose et al., 2019). Hence the impact of financial decision making is relatively significant than any other organizations or agencies.The shift towards climate-resilient economy needs the mobilization of financial resources towards green projects and less investment in fossil energies. OECD continues opening the doors for climate finance and green finance in the financial ecosystem (OECD, 2015).

Another new domain of finance to ensure environmental stability is green finance. The idea of green finance is to involve in such future oriented financial processes which combine economic growth, financial development and environmental improvement (Youssef, 2020). Several financial instruments like green bonds and green equity are becoming popular among investors as they are targeted towards environmental sustainability. It refers to developed countries providing financing through a variety of sources, that promotes multilateral efforts to combat climate change.

Green finance is a wider term that encompasses all financial flows that support sustainable environmental objectives (COP 26). UNFCCC describes climate finance to be "local, national, or transnational financing drawn from public, private, and alternative sources of financing that seeks to support mitigation and adaptation actions that will address climate change." The ideology behind climate finance is to make world's economy take a transition towards low greenhouse gas levels and low carbon path and to build resilience of countries towards climatic change (Hong et al., 2020).

Another domain which focuses on environmental sustainability by mitigating harmful emissions is Carbon Finance. It is a system that puts tax on carbon emissions, allowing companies wishing to offset their GHG emissions to buy carbon credits earned from sustainable organizations and their projects. Carbon finance varies from green finance as it is focused towards carbon credits and reducing CO_2 emissions.The increasing environmental degradation has converged the focus towards clean energy investments as a path to attain climate-resilient economy. The convergence of economies towards pacts like Paris Agreement, COP27 and Kyoto protocols provide a reassurance that world is committed towards the attainment of environmental sustainability and climate change mitigation.

At first, green bonds were introduced in 2007 by European Investment Bank, to channel the investments towards a sustainable path in order to deal with environmental challenges.

But the growing popularity of green investments among investors and their better performance than traditional financial assets, several specialized investment options have been introduced which not only provide better returns but also fulfill the green and sustainable objectives of investors (Naeem et al., 2022).

A sharp increase in green investments could be noticed from $11 billion in 2013 to $350 billion in 2020 (Climate Bonds Initiative, 2020) providing the empirical evidence for effectiveness and scope of environment friendly investments.

The green investments have shown more than 100% growth and are expected to account for a quarter of global assets by the end of 2025. As a result of increasing trend of green and sustainable investments for portfolio diversification, research based upon their implications on asset pricing is also growing rapidly (Bolton & Kacperczyk, 2021).

Green bonds and other sustainable investments have been studied extensively with various financial and commodity markets to check their ability to absorb shocks and respond to market uncertainties (Marshall et al., 2021; Saeed et al., 2021; Le et al., 2021). However, only few studies solely focus on the connectedness and portfolio diversification benefits of sustainable and green investments (Iqbal et al., 2022).

Based on the importance of green finance as an emerging domain of finance, it is inevitable to explore its significance by covering all aspects. Hence, this study is categorized into two phases:

First, this study explores the impact of green finance on environmental sustainability and helping combat climate mitigation in detail.

Second phase explores green finance as an investment vehicle by examining its, also compares green finance with Islamic and sustainable investments to analyze their diversification benefits.

1.2 Green Finance and Environmental Sustainability

A smooth energy transition toward sustainability requires increasing clean energy investments (UNEP, 2022). Hence green finance has been introduced, which emphasizes on efficient resource allocation and environmental sustainability along with efficient investments to reduce climate risk as well as investment risk (Nawaz et al., 2021). Compared to conventional finance options, green finance focuses on environmental sustainability by emphasizing the effective usage of resources (Zhou et al., 2020). The literature available on environmental sustainability has primarily focused on time series data or panel data analysis of countries clubbed together on the basis of economic development or regions (Chin et al., 2022; Huang & Chen, 2022).

Limited studies focus on the global effect of green finance, environmental regulations, and renewable energy on the environmental sustainability. This study contributes to the existing literature in several ways. Initially, it creates and uses a green finance index for the analysis of panel dataset comprising 70 countries pledged to the NDCs, whereas previous studies have either created a country-specific index (Zhou et al., 2020; Lan et al., 2023) or did analysis on a global dataset using a single determinant of green finance.

Secondly, this study adds a new orientation to the variable of environmental regulations by using NDC policy as a determinant of policy regulations.NDCs are the policy mechanism provided by Paris Agreement which specifies the countries to limit their greenhouse gas emissions.These policies aim to help countries in addressing the issue of climatic change by reducing harmful emissions and by adapting to the impacts of climatic change.

Each country has to maintain and communicate their NDC action plan every five years to the UNFCCC.NDCs provide an efficient mechanism for the countries to upgrade their policies and action plans in every domain field such as indutries, agriculture and renewable energy generation.Prior research on environmental regulations has used country-specific regulations for analysis. Dogan et al. (2022a) used Kyoto protocols as an indicator of environmental regulations for a panel dataset focusing on the importance of such pledges. But limited research analyzes the impact of NDC policies on green finance and environmental sustainability using a dataset country which are selected on the basis of these policies.

Finally, this study examines the Environmental Kuznets Curve (EKC) hypothesis for the panel dataset of 70 countries with the addition of green finance as a variable. EKC has been extensively studied in various countries and regions with different economic and environmental variables (Farooq et al., 2022), but its validity in the presence of several green finance indicators joined as an index has not been examined in prior studies, hence, creating a gap. This study includes the green finance index to analyze its importance towards environmental sustainability in the EKC fitting, providing a new dimension for future studies.

1.3 Green Finance as Diversifier among Islamic and Sustainable Investments

The increasing environmental degradation has converged the focus towards clean energy investments as a path to attain climate-resilient economy. The convergence of economies towards pacts like Paris Agreement, COP27 and Kyoto protocols provide a reassurance that world is committed towards the attainment of environmental sustainability and climate change mitigation. At first, green bonds were introduced in 2007 by European Investment Bank (EIB), to channel the investments towards a sustainable path in order to deal with environmental challenges.

But the growing popularity of green investments among investors and their better performance as compared to the traditional financial assets, several specialized investment options have been introduced.Which not only provide better returns but also fulfill the green and sustainable objectives of investors (Naeem et al., 2022).

A sharp increase in green investments from $11billion in 2013 to $350 billion in 2020 is a noticeable change (Climate Bonds Initiative,2020) providing the empirical evidence for effectiveness and scope of environment friendly investments. This shows that green investments have shown more than 100% growth and are expected to account for a quarter of global assets by the end of 2025. As a result of increasing trend of green and sustainable investments for portfolio diversification, research based upon their implications on asset pricing is also growing rapidly (Bolton & Kacperczyk, 2021).

Green bonds and other sustainable investments have been studied extensively with various financial and commodity markets to check their ability to absorb shocks and respond to market uncertainties (Marshall et al., 2021; Saeed et al., 2021; Le et al., 2021). However, there are few studies that focus entirely on the connectedness and portfolio diversification benefits of sustainable and green investments (Iqbal et al., 2022).

Keeping in view the growing trend and better performance of green investments, sustainable investments and Islamic investments as compared to the conventional investment markets, extensive studies must be conducted to analyze their connectedness and diversification benefits. As the primary goal of investors is not only environmental protection but also to gain returns on investment via portfolio diversification (Mazzarisi et al., 2020).

Hence it is imperative to investigate how these green, sustainable and Islamic investment options are connected to each other and to answer the question whether they provide diversification benefits against each other or not. Therefore, given the limited research that solely focuses on the connectedness of green finance with respect to other environment friendly investment options such as ,sustainable and Islamic investments, there is a need to examine their diversification benefits. This study adds to the existing literature on connectedness in the following ways.

First, it investigates the connectedness of green bonds, sustainable investments and Islamic investments exclusively to analyze their diversification benefits, which has not been extensively done before. These investment options have been studied with other asset classes such as cryptocurrencies (Naeem & Karim, 2021; Bariviera & Merediz-Sola, 2021; Yousaf et al., 2023; Le et al., 2021), renewable energy (Yousaf et al., 2022; Tiwari et al., 2022; Liu et al., 2021a), conventional and commodity markets (Reboredo & Ugolini, 2020; Nguyen et al., 2021). But exclusive research investigating the connectedness among these green and sustainable investment options is limited.Second, this study considers extensive data of daily observations from 2013 till 2022 which will give a broader picture of dynamic connectedness pre-covid, post covid and during covid as well as during 2015-2016 oil crises. Also, the analysis is done in three variations i.e. full sample, pre-COVID and during COVID to get the better insight of pandemic situations on asset connectedness. The results will provide ample evidence to debate upon connectedness the response to shocks during global events and economic downturns as mentioned above.

Finally, this study explains the dynamic spillover and connectedness among green finance, sustainable investments and Islamic investments to confirm that although these options share a same theme of environmental sustainability but, whether their reaction to market shocks is different and can they provide diversification benefits among each other or not.

Additionally, this study captures the return spillovers among green bonds and other assets in the time varying net transmitter/recipient pattern. The results provide positive practical implications that could be helpful for policy makers and future investors regarding optimal and environment friendly portfolio allocations.

1.4 Problem Statement

The effect of greenhouse gas emissions on environmental quality cannot be ignored.The society at large is facing challenges regarding sustainability due to climatic changes. Especially environmental degradation have caused a buzz in all domains of life and finance in no exception.Hence it is vital to study the impact of all the financial activities on climate.

It is time to study and evolve such financial instruments that benefits stakeholders, society at large being one of them.The severity of climatic issue needs the investors to be more vigilant while investing into projects or markets to choose environment friendly alternatives. Green finance has emerged as a breath of fresh air with the to address the issue of climate change without effecting the return on investments. This study extensively analyses the role of green finance as a climate mitigator and as an investment option.

Findings of this study will supplement the body of knowledge and provide practical implications to help the researchers, policymakers and stakeholders understand the green finance and its role in environmental sustainability extensively. It will also help the investors in portfolio diversification to optimize their returns by investing in green instruments.

Therefore, saving the planet from environmental degradation and earning better returns using green finance instruments will provide a win-win situation. Similarly, the findings could be helpful for policy makers, company managers,individual investors and stock market administrators to understand the value addition by green instruments towards stakeholders.

1.5 Research Questions

This research will answer the following questions:

Research Question 1

Is green finance capable of improving environmental sustainability?

Research Question 2

Does carbon finance improve the environmental sustainability?

Research Question 3

What is the impact of renewable energy on environmental sustainability?

Research Question 4

What is the role of environmental regulations in improving environmental sustainability?

Research Question 5

Does green finance help in the augmentation of EKC curve?

Research Question 6

Does connectedness exist between green finance and other socially responsible asset classes?

Research Question 7

Whether green finance provides diversification benefits to socially responsible investors and investors of Islamic investments?

1.6 Research Objectives for this Study

Objectives of the study are as follows:

Research objective 1

To construct global green finance development index to study the impact of green finance on environmental sustainability.

Research objective 2

To examine if green finance makes any impact on environmental sustainability.

Research objective 3

To analyze the effect of carbon finance on environmental sustainability.

Research objective 4

To examine if environmental regulations make any impact on environmental sustainability.

Research objective 5

To explore the effect of green finance on EKC curve.

Research objective 6

To study the connectedness among green finance and various environment friendly asset classes.

Research objective 7

To explore the risk diversification among green finance, Islamic finance and socially responsible finance.

1.7 Contribution of the Study

This study aims to contribute in the domain of green finance in the following aspects: At first, this study theoretically analyzes the financial ecosystems and the need to incorporate environmental sustainability in finance. Secondly, it aims to comprehensively analyze if green finance can help in improving environmental sustainability and finally examines the role of green finance as an investment vehicle.

The first innovation in this study is the integration of environmental sustainability and green finance into a unified system and formulation of green finance index (GFI) using green securities, green investment and green credit. The index would be formed using principal component analysis (PCA).

Another contribution is the use of green finance index (GFG) to study and environmental sustainability at global level. Previously, only green finance has been used to study environmental performance (Taghizadeh-Hesary & Yoshino, 2019; Gianfrate & Peri, 2019; Zhao et al., 2021) but no significant research is available which uses a unified system including various types of green finance. Zhou et al. (2020) created similar index to study economic and environmental development in China but no significant literature is available where such index is used for a global analysis. This study adds to previous research by using a unified index comprising of various green finance types rather than green bonds separately to study environmental sustainability.

Another important contribution is the study of EKC curve with respect to green finance. As per EKC theory (Grossman & Krueger, 1991), an inverse relationship exists between economic development and environmental degradation. This study proposes to study the shape of EKC curve for different economies of the world and analyze if green finance has an impact on its shape i.e., whether green finance helps in reducing harmfull emissions or not.

This study further extends the research on environmental sustainability and explore the environmental regulations' impact on environmental sustainability. Several environmental policies and regulations have been introduced globally to ensure environmental sustainability. United Nation's Sustainable Development Goals (SDGs) from (2015-2030) focus on climate along with other sustainable factors as water, energy, urbanization, transport, oceans, science and technology to make this earth a better place for future.

The Paris Agreement signed by different countries of the world plans to limit the average global temperature rise to be below 20°C (International Energy Agency, 2018) is one such agreement which ensures climate sustainability. Further Paris agreement has introduced country specific pledges i.e. Nationally determined contributions (NDCs) for the year 2020 onward to demonstrate the progress towards greenhouse emission reduction (GHGs) and sustainable development. This study proposes to examine the overall impact of introduction of these NDC policies towards CO_2 emission reduction globally.

The second phase of this study focuses on green finance as an investment vehicle. As the scope for environment friendly investments in financial markets is growing, the analysis of relationship among subsectors of green financial markets is very important. Various studies have been conducted to confirm green bonds' connectedness with various asset classes (Hachenberg & Schiereck, 2018; Reboredo et al., 2017; Reboredo, 2018) but working on green equity is very limited. This study proposes to extend the literature by focusing on green finance to study connectedness and spillover with different asset classes.

Finally, this study analyses the relationship of green finance with Islamic finance and socially responsible finance. As the basic theme behind green finance, socially responsible finance and Islamic finance is same and they have similarities among them. For instance, green finance focuses on activities that produce better environmental outcome, socially responsible finance ensures environmental sustainability by focusing on ethical and socially beneficial investments.

On the other hand Islamic finance focuses on avoiding investments that deal with interest and supports businesses which have a linkage mechanism between financial transactions and an underlying real economy activity (Ali et al., 2021). Hence this study confirms if these instruments behave similarly or they act as predator towards each other.

1.8 Organization of the Study

This study examines the role of green finance in two dimensions: (a) its impact on environmental sustainability (b) the spillover between green finance and other asset classes, specifically socially responsible investments, Islamic investments and traditional safe havens. The study comprises of extensive time period incorporating normal time, 2015-16 oil crises, pre-COVID and post-COVID time. This study has been structured as follows:

Chapter 1 comprises of introduction. Chapter 2 discusses the theoretical background and overview of literature review. Chapter 3 provides the data and methodology used during empirical research. Chapter 4 consists of the empirical results of the study. Finally, Chapter 5 briefly concludes the whole discussion also providing future orientation, policy implications and limitations of the study.

Chapter 2

Theoretical Background and Literature Review

This chapter covers the theoretical and conceptual framework done to formulate a link between green finance, environmental sustainability and investment. Following literature is used to explain the theoretical linkages between the two aspects of green finance.

(a) Green finance and its impact on environmental sustainability

(b) Environmental Kuznets Curve and green finance

(c) Green finance as diversifying an investment vehicle

The linkage between environmental sustainability and green finance is explained by stakeholder theory as society is one of the key stakeholders in any business and economic activity.The main reason of massive environmental degradation is ignorance of society at large as a key stakeholder.

Whereas, the role of green finance as portfolio diversifier is explained under the modern portfolio theory.The main aim of investors is maximizing their profits at a certain level of risk they want to bear.The inclusion of environmental sustainability alongwith positive returns is a value addition for investors and society as well.Both of these theories have been extensively explained with context to the methodology and scheme of this study in detail further.

2.1 Impact of Green Finance on Environmental Sustainability

Freeman (2010) presented the stakeholder theory which proposes that companies have the moral obligation to not only concentrate on the interest of shareholders but all the stakeholders. It explains that companies must not aim for profit maximization only but their focus should take into consideration all the social, environmental and ethical aspects of their business processes. Stakeholder theory suggests that an organization must be accountable for all of its stakeholders such as suppliers, customers, shareholders and society at large.

One of the key characteristics of stakeholder theory is that it promotes the socially responsible and environmentally friendly approaches to businesses and investments. Those companies which adapt such socially and ethically sustainable business practices are likely to bring a positive impact on society. Being socially responsible in business practices not only benefits the society but it also beneficial for the organization. Because companies that are seen as socially responsible and environment friendly are often more attractive to customers, hence improving the financial performance of the companies in the long run.

Stakeholder theory has been applied in several studies focusing on financial investments and stakeholder orientation. Pandey et al. (2021) concluded that companies which focus more on stakeholders have tendency to attract more investors. Similarly, Ali et al. (2020) found that the investors are likely to invest in the companies which have strong stakeholder orientation because they are perceived to be socially responsible. The companies which have higher orientation towards stakeholders show better return on assets and return on equity (Feng et al., 2022).

Available literature supports the application of stakeholder theory in the financial performance perspective of the companies. But the impact of green finance, carbon finance and renewable energy for the environmental sustainability is an emerging area which needs to be extensively explored.

Severity of climate change issue has inclined policymakers' and investors' interests towards environmentally sustainable and friendly investments. Various environmentally friendly financial instruments like carbon finance, green equity and green bond are introduced to ensure environmentally friendly economic activities and they are becoming more popular among investors.

Green Bond Principles (GBP) (International Capital Market Association, 2022) defined green bonds as "any type of bond instrument where the proceeds will be exclusively applied to finance or refinance, in part or in full, new and or existing eligible Green Projects." Like conventional bonds, green bonds serve as a fixed income debt instrument but they differ in a way from conventional bonds as they raise the investments which result in greenhouse gases (GHG) emissions reduction (Tolliver et al., 2020).

There is an evident spike in the renewable energy sector globally as they have increased from less than USD 50 billion in year 2004 to almost USD 300 billion in recent years (Bloomberg, 2019). With the growth of financial markets for environmentally friendly investments, studying the relationship between green financial markets and other financial instruments becomes inevitable. This helps investors to identify if green financial instruments are useful diversification tools. This study explores green finance in the following aspects.

(a) Analyzing green finance and its objective to improve environmental sustainability and reduce CO_2 emissions. Examining the effect of environmental regulations and policies on environmental sustainability. The role of green finance in environmental Kuznets curve to reduce environmental degradation

(b) Analyzing the role of green finance as an investment vehicle. The primary goal of investors is to gain returns on their investments; hence it is a vital to analyze the diversification benefits provided by green finance.

2.1.1 Green Finance and Environmental Sustainability

Green Finance is a broad term, it could be referred to those investment options which focus on the projects that are sustainable, financial products that are environmentally friendly. It also refers to attaining other environmental objective via investments such as climate mitigation, greenhouse gases (GHG) control etc. It attains the goals by directing the financial flows towards environment friendly investments (Höhne et al., 2015). As per United Nations Environment Program (UNEP), the role of green finance is to increase the financial flow from areas such as micro-credit financing, banking, investment from private and public organizations towards environmentally friendly and sustainable options.

As compared to standard finance, green finance focuses on protecting the environment and optimized use of resources. Green finance is an investment vehicle which combines the environmental sustainability and financial interests of the investors (Wang and Zhi 2016). Similarly, Wang et al. (2019) found that green finance focuses on the two domains i.e. green benefits and financial benefits, and proposed that while making financing and investment decisions their potential environmental impacts should be considered.

In 2015, 178 countries signed the Paris Agreement to collectively address the global problem of climatic change. The severity of climatic change is alarming as the potential rise in temperatures by 2030 is expected to be around 2.8°C (UNEP, 2022). According to the report by International Energy Agency (2014), 53 trillion dollars will be required by 2035 to limit the rise in temperature up to 2°C.

The recent innovations in financial instruments and the introduction of environmentally friendly financial products have a substantial impact on several facets of society hence promoting environmental sustainability with the utilization of financial funds (Scholtens, 2017; Galaz et al., 2015). Climate risk is actually the investment risk for the investors, and green finance is a solution to deal with climate risk as well as to improve environmental sustainability (Nawaz et al., 2021). The threats of climatic change could be avoided by using green finance as a source of investment (Zhou et al., 2021).

Several studies have been conducted to analyze the role of green finance in supporting environmental sustainability such as Gianfrate and Peri (2019) propose that carbon reduction targets could be achieved by mobilizing financial resources via green bonds. Glomsrod and Wei (2018) confirm that the efficient use of green financial products as green bonds, 4.7 Gt of carbon dioxide emissions can be avoided by 2030.

Most of the research focuses on environmental sustainability by analyzing financial development independently. For instance, Saidi (2020) found that factors such as urbanization and financial development effect the CO_2 emissions. Muhammad (2019) studied the MENA countries and found a positive impact of financial development and energy consumption. Ekwueme and Zoaka (2020) also analyzed the effect of financial development and utilization of energy on CO_2 emissions.

Green finance in another strand has been extensively studied with various other variables. Wang et al., (2020) examines the reaction of stock market towards green bond issuance.

The study highlights the role of bond investors, issuers and underwriters in determining the green bond premium. The study conclude that market react positively towards green bonds' issuance. Similarly, Flammer (2020) also confirm that investors respond positively towards the news of green bond issuance, also the positive response is stronger if the announcement is made first time. These studies confirm that investors are attracted towards green investments and green bonds.

Madaleno et al. (2022) investigate the impact of clean and green investments on the environmental protection by analyzing the causal relationship among green finance, clean energy investments, green technology and environmental sustainability. They use data from 2014 to 2021 and apply granger causality test. The results concluded the occurrence of bidirectional causalities among variable except some detachments during Covid-19 outbreak. Hence confirming the need for promoting green finance in order to protect the environment.

Khan et al. (2022a) examines if green finance actually helps in decreasing the ecological footprint in 26 Asian economies and conclude that green finance shows a significant impact on economic growth and reduction in ecological footprint of sample countries.

Similarly, Sharif et al. (2022) study the green finance and green innovation effect on creating sustainable environment. The study uses empirical data of G7 countries from 1995 -2019 and employs ARDL for analysis. The findings suggest that in order to meet United Nation's sustainable development goals, the G7 must employ green investing options as it helps in reduction of harmful gas emissions.

Ma et al. (2023) examines the link between green finance, environmental sustainability, renewable investments and green economic activities. The data is used from 2010 to 2020 for G-20 countries and quantile regression model is applied. The study conclude that the effects of green finance are different according to the level of economic development of the country.

Those regions which have less or not efficiently developed capital markets witness a boost in environmental performance due to the initiation of green finance, whereas those countries which are developing or developed a negative effect is noticed on green product innovation.

Accelerating the transition of economy towards green finance and renewable investments is one way of dealing with climate mitigation. The growing concerns over escalated rated of CO_2 emissions and greenhouse gas emissions have let the focus of research in this orientation. Zhao et al. (2023) examines in depth the effect of green growth in CO_2 emissions reduction in China.

The study uses provincial data to analyze the regional heterogeneity for the time period 2004 to 2018. The results provide evidence that green growth has been significantly effective for China's emissions reductions.

Secondly, the regional heterogeneity has been observed indicating that the CO_2 reduction is not same in whole country but only central and western regions succeeded in CO_2 emissions. Furthermore, the eastern and central regions show negative effects of green growth in the form of increased emissions.

Most of the studies focusing on green finance and environmental sustainability have focused on limited dataset. Further, the measures used to analyze the variable of green finance have been been extensively developed.

Zhou et al. (2020) formulated a green finance development index for 30 provinces of China and examined the impact on economic development and environmental performance showing that green finance improves the environment also the effect of green finance on environmental sustainability differs with the levels of economic development.

But the literature examining the effect of such indices which incorporate various aspects of green finance on a larger dataset is missing. For the attainment of clean and green ecosystem, the analysis of green finance implications that green finance can provide at a global level is very important.

This study tries to explore this understudied domain and provide empirical evidence for future implications and resources planning.

Based on the above findings, this study aims to construct green finance index using data of 70 countries to study the combined effect of several green financial products on environmental sustainability at global level and hypothesizes:

H1: Green finance positively affects environmental sustainability.

2.1.2 Renewable Energy and Environmental Sustainability

The most important issue for the last few decades is global warming as the after effects are quite intense. The economic growth and industrialization on one hand have led the mankind to experience new avenues for growth and progression the other hand all the industrialization has used natural resources, labor and capital resources as well (Owusu and Asumadu, 2016).

This competition for natural and human resources has shown some serious consequences in the form of exhaustion of resources. As a result, environmental degradation could be witnessed globally.The increased production of greenhouse gases (GHG), such as, CO_2 emissions, methane, Sulphur dioxide due to increased power generated industrial activities has caused the global temperature to increase by 1.5^{o}C (UNFCCC).

The threatening environmental situation have led researchers and policy makers to find out ways of combating the issue of environmental sustainability and CO_2 reduction. The severity of climate mitigation caused the formation of several international regulatory bodies such as Kyoto protocol, Conference of parties, United Nations Framework Convention on Climate Change and Paris agreement etc.

Researchers have investigated various dynamics which could help in mitigating the environmental degradation and use of renewable energy sources is on such area. Sorensen (2004) explains that renewable energy is characterized as a type of energy source that could be replenished and reused such as wind energy, water, sunlight, geothermal heat. Renewable energy sources are different from standard energy sources such as fossil fuels as they could not be replenished once exhausted.

Hence leading towards environmental degradation. Renewable energy sources on the other hands could be replenished and reused. Due to these attributes of renewable energy, they could help in reducing environmental damage be contributing less towards environmental degradation. Due to this reason that in recent years, a strand of research on environmental sustainability focuses on renewable energy as well.Several studies have examined the role of renewable energy, green finance and carbon finance in supporting environmental sustainability.

Most of the research focuses on environmental sustainability by analyzing financial development independently (Saidi, 2020; Muhammad, 2019; Ekwueme & Zoaka, 2020), while green finance and renewable energy have been mostly studied in relationship with economic efficiency (Yang et al., 2021; Zhou et al., 2022a; Munitlak-Ivanovic et al., 2017; Bei & Wang, 2023) reporting significant results.

Yang (2022) examines the effect of renewable energy in G7 countries and finds it helpful in preserving the environment and reversing the ecological footprint. Chu and Le (2022) studies the effects of ecological footprint, economic policies, and renewable energy on the environmental sustainability of G7 countries and found their significant impact, also confirming the presence of EKC.

Balsalobre-Lorente et al. (2018) studies the directional causality among resources rent, education and financial development using vector error corrections model (VECM) for the time period 1960-2016 and conclude that a positive and significant relationship is present between resources rent and financial development.Nguyen and Kakinaka (2019) analyze the relationship between CO_2 emissions and renewable energy in 107 countries.

Panel cointegration method is employed for the time period 1990 to 2013 to examine the relationship. The results depict that renewable energy consumption has different impact on emission reduction depending on level of income of the countries. For low-income countries, renewable energy helps in decreasing the CO_2 emissions, whereas, the high-income countries, renewable energy consumption is negatively associated with emissions reductions.Khezri et al. (2022) examines the effect of renewable energy on CO_2 emissions in the sample data of 29 Asia Pacific countries. The study uses panel data from 2000-2018 for empirical analysis and concludes that renewable energy such as wind and solar energy help in reducing emissions in less economically developed countries, while economically developed countries show a scale effect in usage of renewable energy and hence reduction in harmful emissions.

In another study, Mirziyoyeva and Salahodjaev (2022) employs the GMM methodology for the time period 2000-2015 and examine the effect of renewable energy on environmental sustainability in 50 countries and provide the result are in accordance with the existing literature proving that renewable energy helps in reducing harmful emissions. The results suggest that 1% increase in renewable energy results in 0.98% decrease in CO_2 emissions for the sample data.

The global concern to reduce harmful emissions has created a spike in the research in this domain, hence researchers are examining various strands if variables that could be helpful in mitigating the environmental risk. Renewable energy has been studied with several other variable to analyze its impact in several datasets. Such as Jamil et al. (2022) employs dynamic ordinary least square (DOLS) and fully modified ordinary least square (FMOLS) from 1990-2019 in G-20 countries and compare renewable energy, trade openness, remittance, GDP and financial development.

The findings show that environmental degradation is positively associated with economic growth, financial development and remittances. Whereas, trade openness does not show any significant impact, but renewable energy shows a positive effect in recuing degradation in the form of CO_2 emissions reduction. Hence proving that renewable energy could be a better alternative to fossil fuels and traditional energy consumption options.

The attainment of SDGs is one of the primary focus of leading economies of the world. Policy makers and researchers are focusing to provide such policies which could help in attainment of SDGs in the form of reduced pollution and decrease in harmful emissions.

Converging towards renewable energy sources could be an efficient way to attain this goal (Wang et al., 2022). Xu et al. (2022) provides policy implications on renewable energy consumption by analyzing the non-linear and asymmetric effect of renewable energy consumption and financial development on CO_2 emissions reduction.The study applies non-linear Autoregressive distributed lag (NARDL) and two-stage least square (2SLS) methods on G-7 countries from 1986-2019. The results provide policy implications not only for the dataset but other countries as well.

Suki et al. (2022) investigates the relationship between ecological footprint, CO_2 emissions, renewable energy and technological innovation in Malaysia. The results confirm the positive and significant impact of ecological footprint and renewable energy in reducing environmental degradation. Further, the study also confirms the presence of inverted U-shaped EKC curve in Malaysia.

Li et al. (2022a) analyzes the variables of renewable energy, green finance, urbanization, and environmental pollution in MINT economies for the period 1990-2020 using the CS-ARDL approach to conclude their significant impact on sustainability.

Zhang et al. (2022a) examines the effect of technological innovation, green finance, and renewable energy on environmental sustainability in G20 countries for the period 2008-2018 and confirm that these variables cause a reduction in CO_2 emissions.

The above literature confirms the positive and significant effect on reducing harmful emissions and environmental degradation in different data setting. The available literature provide evidence to analyze the role of renewable energy in detail towards maintaining environmental sustainability and reducing environmental degradation.

Hence it is hypothesized:

H2: Renewable energy positively affects environmental sustainability.

2.1.3 Carbon Finance and Environmental Sustainability

The international panel on climate change (IPCC) in a recent report of 2021 has evaluated the global progress towards the climate mitigation and stated that the progress is very slow.

Greenhouse gas emissions (GHG) has been rising although at a slower pace and to slow down the pace of temperature rise of our planet; we need to control GHG emissions. As per NDCs, developing countries need to raise up-to US $6trillion to finance their climate mitigation goals. This amount could cater only half of the climate goals (UNDP). Hence, availability of investment is one of the important factors to fight climate damage.

One way of investing and financing the climate change transformation could be the use of carbon finance. Carbon finance refers to those strategies and mechanisms which put incentives on the reduction of Greenhouse gas emissions (GHG), specifically CO_2 emissions. The basic principle behind the operationalization of carbon finance is that reducing harmful emissions has an economic value associated to it, and the aim is to encourage institutions and businesses to adopt sustainable practices by assigning cost to these harmful emissions.

Carbon finance could be implemented in two ways. In the form of "carbon" taxes or as carbon markets emissions trading system. The taxes directly imposed by the government on the harmful emissions are the carbon taxes. The basic idea behind carbon taxes is that the governed put a price on the harmful emissions. The tax could be applied in two ways. a) identifying a specific tax rate for the CO_2 emissions b) by putting a tax on the carbon content of the non-renewable fuels or fossil fuels.

The second and widely implemented way is the emissions trading systems (ETS) or carbon markets. The core idea upon which carbon finance is established is the development of markets for carbon credits or "carbon markets". The core purpose of these carbon markets is the trading of carbon credits. In carbon markets, companies or individuals could buy carbon credits as a compensation of their greenhouse gas emissions from those entities who have reduced or eliminated the harmful gas emissions (UNDP). These carbon credits are sometimes referred to as emissions permits as well. The carbon credits are a quantified measure of reduction in greenhouse gas emissions from the environment. One tradeable carbon credit is equal to reduction in one metric ton of CO_2 emissions reduction or other greenhouse gas reduction.

To better understand the potential benefits and effect of carbon finance, it is important to understand its mechanism. First step is emissions measurement which is executed by establishing a baseline to determine the initial emissions' value of any country or institution. Once the actual or initial emissions are noted, the next step is to set an emission reduction target. The target is based upon any international agreement such as Paris agreement, Kyoto protocols etc which is observed by a country or institutions abide by. These targets define the level of emissions reductions that needs to be achieved during a specific period of time.

After the threshold of limiting emissions is set, the next step is the initiation of such projects or initiatives that would help in attaining the goals of reducing GHG. This is the phase where economies and companies strategize their action plans and make a shift from fossil fuel to renewable sources, plan and implement energy efficient processes to cope up with climate mitigation goals. The next step is the verification of action plans.

A third party accredited by UNFCCC verifies the emission reduction projects and ensure their credibility and transparency. Once the verification is done, the country or organization is issued carbon credits based on the number of emissions that have been reduced in a specific time period. These carbon credits could be traded in the carbon markets and the buyers who want to offset their own emissions typically purchase these carbon credits to help sustainable projects and to meet their need of emissions reduction to reach their targets.

But the main agenda for buyers behind purchasing the carbon credits is offsetting their own emissions value by claiming the emission reduction represented by carbon credit as equivalent to their own hence neutralizing their carbon footprint.

The effect of greenhouse gas emissions on environmental sustainability cannot be ignored and financial markets are positioned with climatic change by enabling investments in carbon finance with the aim to limit carbon emissions (Bridge et al. 2020). There are various studies confirming the relationship of CO_2 emissions and financial development (Tolliver et al., 2020; Kanamura, 2020; Hammoudeh et al., 2020), but significant literature on carbon finance and environmental sustainability is lacking.

This study adds to the growing literature by analyzing the effect of carbon finance and green finance on environmental sustainability simultaneously.Carbon finance could be a helpful mechanism in achieving the net zero emissions goal by 2050 as number of countries and industries have converged towards the usage of carbon credits to limit the harmful emissions (World Bank, 2020) The importance of carbon finance is inevitable towards environmental sustainability (Leitao et al. (2021). The recent literature analyzes carbon finance using various determinants and in different strands showing significant results.

The focus on carbon finance research is bent towards CO_2 emissions allowances with various asset classes, for instance, (Hammoudeh et al. (2020) examines the time-varying relationship carbon allowances, green bonds and conventional asset classes for the period of 2014-2020.The study employs granger causality test to determine the relationship among the asset classes and no specific directional causality is reported.

Wang and Guo (2018) examine the asymmetric spillover between carbon and oil markets and conclude that oil markets such as WTI, Brent oil and natural gas has spillover effect on the system and carbon markets.

Mohsin et al. (2021) develops a low carbon finance index to attract the direct and foreign investments in the low carbon energy sector. DEA methodology is used for the development of index and the results suggest that some countries have low index number than others indicating that developing countries need to comply and develop policies for carbon emission reductions.

Bridge et al. (2020) suggests that there is no single category that could adequately translate carbon into financial value across multiple forms of carbon finance. To consider diverse forms of carbon finance in mitigation processes, the study identifies four categories of carbon finance (natural capital investments, carbon credit markets, ecosystem services, low-carbon credit business) and discussed the processes through which carbon credits are translated to financial value.

Such research opens the door for future analysis on the actual performance of carbon finance as a mechanism for environmental sustainability.Gu et al. (2023) employs the VAR model to analyze the relationship between carbon finance and environmental regulations in China. The analyzes provide shot term and long-term implications. Results depict that environmental regulations do not have a significant impact on innovation and carbon finance in the short run, but the innovation could be enhanced in the presence of environmental regulations in the long-run.

Zhou et al.(2022a) examined the herding behavior in China's carbon market and the analysis do not report any herding behavior in the any of the 8 carbon markets in China. The occurrence of herding behavior is high when the markets are volatile, with low volatility in price fluctuations, chances of herding behavior are low.

Zhou et al.(2022b) examines the impact of carbon credit markets on the environmental sustainability in China. Data from 30 provinces is used from the time period 2000-2017 and DID approach is employed for the analyses. The results depict that the usage of carbon markets has helped in attaining energy efficiency but no significant results show that carbon finance helps in obtaining carbon emissions efficiency in the form of low CO_2 emissions in the long term.

Xu and Wu (2023) employ modern machine learning methods to study the integrated system of carbon and energy markets. The analysis simulates the results till 2030 and conclude that an efficient carbon-energy market mix could be very helpful in increasing GDP around 49%. The analysis shows promising results that by building an efficient combination of energy and carbon markets, countries could not only attain the optimal environmental performance but the economic benefits could also be achieved.

The above studies provide future orientation to further explore the impact of carbon finance and its role in achieving environmental sustainability. Hence, this study extensively analyzes carbon finance and its impact on environment and hypothesizes:

H3: Carbon finance positively affects environmental sustainability.

2.1.4 Environmental Regulations and Sustainability

Environmental regulations indicate effective regulatory measures to control pollution and ensure environmental protection. Green finance policies provide a win-win situation as they not only help in reducing harmful emissions but also escalate the green finances (Liu et al., 2019). Some scholars have supported the relationship between CO_2 emissions and environmental regulations, indicating that environmental regulations may help in reducing CO_2 emissions substantially (Hashmi & Alam, 2019), while several studies examine the relationship between eco-friendly regulations and climatic change (Tolliver et al., 2020; Abbas et al., 2021; Zhang et al., 2021; Liu et al., 2020) but, the existing literature on the policy, regulations, and green finance, apart from green bond-based investments, is limited (Tolliver et al., 2020).

Recently, CO_2 and other harmful emissions have been a great concern for environment. Extensive literature examines the impact of policies on renewable energy investments. The impact of environmental regulations on renewable energy and CO_2 emissions have been studied extensively. Van der Ploeg and Withagen (2012) suggests that renewable energy will become more affordable with the gradual of technological advancement. Similarly, Guo and Wang (2023) examined the relationship between environmental regulation and CO_2 emissions and found that environmental regulation inhibit excessive CO_2 emissions. The existing literature on the policy and regulations behind green bond-based investments is limited (Tolliver et al., 2020).

Muganyi et al. (2021) comprehensively analyzed the role of policies in implementing green finance in China by using panel data of 290 cities for the time period of 2011-2018.The study applies Semi-parametric Difference-in-Differences (SDID) approach for analysis and conclude that the introduction of policies related to green finance have led towards a significant reduction in industrial gas emissions. Zhang et al. (2021) examines the mediating role of green finance on economic growth and public spending in belt and road (BRI) region. Their results show a significant impact of green finance on economic growth.

As green bonds are issued under certification schemes to ensure that their proceeds are focused towards renewable energy and other similar investments conducive to Paris Agreement, UN SDGs, and IEA SDS outcomes, there is a need for empirical assessment and analyses of these policies. This study proposes to analyze the impact of nationally determined contributions (NDC) policy introduction on environmental sustainability.

The role of environmental regulations as a moderator has been examined previously in relation to other variables. Yang et al. (2021) analyzes the moderating role of ER on green innovation in China from 2008-2019 and find a positive impact. Zhao et al. (2019) study the role of environmental regulations and knowledge spillover as moderators of green economy in China for the period of 2012- 2016 and report the negative impact.

Dong et al. (2022) analyzed the moderating role of pollution fee as a determinant of regulations in the innovation-emission nexus across 30 provinces of China to find a significant effect. But the moderating role of environmental regulations, specifically NDCs between CO_2 emissions and green finance with a panel dataset is understudied in the literature.

Climate risk is actually the investment risk for the investors and green finance is a solution to deal with climate risk and improve environmental sustainability (Nawaz et al. 2021). The scientific evidences of climatic changes are so evident that the world is planning to act and avert it's the disastrous consequences. Hence several environmental goals and actions such as Paris Agreement, NDCs, COP26, MDGs, SDGs have been introduced to address environmental sustainability and improve environmental sustainability.

Green finance is a fundamental instrument to curb the threats of climatic change (Zhou et al., 2021). Zhou et al. (2021) analyzed the mediating moderating effect of green credit while studying the relation between bank financial performance and corporate social responsibility (CSR) and found a positive impact. Zhang et al. (2021) explored the mediating effect of green finance on public spending and green economic growth in Belt and Road Initiative (BRI) region and found a fluctuating green economic indicator.

Limited literature is available that analyses the role of green finance as a moderator between environmental regulations and environmental sustainability. Abbas et al. (2021) studied the moderating effect of renewable energy on the energy policy of China giving an orientation to further explore this dimension of green finance.

Also, the impact of environmental regulations in the form of international commitments such as Kyoto protocols and NDCs to reduce harmful emissions is understudied. Dogan et al. (2022a) uses Kyoto Protocols as a proxy for environmental regulations in G-7 countries.

Tzeremes et al. (2023) also study the energy transition in relation to Kyoto protocols giving a future direction to use such international policies as a measure of environmental regulations for future studies. Paris agreement has introduced country-specific pledges i.e. NDCs to demonstrate the progress towards greenhouse emission reduction (GHGs) and sustainability. The impact of these policies on environmental sustainability has not been examined earlier; hence, this study is the first to use them as a proxy for environmental regulations at a global level. On the basis of prior studies, we hypothesize:

H4: Environmental regulations act as a moderator between the relationship of green finance and environmental sustainability.

2.2 Environmental Kuznets Curve (EKC)

Grossman & Krueger (1991) proposed EKC hypothesis, which suggests the relationship between economic activity and environmental degradation. The theory suggests that as an economy develops, it goes through several phases with respect to environmental degradation.

Initially the state of economy worsens due to high level of environmental degradation but eventually the situation improves with the increase in the economic activity. EKC suggests three phases of environmental degradation and economic development.

1. The initial stage is identified by low-income levels or low economic development. In this phase the environmental degradation tends to be low due to low level of economic activity. As there is less industrialization in this stage hence the lower level of pollution and bi-products are products keeping the environmental degradation at a lower side.

2. The second stage comes when the economic activity starts rising. With the increase in development and income levels, the environmental degradation starts to increase rapidly in the form of increased pollution, energy consumption and resources consumption.

3. The final stage or decline in the environmental degradation starts after a certain level of economic development.This depicts that after the economy has

reached a specific maturity economically, the environmental damage starts decling.The possible reason for the decline in the environmental degradation could be environmental regulations, shift towards green and sustainable investments, technological advancements.

These stages of EKC form an inverted U-shape curve. The turning point of U-shaped curve could be reduced by the introduction of factors such as green finance, renewable energy in the EKC fitting (Zhou et al., 2020). This study investigates the effect of green finance in mitigating environmental degradation by positively affecting the EKC.

2.2.1 EKC Hypothesis and Green Finance

The debate on green finance cannot be complete without taking into consideration the factors that influence our daily lives and our environment. As per Grossman and Krueger (1995) "our lives are affected by the air we breathe, the water we drink, the beauty we observe in nature, and the diversity of species with which we come into contact."

This indicates that environmental sustainability holds a very important place in a healthy society. Hence, while discussing the implications of industrialization and economic growth on the society at large, the impact it holds on the environment cannot be ignored.

The effects of increased industrialization could be noticed in the form of resources exhaustion such as increase labor, fossil fuel energy consumption, increased deforestation, harmful gas emissions, water pollution etc.

As we celebrate the economic development of societies on one hand, we cannot ignore the drastic effects it brings on the mother nature in the form of environmental degradation.In the early 1990's, Grossman and Krueger (1991) introduced the relationship between economic development and environmental sustainability in the form of "Environmental Kuznets Curve".

As per EKC theory, an inverse relationship exists between environmental degradation and per capita GDP (Grossman & Krueger, 1991). This can be represented by the following quadratic function:

$$E_{i,t} = \alpha Y_{i,t} + \beta Y_{i,t}^2 + \gamma Z_{k,i,t} + c + \epsilon_{i,t} \tag{2.1}$$

Here $E_{i,t}$, $Y_{i,t}$, and $Z_{k,i,t}$, respectively, represent environmental sustainability indicators, economic development indicators, and control variables. α, β, and γ are coefficients, c denotes a constant term, and $\epsilon_{i,t}$ represents the error term.

EKC could hold different shapes on the basis of different functional forms. Such as:

a) $\beta_1 = \beta_2 = 0$; no association between economic growth and environmental degradation.

b) $\beta_1 > \beta_2 = 0$; Linear increase in economic growth-environmental degradation association.

c) $\beta_1 < \beta_2 = 0$; Linear decrease in economic growth-environmental degradation association.

d) $\beta_1 > \beta_2 < 0$; Inverted U-Shape economic growth-environmental degradation association curve.

e) $\beta_1 < \beta_2 > 0$; U-shaped economic growth-environmental degradation association curve.

f) $\beta_1 > \beta_2 < 0, \beta_3 > 0$; N-shape economic growth-environmental degradation association curve.

g) $\beta_1 < \beta_2 > 0, \beta_3 < 0$; Inverted N-shape economic growth-environmental degradation association curve.

For a valid U-shape EKC curve, the condition $\beta_1 > 0$ and $\beta_2 < 0$ should be met. Only under this condition, the inverted U-shape curve is valid, and the turning point for an inverted U-shape curve is calculated by $Y = \exp(-\beta_1/2\beta_2)$.

EKCs have different shapes in different regions due to the difference in population size, policies, economic and other factors. Some researchers suggest that a direct relation exists between CO_2 emissions and income (Omri, 2013; Shafik, 1994), a U-shaped (Omri, 2018; Apergis & Payne, 2009; Murshed & Dao, 2022) and some report an N-shaped curve (Onafowora and Owoye, 2014; Jahanger et al., 2023; Lan et al., 2023) or no linkage at all (Richmond & Kaufmann, 2006; Pata et al., 2022; Onifade, 2022). EKC has been supported in various regions such as China (Zhou et al., 202; Riti et al., 2017), the USA (Apergis & Payne, 2009; Alula & Oztturk, 2021).

Youssef et al. (2020) studies the EKC curve in Middle eastern and North American (MENA) countries. The study also analyzes financial development in relation to EKC. The results depict the presence of linear and non-linear relationship between environmental degradation and financial development. Also, presence of EKC is validated.

Weimin et al. (2022) analyzed the validity of EKC curve in the top nine economies by examining the effect of electricity consumption and globalization on CO_2 emissions and supporting the presence of EKC curve and unidirectionality among the variables. Han and Jun (2022) examine EKC curve of 141 countries by taking into consideration the climate mitigation effect and conclude that only increasing mitigation aid is not helpful in lowering emissions. Leal and Marques (2022) extensively reviewed the literature and identified several variables used in studies for environmental sustainability with respect to EKC.

Mehmood (2022) investigates the impact of renewable energy, economic activities, and globalization on CO_2 emissions in EKC context in four Asian countries, i.e., Pakistan, Bangladesh, India, and Sri Lanka, and recommend that these countries revise their policies to reduce harmful emissions. Lorente et al. (2023) examines the validity of EKC hypothesis in the presence of renewable energy, economic growth and natural resources for the extensive time period from 1985-2016.The results depict an N-shape curve between economic growth and environmental degradation. Whereas the renewable energy and natural resources are shown to impede environmental degradation.

In another strand of literature on EKC, financial inclusion has been studied in the EKC fitting. Usman et al. (2022) examines economic growth, renewable energy, globalization and financial inclusion to test the EKC hypothesis for South Asian countries. The data from 1990-2017 is used and CS-ARDL model is applied. The results depict a decrease in CO_2 emissions with the usage of renewable energy. Whereas, financial inclusion proves to be increasing the environmental degradation in the form of increased emissions.

Zaidi et al (2019) examine the dynamic relationship among harmful emissions, financial development and globalization under the framework of EKC. This study uses panel data of Asia Pacific Economic Corporation countries from 1990-2016. Westerlund cointegration technique is used to find the long-term cointegration and Dumitrescu and Hurlin causality analysis used to analyze the causality among variables.

The results support the EKC hypothesis, confirming that globalization and financial development help in reducing CO_2 emissions, whereas economic development has inverse relationship with harmful emissions. The causality analysis depicts that globalization directs and supports financial development and energy intensity. The results show the positive impact of financial inclusion in EKC setting paving way for the analysis of other factors in EKC fitting.

Gu et al (2023) includes the variables of green finance and green growth in the EKC analysis to observe their effect in declining harmful emissions. Other variables used are globalization, trade adjusted carbon emissions (CCO_2) and data is taken from 1990-2021 for the G-7 countries. The study uses quantile regression approach for the analysis and the results depict an increase in CCO_2 emissions with the increase in globalization, similarly, adverse effects of economic growth could be seen on degradation. The variables of green finance and green growth did not show any significant effect proposing that these variables are not yet completely developed. These findings provide future implications to extend the research of EKC by employing variables of green investments to practically analyze their share in helping climate mitigation.

Bei et al (2023) examines the role of green finance in the EKC setting in China for 2003-2003.The aim is to analyze the effect of Government adapted green finance practices on environmental degradation. The study employs Hensen Threshold regression model on economic growth, and industrial structure along with carbon emissions and green finance. The results indicate the presence of an N- shape curve.

Green finance proves to be significant in mitigating emission in the eastern regions of China, an inverted U-shape curve in the central region is analyzed which suggests the initially with introduction of green finance the emissions spiked but after a certain level they started decreasing. In the western region a weak relationship is reported.

Lan et al (2023) investigate the variable of green finance in the EKC fitting in China using a data of 30 provinces from 2000 to 2021. First, they calculate a green finance index for China ant the provincial level and later examine the non-linear relationship among economic activity, environmental degradation and green finance. The results show the existence of an N-shaped curve for the results of green finance and industrial pollution as a determinant of environmental degradation. The results suggest China's industries to upgrade their industries towards green solutions in order to decrease pollution and increased productivity creating a win-win situation.

The recent studies on EKC have shown a trend of addressing the issue of sustainability by including the variables that have been introduced with the purpose of climate mitigation. The relationship of environmental degradation and economic growth is well studied and extensive literature is available that uses various datasets (country specific, region-specific, growth segments, global economies, developed and under developed countries) in various time periods.

Researchers need to upgrade the research on EKC and change the focus of analysis to find the actual impact of these environment friendly investment options that are recently used globally. The available literature extensively analyzes EKC using several other indicators, but the significance of green finance towards EKC fitting is understudied, creating a gap in the literature. This study analyzes the EKC curve of 70 countries by considering the green finance index, along with other economic indicators, to test their effect on environmental degradation.

On the basis of above findings, we hypothesize:

H5: Green finance positively affects the EKC curve.

2.3 Modern Portfolio Theory

Modern Portfolio Theory (MPT), proposed by Markowitz (1952) and also known as the mean-variance theory, is extensively used to construct efficient portfolios for investment with the aim to provide maximum returns for a certain level of risk or to minimize the risk via portfolio diversification for a certain level of returns. The basis of Modern Portfolio Theory is diversification. By combining several asset classes into an optimized portfolio, investors can receive a better risk-return tradeoff as compared to the investments in the individual assets.

MPT mathematically operationalizes the diversification objectives of the investors by providing the opportunity to select such investment options, that bear the minimum level of risk for their desired return. Hence, the whole mechanism of portfolio diversification evolves around risk-return management (Omisore et al., 2012).

MPT has been used for portfolio diversification using traditional asset classes, but with the introduction of green finance and other sustainable investment options such as Socially responsible investments, carbon finance, renewable energy, Islamic finance etc, the orientation of portfolio diversification strategies needs to take a shift towards these environment friendly options.

With the emerging trend of green finance, the investors get a better and sustainable option of portfolio diversification (Khalfaoui et al., 2022). As the focus of green finance is long-term sustainability and resilience of the society. Hence by integrating green finance options in the portfolio as per MPT, the investors would not only get the diversification benefits but would also be contributing towards long-term sustainability of the environment.

This could also help investors to be better aware of the potential risks associated with climatic change and environmental degradation which would lead towards informed decision making in the long-term perspective. Therefore, creating a win-win situation for the investors, as they will meet their financial and sustainability goals by creating efficient diversified portfolios.

2.3.1 Dynamic Connectedness among Green Finance, Sustainable Investments and Islamic Investments

As per modern portfolio theory (MPT) Markowitz (1952), a diversified portfolio could help obtain market returns in connection to a certain level of market risk.

MPT basically quantifies the investors' objective of profit maximization via diversification into relatively less risky set of investments than a single asset. The literature on green bonds and green investments is growing due to the global concerns of climatic change and environmental sustainability and they are not only environment friendly investment options but also offer diversification benefits (Khalfaoui et al., 2022).

The portfolio diversification strategies of investors are dependent upon the connectivity of various financial instruments. As connectedness framework evolve over time; the investors change their strategies along with it. Green bonds have gained the attention of academicians and practitioners as a sustainable investment option for a diversified portfolio (Park et al., 2020; Huynh et al., 2020). Park et al. (2020) analyzes that unlike the volatility of equity, green bonds exhibit the asymmetric volatility phenomenon, and they sensitively act towards positive shock returns.

Pham (2016) studies green and common bonds and found that volatility clustering exists in these markets. Reboredo (2018) examines green bond, general stock, energy and bond markets and concludes that green bond can be an effective diversification tool for stock and energy markets. Reboredo & Ugolini (2020) examines the volatility between green bond and other assets and the results shows that green bond is under significant influences from the corporate and Treasury bond markets.

Recently, Huynh et al. (2020) and Le et al. (2021) emphasize that gold is a safe investment, and is useful as good hedger. The use of financial assets in the 4th industrial revolution different classes of technology stocks diversify portfolio has shown mixed results. Ahmed and Alhadab (2020) suggest that stocks of high-tech firms give greater returns in U.S. stock. Le et al. (2021) also confirm the hedging effect offered by tech stocks.

The growing trend of using green and sustainable investment in practical portfolio settings have triggered the research towards asset pricing implications of these investment options (Bolton & Kacperczyk, 2021). Existing literature focusing on investing implications of these investments show that green bonds are considered be to be a potential diversifier against various asset classes, such as commodities , conventional stocks (Reboredo et al., 2020; Nguyen et al., 2021; Ferrer et al., 2021), renewable investments, ESG investments and green equity markets (Dogan et al., 2022b; Lorente et al., 2023; Liu et al., 2021), cryptocurrencies and bitcoin (Naeem et al., 2021; Chatziantoniou et al., 2022; Hassan et al., 2022; Ul Haq et al., 2023). But the literature examining the connectedness of green bonds with other types of sustainable investments and their portfolio diversification characteristics against each other is very limited creating a room for further exploration.

Furthermore, the research orientation towards risk-return benefits and connectedness of Islamic securities against other asset classes have increased in the recent years (Bossman, 2021). Empirical studies have shown that Islamic based investments and securities are gaining considerable attention internationally for portfolio diversification, safe haven properties and hedging strategies (Bossman et al., 2022).

Several studies have examined the connectedness between Islamic investments i.e. Islamic stocks and conventional investments. Aloui et al. (2022) study the impact of announcement of global pandemic on Islamic and conventional security markets in China. Daily data from December 2019 till May 2020 is used and GJR-BARCH model is applied under dynamic conditional correlation (DCC). The results depict that the announcement of bad news such pandemic affect the volatilities in Islam and conventional stock markets.The findings depict that equity markets do not behave in the regular manner in crises situations such as pandemic. announcement of any new related to COVID is responded back to immediately by the investors, creating a volatile situation in markets.

Bahloul et al. (2021) also examine the relationship of Islamic and conventional stocks. The dynamic connectedness and volatilities are calculated from the daily data for time period 2007 till 2020 using Diebold and Yilmaz method. The study analyses the net connectedness, net-pairwise connectedness and net directional connectedness of Islamic and conventional assets. The results show conventional stocks transmit more shocks to the Islamic stocks.

Suleman et al., (2021) analyzes the asymmetric spillover among Islamic stock markets, crude oil, gold and silver markets by employing Diebold and Yilmaz (2012) method. The results show high spillovers from commodity markets to Islamic stocks. Asl et al. (2022) studies the dynamic connectedness between Islamic stocks and oil prices for seven major oil exporting countries. The results depict that Islamic stock market in Iran do not show connectedness with oil markets whereas the UAE and Saudi Arabia's Islamic stock market are the leader among all.

Similarly, the literature examining the risk-return behavior and connectedness among sustainable investments and traditional investments is growing. Saeed et al. (2021) study the connectedness among clean energy investments, crude oil, green bonds and ETF stocks. The results show asymmetric behavior depicting that connectedness vary with the time dynamics.

Zhang et al. (2022) study the spillover and connectedness among carbon finance, ESG stocks, renewable energy stocks, and green bonds. DCC-GARCH methodology is used analyze dynamic connectedness while, DCC-GARCH t-copulas is used to calculate weights and hedge ratios. The results show that carbon markets are the volatility transmitters while green bonds act as shock recipients.In the recent years green, sustainable and Islamic investments have gained popularity among policy makers, investors and stakeholders. However, very few have focused solely on the connectedness and portfolio diversification implications among ethical and sustainable investments (Iqbal et al., 2022). The objectives of green finance, sustainable investments and Islamic investments are quite similar, specifically Islamic investments and sustainable investments focus towards social welfare via ethics (Erragraguy et al., 2015). But the question arises that if these investments options share some similarities, then whether they provide diversification benefits against each other or not? The literature exploring the answer to this question is very limited (Yousaf et al., 2022).

Prior studies on market portfolios with various asset classes show that clean technology indexes outperform other classes in terms of returns and volatility (Ortas and Moneva, 2013) but green bonds have shown lower returns than traditional bonds (Hachenberg & Schiereck, 2018; Reboredo et al., 2017). Reboredo & Ugolini (2020) analyzed minimal correlation between green bonds, energy, and high-yield corporate bonds. These findings provide implications to formulate a diversified portfolio, which is consistent with the findings by Pham & Huynh (2020).

As the basic idea behind green finance, socially responsible finance and Islamic finance has a commonality i.e. environmental sustainability. They similarly focus on the investments with interests in social welfare and environmental sustainability. Islamic finance is a system based on values whereas socially responsible investment is a financial return-oriented approach which focuses on the integration of environmental, social and governance (ESG) data in financial analysis to support the greater welfare of the society and environment. Similarly green bonds' proceeds aim to finance environmentally sustainable and climate-friendly projects, such as renewable energy, green buildings etc. (Flammer, 2018).

In the limited literature available exploring solely green finance, sustainable investments and Islamic investments, Naeem et al. (2023) investigated the dynamic connectedness between sustainable and Islamic investments in nineteen countries and the results suggest a spike in connectedness in the period of crisis like COVID-19 and European debt crises. Similarly, Iqbal et al., (2022) investigated time and frequency spillover among global sustainable investments from 2005-2021. They examined high level of connectedness at intra-regional level in Asian countries. Also, the level of connectedness increases in situation of crises such as Covid-19.

Chatziantoniou et al., (2022) investigated dynamic integration among four environmental indices from 2008-2022 and concluded that total connectedness indices show heterogenous behavior over time and are economic event dependent. While some indices (S&P Green Bond Index and S&P Global Clean Energy) depicted net-recipient behavior in short and long term whereas MSCI Global Environment and Dow Jones Sustainability Index World indicated to be the net transmitters of shocks.

All of the abovementioned studies provide mixed results on the spillover and connectedness characteristics of green finance, sustainable finance and Shariah compliant investment suggesting further exploration of connectedness among these investment options. Also, limited studies explore the dynamic connectedness and portfolio diversification characteristics of green finance, sustainable investments and Shariah compliant investments among each other creating a gap in literature for further exploration.

In the climate resilient economic times, the need to explore the behavior of green and clean investments for return purposes is eminent. To make a decision between standard and green finance investments, the analysis of risk-return tradeoff is very important. Extensive literature analyses the standard finance options and their return benefits. But green and sustainable investments' diversification benefits are not extensively covered yet.

This study attempts to enhance investors' understanding of the green investments, sustainable investments and Islamic investments in terms of their dynamic connectedness and provide policy implications for future investments.

H6: There exists connectedness among green finance, sustainable finance and Islamic investments.

The above literature review extensively examines the avaible research in the domain of green finance and environmental sustainability. Also,extensive literature has been reviewed on the connectedness of green finance with sustainable and Islamic investments.On the basis of this review the global concern for climatic change and the dire need to find ways to combat this problem have been identified.These problem identifications have paved the way to analyze new domains towards attaining environmental sustainability as well as achieving financial gains through environment friendly investments.

2.4 Summary of Hypotheses

H1: Green finance positively affects environmental sustainability.

H2 Renewable energy positively affects environmental sustainability.

H3: Carbon finance positively affects environmental sustainability.

H4: Environmental regulations act as a moderator between the relationship of green finance and environmental sustainability.

H5: Green finance positively affects the EKC curve.

H6: There exists connectedness among green finance, sustainable finance and Islamic investments.

Chapter 3

Research Methodology

3.1 Data Description

The study analyses green finance in various aspects such as: impact of green finance on environmental sustainability and impact of green finance as an investment diversifying option. Data is collected for the period of 2012-2022 for all the variables examing impact on environmental sustainability and from 2013-2022 for exploring connectedness among variables.

The impact on environmental sustainability is examined on 70 countries, shown in Table 3.1. and the variables used in models are green finance index, environmental regulations, carbon finance, renewable energy, GDP per capita and CO_2 emissions. Similarly, to analyze the impact of green finance as a diversifying agent among sustainable investments, the variables of green bonds, clean energy stocks, sustainable investments and Islamic investments are used. All the variables and models are discussed in the following sections.

3.2 Green Finance and Environmental Sustainability

For the first phase of study, we examine the role of green finance, environmental regulations, renewable energy and carbon finance towards climate mitigation by analyzing their effect on CO_2 emissions reduction.

Table 3.1: Country Names and Codes

Country Name	**Country Code**	**Country Name**	**Country Code**	**Country Name**	**Country Code**
Australia	AUS	Germany	DEU	Nicaragua	NIC
Argentina	ARG	Greece	GRC	Norway	NOR
Austria	AUT	Ghana	GHA	Pakistan	PAK
Bangladesh	BGD	Guinea	GIN	Panama	PAN
Belarus	BLR	Honduras	HND	Peru	PER
Belgium	BEL	India	IND	Philippines	PHL
Bosnia and Herzegovina	BIH	Iceland	ISL	Poland	POL
Brazil	BRA	Indonesia	IDN	Romania	ROU
Bulgaria	BGR	Ireland	IRL	Rwanda	RWA
Canada	CAN	Israel	ISR	Serbia	SRB
Chad	TCD	Italy	ITA	South Africa	ZAF
Chile	CHL	Jamaica	JAM	Spain	ESP
China	CHN	Jordan	JOR	Sri Lanka	LKA
Costa Rica	CRI	Kenya	KEN	Sweden	SWE
Croatia	HRV	Latvia	LVA	Tanzania	TZA
Czech Republic	CZE	Lebanon	LBN	Thailand	THA
Denmark	DNK	Lithuania	LTU	Turkey	TUR

The explained variable is environmental sustainability (measured by CO_2 emissions reduction). CO_2 emissions data (metric tons per capita) is used for determining environmental sustainability of each country in panel dataset. The explanatory variables are green finance index, carbon finance, environmental regulations, renewable energy, and GDP.

Green finance index is formulated by employing 4 green indicators, including investments, securities, bonds, and carbon finance. S&P green bond (GB) index is used as global green bonds variable. WilderHill clean energy index for green securities(WCE), NASDAQ OMX Green Economy index family, i.e. (Green Building (GB), Clean Energy Focused (CE), Green Transportation (GT), and Global Water (GW) is used to measure green investments. Carbon emissions futures (CF) is used as a proxy for carbon finance. Renewable energy is measured as renewable energy consumption (% of total final energy consumption) for each country. Carbon emissions futures is used as an indicator of carbon finance. Environmental Regulations (ER) are presented by the nationally determined contributions

(NDC) policy adaptation. NDCs are policies to cut harmful emissions and adapt to climatic changes.

Each country that has signed Paris Agreement has to submit the NDC plan every five years. NDCs were adopted in 2015; hence this study takes it as a dummy variable, the value is 0 before the NDC policy introduction in 2015 and 1 afterward. The panel data is selected based on NDC policy, and those 70 countries are chosen that have agreed upon NDC policy for the period of 2012-2022, as done by Tolliver et al. (2020). The sources are shown in Table 3.2.

3.2.1 Constructing Green Finance Index (GFG)

Principal component analysis (PCA) has been used in this study to construct green finance index using a panel dataset of 70 countries. Previous studies primarily focus on a single dimension of green finance, whereas this index incorporates various aspects to comprehensively capture its effect.

Earlier, (Lan et al., 2023; Zhou et al., 2020) constructed country-specific indexes using different green finance instruments for respective studies in China. Taking into consideration the availability of valid data, 4 green indicators, including investments, securities, bonds, and carbon finance, have been used. S&P green bond (GB) index is used as global green bonds variable.

WilderHill clean energy index (WCE) for green securities, NASDAQ OMX Green Economy index family, i.e. (Green Building (GBL), Clean Energy Focused (CE), Green Transportation (GT), and Global Water (GW) is used to measure green investments. Carbon emissions futures (CF) is used as a proxy for carbon finance.

Descriptives statistics of all the indicators are shown in Table 3.3.The minimum, maximum and mean values of all the indicators are shown.Skewness is positive in all the cases and kurtosis is positive in most of the cases showing indicators are leptokurtic but the variable of Clean Energy and Carbon Finance show negative values and platykurtic behavior.

The correlation of the data are shown in 3.4 indicating that strong correlation is present among all the variables.Hence, providing evidence to use them in formation of an index.

TABLE 3.2: Variables and Sources

Variable	Indicators	Source
Green Finance Index (GFG)	❑ **Green securities:** WilderHill clean energy index for green securities (WCE) ❑ **Green investments:** Green Building (GBL) Clean Energy Focused (CE) Green Transportation (GT) Global Water (GW) ❑ **Green bonds** S&P green bond (GB) ❑ **Carbon finance** Carbon emissions futures (CF)	Datastream
environmental sustainability (EQ)	CO_2 emissions (mt per capita)	World development indicators (WDI)
Renewable energy (RE)	Percentage of total energy consumption	WDI
GDP	GDP/capita	WDI
Environmental regulations (ER)	Ratification of NDC policy	UNFCC Paris Agreement

TABLE 3.3: Descriptive Statistics

	N	Min.	Max.	Mean	Std. Dev.	Skewness	Kurtosis
GB	2307	121.78	158.82	134.9498	6.724098	0.672	1.043
GT	2306	931.6	5927.6	1812.084	691.8384	3.028	11.549
CE	2307	761.4	2514.6	1330.074	354.7672	0.674	-0.135
GW	2307	832.3	1864.8	1252.571	209.8118	0.468	0.121
WCE	2307	36.53	225	58.36137	24.0393	3.594	16.391
CF	2307	2.7	33.44	11.73796	8.482203	0.947	-0.771
GBL	2307	392.63	1797.23	641.7948	177.9885	2.965	12.093

GB= green bonds, GT=green transport, CE= clean energy, GW=green water, WCE= Wilderhill clean energy, CF=carbon finance, GBL=green building

TABLE 3.4: Correlation Matrix

		GB	GT	CE	GW	WCE	CF	GBL
Correlation	**GB**	1	0.692	0.683	0.688	0.757	0.631	0.655
	GT	0.692	1	0.825	0.83	0.888	0.621	0.911
	CE	0.683	0.825	1	0.956	0.63	0.843	0.673
	GW	0.688	0.83	0.956	1	0.688	0.776	0.762
	WCE	0.757	0.888	0.63	0.688	1	0.525	0.955
	CF	0.631	0.621	0.843	0.776	0.525	1	0.517
	GBL	0.655	0.911	0.673	0.762	0.955	0.517	1
Sig. (1-tailed)	**GB**		0	0	0	0	0	0
	GT	0		0	0	0	0	0
	CE	0	0		0	0	0	0
	GW	0	0	0		0	0	0
	WCE	0	0	0	0		0	0
	CF	0	0	0	0	0		0
	GBL	0	0	0	0	0	0	

a. Determinant = 7.93E-006

To determine if PCA could be run on the data, Kaiser-Meyer-Olkin (KMO) test and Bartlett's test have been conducted. KMO test is conducted to measure the sampling adequacy for PCA.

It analyses the common shared variance among the variables. If the value ranges between 0.7-0.8 (closer to) it shows that factors are suitable for factor analyses as the have substantial shared variance.If the value is below 0.5 it shows that factors have weak common variance hence not suitable for factor analysis.

The results shown in Table 3.5 yielded by the KMO test is 0.743 (>0.5), which shows that indicators are strongly correlated. The null hypothesis of Bartlett's test is that variables are uncorrelated. If the null hypothesis is rejected it indicates that the variables are corelated and suitable for factor analysis.

The approx. chi-square value of Bartlett's test is 27035.586 and is significant at 0.000(<0.05), signifying that the null hypothesis is rejected. Hence the data could be analyzed using PCA.

The next step in the factor extraction is to determine the eigen values that represent the variance explained by each factor.The role of eigen values is to find the direction of maximum variance. The larger the eigen value is, the corresponding eigen vector is more important. The eigen values are arranged in descending order

TABLE 3.5: KMO test and Bartlett's test

Methods	**Statistics**	**Results**
KMO	Measure of sampling adequacy	0.731
Bartlett's test of sphericity	Approx. chi square	27035.586
	Df.	21
	Sig.	0

with the first factor corresponding to the highest eigen value and so on. As per Kaiser's criterion, factors with eigen values greater than 1 are retained and factors below 1 are discarded.

The variance contribution rate a_j and cumulative variance of principal component F_j is computed by Eq. 3.1 and Eq. 3.2, respectively.

$$a_j = \frac{\lambda_j}{\sum_{j=1}^{p} \lambda_j} \tag{3.1}$$

$$a_1 + a_2 + \cdots + a_j = \frac{\sum_{j=1}^{j} \lambda_j}{\sum_{j=1}^{p} \lambda_j} \tag{3.2}$$

The results of these calculations are displayed in Table 3.6. Furthermore, the retained components, according to the principal $\lambda_j \geq 1$, are shown in Table 3.6.

After the principal component analysis, 1 component was extracted as only one factor has eigen value > 2.The results shown by Scree Plot (Figure 3.1) visualize the eigen values. The plot shows only 1 value before the point of inflection confirming the results.

The component matrix shows number of components the factors are loaded on 1 component. Table 3.7 displays that all the factors loaded on 1 component hence only one component has been extracted. The solution does not need any rotation as only one component has been extracted.Hence only 1 component was retained.

The retention of 1 component is also confirmed from scree plot.Scree plot identifies the number of components to be retained from the point of inflection. In this analysis, the point of inflection on the scree plot also shows the data being inflected after 1 point meaning only 1 component must be extracted.After the factor extration, the final equation is formulated and an index is created.

Table 3.6: Variance Iinterpretation Results

Component	Total	Variance %	Cumulative Variance %	Total	Variance %	Cumulative Variance %
1	5.447	77.81	77.81	5.447	77.81	77.81
2	0.817	11.676	89.486			
3	0.409	5.841	95.327			
4	0.205	2.923	98.25			
5	0.091	1.296	99.546			
6	0.02	0.287	99.833			
7	0.012	0.167	100			

Extraction Method: Principal Component Analysis.

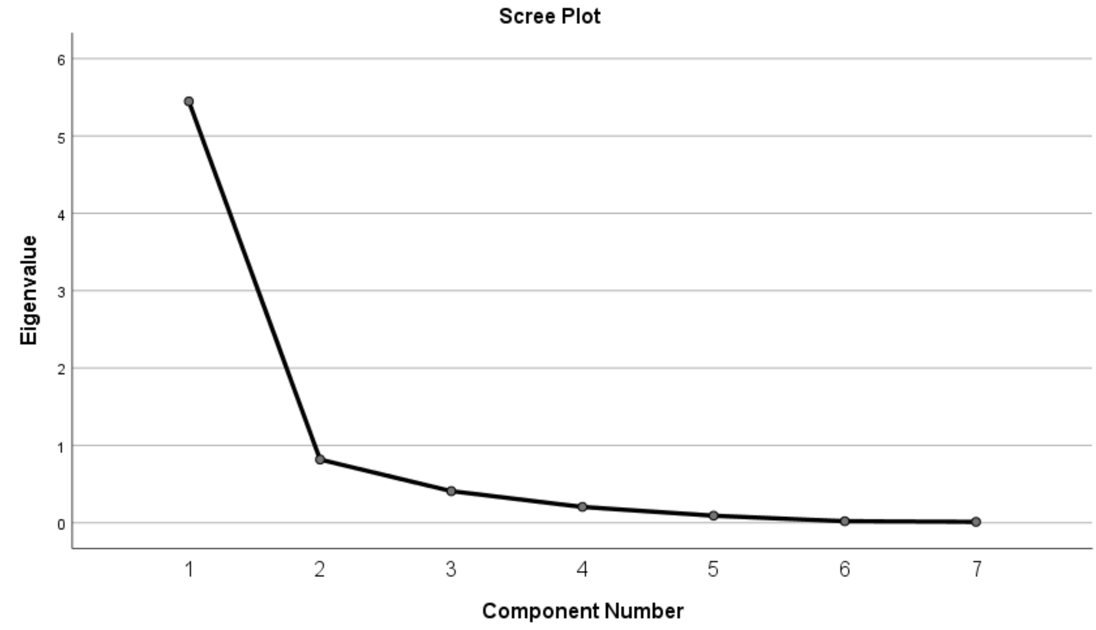


Figure 3.1: Scree Plot

Table 3.7: Component Matrix

Component	Value
GW	0.926
CE	0.91
GB	0.892
WCE	0.885
GBL	0.823
CF	0.79

Extraction Method: Principal Component Analysis.
(1 component extracted)

GB= green bonds, GT=green transport, CE= clean energy,
GW=green water, WCE= Wilderhill clean energy,
CF=carbon finance, GBL=green building

The final equation of PCA for the construction of green finance index (GFG) is as follows:In the equation below, GFG is the Green Finance index that is created after PCA.GT represents Green Transport, GW shows green Water, CE is the variable of Clean Energy, GB represents Green Bonds, WCE depicts WilderHill Clean Energy, GBL is the variable of Green Building and CF depicts Carbon Finance.

$$\begin{aligned} GFG_t &= 0.939(GT_t) + 0.926(GW_t) + 0.91(CE_t) \\ &\quad + 0.892(GB_t) + 0.885(WCE_t) + 0.823(GBL_t) + 0.79(CF_t) \end{aligned} \tag{3.3}$$

3.2.2 Moderating role of Environmental Regulations between Green Finance and Environmental Sustainability

Following equation examines the moderationg role of environmental regulations between green finance and environmental sustainability.

$$\begin{aligned}\ln EQ_{i,t} = \beta_1 \ln EQ_{i,t-1} + \beta_2 GFG_t + \beta_3 ER_t \\ + \beta_4 GFG_t \times ER_t + \beta_5 GDPgr_{i,t} + \epsilon_{i,t}\end{aligned} \tag{3.4}$$

In the above equation, $\ln EQ_{i,t}$ is environmental sustainability, $\ln EQ_{i,t-1}$ is the lag term of environmental sustainability, $GDPgr_{i,t}$ is GDP per capita, GFG is the green finance index, ER is environmental regulations and $GFG \times ER$ is the interaction term.

3.2.3 Impact of Panel EKC Model and Green Finance on Environmental Sustainability

For a valid U-shape EKC curve, the condition $\beta_1 > 0$ and $\beta\alpha_2 < 0$ should be met. Only under this condition, the inverted U-shape curve is valid, and the turning point could be calculated by $Y = \exp(-\beta_1/2\beta_2)$. The equation for our panel EKC model is as follows.

$$\begin{aligned}\ln EQ_{i,t} = \beta_1 \ln EQ_{i,t-1} + \beta_2 GDPgr_{i,t} + \beta_3 GDPgr^2_{i,t} \\ + \beta_3 GFG_t + \epsilon_{i,t}\end{aligned} \tag{3.5}$$

In the above equation, $\ln EQ_{i,t}$ is environmental sustainability, $\ln EQ_{i,t-1}$ is the lag term of environmental sustainability, $GDPgr_{i,t}$ is GDP per capita, $GDPgr^2_{i,t}$ is squared term of GDP per capita and GFG is the green finance index.For EKC curve calculation, generally an economic indicator and its square are taken as independant variables to check its impact on environmental degradation.But, by adding the variable of green finance as an explanatory variable in this equation, a new perspective has been added to the study of EKC and environmental degradation.

3.2.4 Impact of Green Finance, Renewable Energy, Carbon Finance and Environmental Regulations on Environmental Sustainability using GMM Approach

The environmental sustainability indicators, such as CO_2 emissions, environmental regulations, and green finance factors, such as renewable energy, etc., are different for all countries.

Hence the use of time series or cross-sectional data may obscure the actual effects among the variables. Alternatively, panel data gives the advantage of observing the time series and individual effects of different cross-sections.

Also, panel data provides greater insight than the cross-sectional or time-series data separately, thus reducing the chances of collinearity among variables as well as increasing the degree of freedom and therefore improving the estimation of validity (Sun & Chen., 2022). Hence, this study chooses panel data for model development and carrying the research forward. The general dynamic panel model is shown in Eq. 3.6.

$$Y_{i,t} = \alpha + \rho Y_{i,t-1} + \beta \sum X_{i,t} + \mu_i + \epsilon_{i,t} \tag{3.6}$$

Here, $Y_{i,t}$ is the explained variable, whereas explanatory variables are the lag term of the dependent variable and $X_{i,t}$. μ_i represents unobservable individual effect, and $\epsilon i, t$ denotes the random error term. Generally, while estimating the dynamic panel models, either fixed or random-effect model, there is a problem of endogeneity as the explanatory variables $X_{i,t}$, the lag term, and the unobservable individual effect μ_i may be correlated to each other.

To deal with the problem of endogeneity in the model, Arellano and Bond (1991) devised horizontal GMM and differential GMM estimation methods.Furthermore, to deal with the endogeneity of panel dataset, this study adapts GMM methodology for better model fit.

The general equation of GMM is as follows.

$$Y_{i,t} = \alpha Y_{i,t-1} + \beta \sum X_{i,t} + \mu_i + \epsilon_{i,t} \tag{3.7}$$

This study uses GMM methodology by Arellano and Bond (1991) to deal with the problem of endogeneity. The equations for specific models are as follows:

$$\ln EQ_{i,t} = \beta_1 \ln EQ_{i,t-1} + \beta_2 GFG_t + \beta_3 \ln CF_t + \beta_3 REG_{i,t} + \epsilon_{i,t} \tag{3.8}$$

$$\begin{aligned}\ln EQ_{i,t} = \beta_1 \ln EQ_{i,t-1} + \beta_2 GFG_t + \beta_3 ER_t \\ + \beta_4 GFG_t \times ER_t + \beta_5 GDPgr_{i,t} + \epsilon_{i,t}\end{aligned} \tag{3.9}$$

$$\ln EQ_{i,t} = \beta_1 \ln EQ_{i,t-1} + \beta_2 GDPgr_{i,t} + \beta_3 GDPgr_{i,t}^2 + \beta_3 GFG_t + \epsilon_{i,t} \tag{3.10}$$

The descriptive statistics for the panel data of 70 countries and all the variables used in analysis are displayed in Table 3.8.

Table 3.8: Descriptive Statistics Results

Variable	No. of Samples	Mean	Standard Deviation	Min.	Max.
CF	630	11.65598	8.102666	4.491447	25.61485
EQ	630	4.632738	4.086040	0.056000	27.50000
RE	630	3.104283	0.902168	1.007374	4.538621
GDP	630	904.4447	2679.305	7.304000	21372.60
GFI	630	3.832591	1.497358	0.008858	5.283611
ER	630	0.666667	0.471779	0.000000	1.000000

CF=carbon finance, EQ= environmental sustainability, RE=renewable energy,
GDP=gross domestic product, GFI=green finance index
ER= environmental regulations

To continue with the analysis, the data has been verified to be ready for further investigation.The stationarity of the data has been tested by using ADF-Fischer and LLC tests, and the results are shown in Table 3.9. The results show that all the series are stationary at first order difference at 5% level of significance.

Further, the long-term equilibrium association among the variables is tested using the cointegration analysis. The pre-requisite for cointegration is that all the variables must be integrated at first difference I (1).The dataset fulfills this prerequisite, as all the series are stationary at first difference.

TABLE 3.9: Unit root Results

Variable	LLC-Test	ADF-Test	Stationarity
CF	-19.1870***	228.326***	Smooth
EQ	-8.22356***	224.994***	Smooth
RE	-56.3771***	291.817***	Smooth
GF	-22.0132***	240.764***	Smooth
GDP	-14.5022***	211.684***	Smooth

CF=carbon finance, EQ= environmental sustainability,
RE=renewable energy, GDP=gross domestic product,
ER= environmental regulations

3.3 Green Finance and its Connectedness with other Sustainable Asset Classes

The daily data of S&P Green Bond Index (GBI) and S&P Global Clean Energy index (GCEI) is used to represent green finance, DJ Sustainability World Index (SWI) is used to measure sustainable investments, Islamic investment is measured by two indices (DJ Islamic Market World Index (IMWI) and DJ Sukuk Total Return Index (STRI) and gold is added in the analysis as the traditional safe haven which is measured by S&P GSCI Gold (Gold).The daily data taken from the period January 2013 – December 2022. Data is collected from Datastream. The sources are shown in Table 3.10.

The daily returns are calculated by taking the log difference between two consecutive prices using the formula:

$$r_t = \ln\left(\frac{p_t}{p_{t-1}}\right) \times 100 \tag{3.11}$$

By using the above formula, log difference is calculated for all the variables's two consecutive prices.This treatment helps to remove any unit root or any trend component available in data,and helps in making data more stationary.Further, this study emplys TVP-VAR methodology on the dataset in three time periods.First a complete sample analysis is done, the a pre-Covid and Covid sample analysis are done seperatedly.Finally all the results are compared and suggestions are given on their basis.

Table 3.10: Variables and sources (TVP-VAR)

Variable	Indicators	Source
Green Finance	S&P Green Bond Index (GBI) S&P Global Clean Energy index (GCEI)	Datastream
Sustainable Investment	DJ Sustainability World Index (SWI)	Datastream
Islamic Investment	DJ Islamic Market World Index (IMWI) DJ Sukuk Total Return Index (STRI)	Datastream
Gold	S&P GSCI Gold	Datastream

3.3.1 Dynamic Connectedness among Green Finance, Sustainable Investments and Islamic Investments using TVP-VAR Approach

To determine the time-varying return transmission process among green finance, sustainable finance, Islamic finance, and Gold in the periods before, between, and after the COVID-19 pandemic, we employ the TVP-VAR methodology proposed by, (Antonakakis & Gabauer, 2017).The use of TVP-VAR helps in determining the time varying pattern of all the assets under study.On the basis of the results, the connectedness among variables across different time periods could be determined.

The TVP-VAR approach is the extension of (Diebold & Yilmaz, 2012, 2014) methodology as it overcomes the burden of arbitrary rolling size window. As per BIC criteria of lags, this study employs TVP-VAR(1) expressed as follows.

$$\mathbf{x}_t = \mathbf{\Phi}_t \mathbf{x}_{t-1} + \boldsymbol{\epsilon}_t \qquad \boldsymbol{\epsilon}_t \sim \mathcal{N}(\mathbf{0}, \mathbf{S}_t) \tag{3.12}$$

$$vec(\mathbf{\Phi}_t) = vec(\mathbf{\Phi}_{t-1}) + \boldsymbol{\xi}_t \qquad \boldsymbol{\xi}_t \sim \mathcal{N}(\mathbf{0}, \mathbf{\Xi}_t) \tag{3.13}$$

In the above equations, $\mathbf{x}_t$, $\boldsymbol{\epsilon}_t$, and $\boldsymbol{\xi}_t$ are $N \times 1$ vectors, whereas $\mathbf{\Xi}_t$, $\mathbf{S}_t$, and $\mathbf{\Phi}_t$ are $N \times N$ dimensional matrices. Furthermore, the TVP-VAR model's Wold representation is $\mathbf{x}_t = \sum_{i=1}^{p} \mathbf{\Phi}_{it} \mathbf{x}_{t-i} + \boldsymbol{\epsilon}_t = \sum_{j=1}^{\infty} \mathbf{A}_{jt} \boldsymbol{\epsilon}_{t-j} + \boldsymbol{\epsilon}_t$.

The dynamic coefficients of vector moving average (VMA) are the fundamentals of connectedness index presented by Diebold & Yilmaz (2012) implementing the generalized impulse response functions (GIRF), $\boldsymbol{\psi}^g_{ijt}$, and generalized forecast error variance decompositions (GFEVD), $\tilde{\boldsymbol{\phi}}^g_{ij,t}(J)$, presented by Koop et al. (1996) and Pesaran & Shin (1998).

Where, GFEVD can be interpreted as the variance share of variable i, explained by variable j.

$$\boldsymbol{\phi}^g_{ij,t}(J) = \frac{\boldsymbol{S}^{-1}_{ii,t} \sum_{t=1}^{J-1} (\boldsymbol{\iota}'_i \boldsymbol{A}_t \boldsymbol{S}_t \boldsymbol{\iota}_j)^2}{\sum_{j=1}^{N} \sum_{t=1}^{J-1} (\boldsymbol{\iota}_j \boldsymbol{A}_t \boldsymbol{S}_t \boldsymbol{A}'_t \boldsymbol{\iota}_j)} \tag{3.14}$$

$$\tilde{\boldsymbol{\phi}}^g_{ij,t}(J) = \frac{\boldsymbol{\phi}^g_{ij,t}(J)}{\sum_{j=1}^{N} \boldsymbol{\phi}^g_{ij,t}(J)} \tag{3.15}$$

In the above equation,ι_i represents the zero vector with the unity on the ith position, $\sum_{j=1}^{N}[\tilde{\phi}^N_{ij,t}(J)] = 1$ and $\sum_{i,j=1}^{N}[\tilde{\phi}^N_{ij,t}(J)] = N$. The interconnectedness of the network is based on the GFEVD, explained as follows:

$$C^g_t(J) = \frac{\sum_{i,j=1,i\neq j}^{N} \tilde{\phi}^g_{ij,t}(J)}{\sum_{i,j=1}^{N} \tilde{\phi}^g_{ij,t}(J)} \tag{3.16}$$

It can be explained as the average off-diagonal spillover from all other markets to a specific market under consideration, ignoring the effect a market has on it itself via lags. At first, we are interested in calculating the spillover from variable i towards all other variables j, thus representing the total directional connectedness to other variables and is expressed as follows:

$$C^g_{(i\to j,t)}(J) = \sum_{j=1,i\neq j}^{N} \tilde{\phi}^g_{ji,t}(J) \tag{3.17}$$

Secondly, we calculate the spillover from all the variables j towards the variable i, excluding the variable i itself, named as "directional connectedness from others" and is expressed as follows:

$$C^g_{(i\leftarrow j,t)}(J) = \sum_{j=1,i\neq j}^{N} \tilde{\phi}^g_{ij,t}(J) \tag{3.18}$$

Thirdly, we compute the net total directional connectedness among variables, which is computed by subtracting the "total directional to others" from the "total directional connectedness from others". It can be interpreted as the influence of variable i on all the other variables.

$$C^g_{i,t} = C^g_{i\to j,t}(J) - C^g_{i\leftarrow j,t}(J) \tag{3.19}$$

The net total directional connectedness explains if variable i is influencing the network or being influenced by it. If $(C^g_{i,t} > 0)$ it expresses that variable i influences the network and vice versa if $(C^g_{i,t} < 0)$. Finally, we compute the net pairwise directional connectedness (NPDC) to examine the bidirectional relationships among variables. The net pairwise connectedness explains if variable i influences variable j or the other way round. The NPDC is expressed as:

$$NPDC_{ij}(H) = \tilde{\phi}_{ji,t}(H) - \tilde{\phi}_{ij,t}(H) \tag{3.20}$$

3.3.2 Green Finance and its Connectedness with other Sustainable Asset Classes during Full Sample Period [Jan2013-Dec2022]

Table 3.11 shows the descriptive statistics of the log returns of all the variables for the complete sample period. Overall, all the assets have positive average returns except GBI.Among all the variables, GCEI depicts the highest returns and highest volatility whereas, Gold shows the lowest positive returns. Whereas, STRI shows the lowest volatility among all the assets.

Kurtosis and skewness results depict that all the variables are asymmetric as well as leptokurtic. The ADF test confirms the stationarity of the variables whereas the Jarque-Bera test rejects the normality of the variables.

Table 3.12 shows the correlation results depicting that sustainability investments and Islamic investments show a positive correlation, similarly, clean energy investments and Islamic investments also depict positive correlations. Whereas, gold has a weak correlation with all the other variables indicating that it could be used

Table 3.11: Descriptives full sample [Jan2013-Dec222]

	IMWI	**STRI**	**SWI**	**GBI**	**GCEI**	**GOLD**
Mean	0.028042	0.010437	0.020858	-0.00578	0.0337759	0.00243
Median	0.059448	0.014074	0.043319	0.000000	0.073096	0.00000
Max	7.915943	0.729341	7.693916	2.271737	11.03300	5.60116
Min	-9.63856	-1.33983	-10.6051	-2.42391	-12.4971	-9.8112
Std. Dev.	0.934691	0.129020	0.908656	0.351311	1.467789	0.97258
Skewness	-0.85288	-1.51574	-1.15677	-0.40818	-0.42244	-0.5274
Kurtosis	16.87897	17.91719	19.59522	8.591121	11.58196	10.8171
JB	21240.04	24957.35	30496.88	34865.419	8046.791	6743.08
ADF	-15.91***	-24.67***	-16.07***	-31.98***	-17.52***	-52.7***

GB= Green bonds, SWI=Socially responsible investments, IMWI=Islamic investments, STRI=Shariah compliant investments, GCEI=Clean energy investments, Gold = gold

Table 3.12: Correlation

	GOLD	GCEI	GBI	SWI	STRI	IMWI
GOLD	1					
GCEI	0.00807	1				
GBI	0.004155	0.221107	1			
SWI	0.010369	0.669322	0.295878	1		
STRI	0.025202	0.208137	0.438822	0.195258	1	
IMWI	0.012561	0.699225	0.229753	0.926417	0.18597	1

GB=Green bonds, SWI=socially responsible investments, IMWI=Islamic investments, STRI=Shariah compliant investments, GCEI=Clean energy investments, Gold = gold

as a diversifier in the portfolio. It can be seen that only SWI and IMWI show a strong correlation with each other.All the other assets show a moderate correlation.The correlation results depicts that all the asset classes in datasets could be helpful in portfolio diversification and further analysis sould to conducted to confirm.Figure 3.2 represents the price dynamics of all the investment options (green, sustainable, Islamic, and gold) for the full sample period.The figures show that all the assets except gold are following a similar price trend during COVID-19. A downward trend is seen in all the assets except gold during early 2020, followed by an upward trend till the end of 2022, followed by a downward trend, whereas gold shows a different trend during the COVID-19 outbreak i.e., a spike in prices in early 2020 and 2022. However, the time dynamics of all the assets are quite similar.These dynamics depict the behavioral changes of the investors during the pandemic situation.

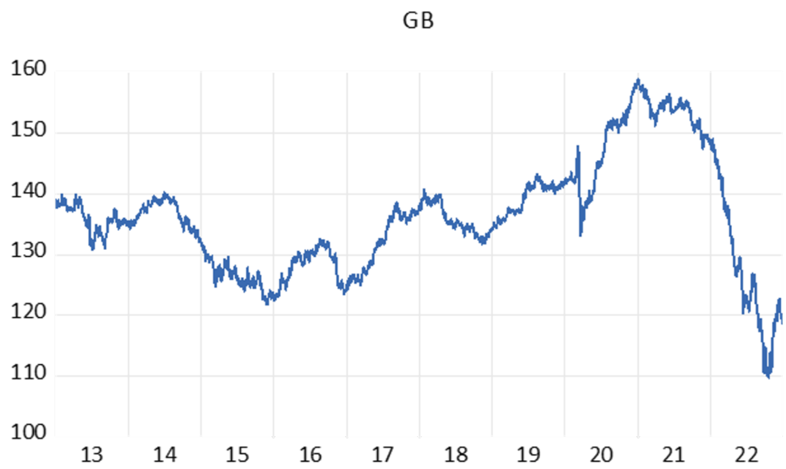


FIGURE 3.2: Time-varying Price Dynamics Full Sample [Jan2013-Dec2022]

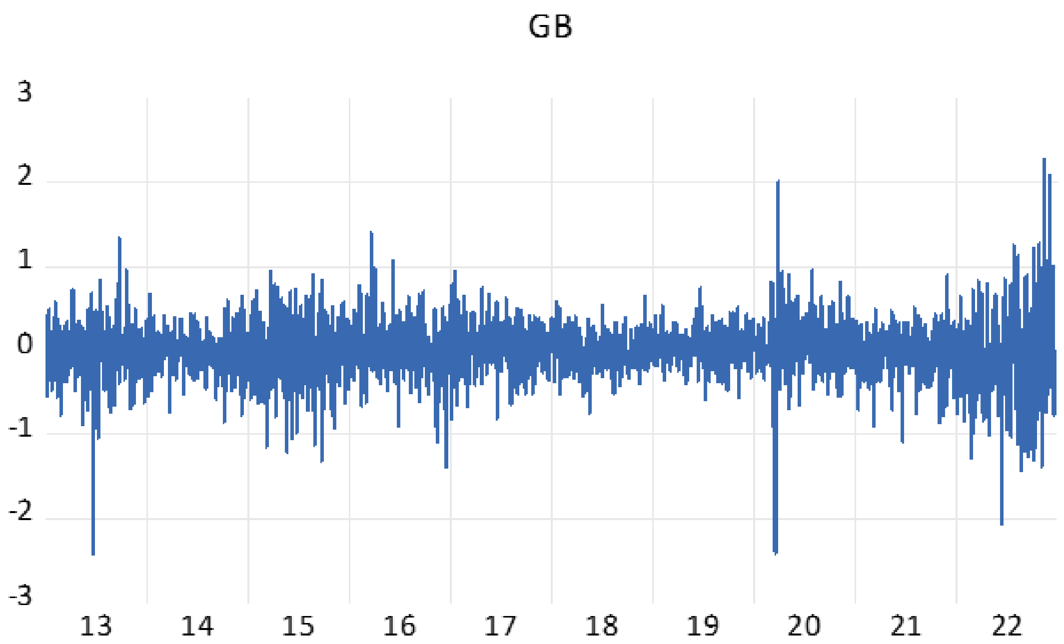
Furthermore, Figure 3.3 depicts the volatility clustering among the time-varying returns of all the assets for the full sample period.

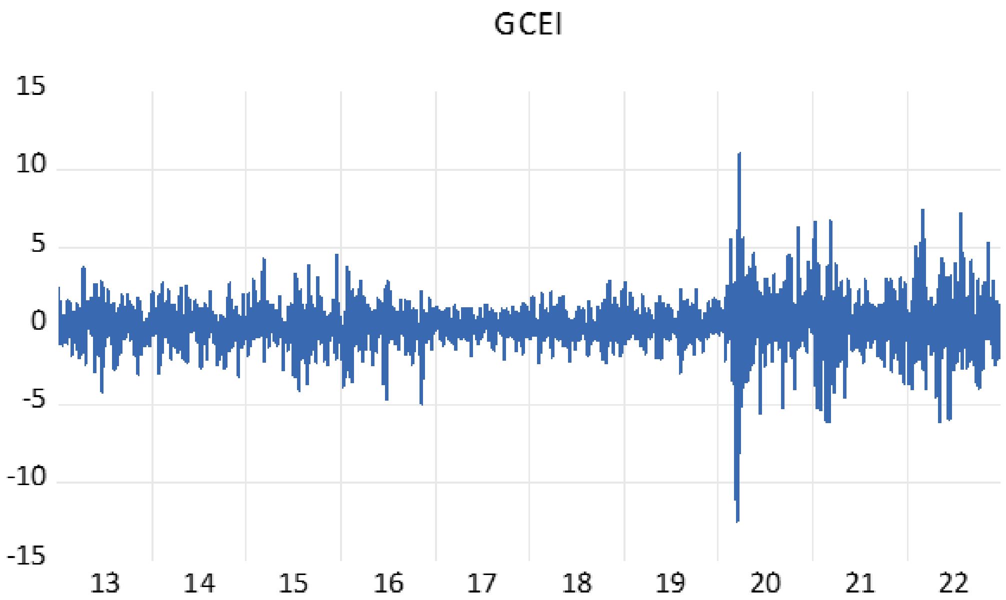
There is a significant spike in returns during the early 2020 period which is the peak of COVID-19 for all the asset classes which shows that all the assets reacted in the same manner to COVID-19 outbreak.This similar reaction in investor's behavior shows a herding pattern where the fear and panic created an uncertain situation.

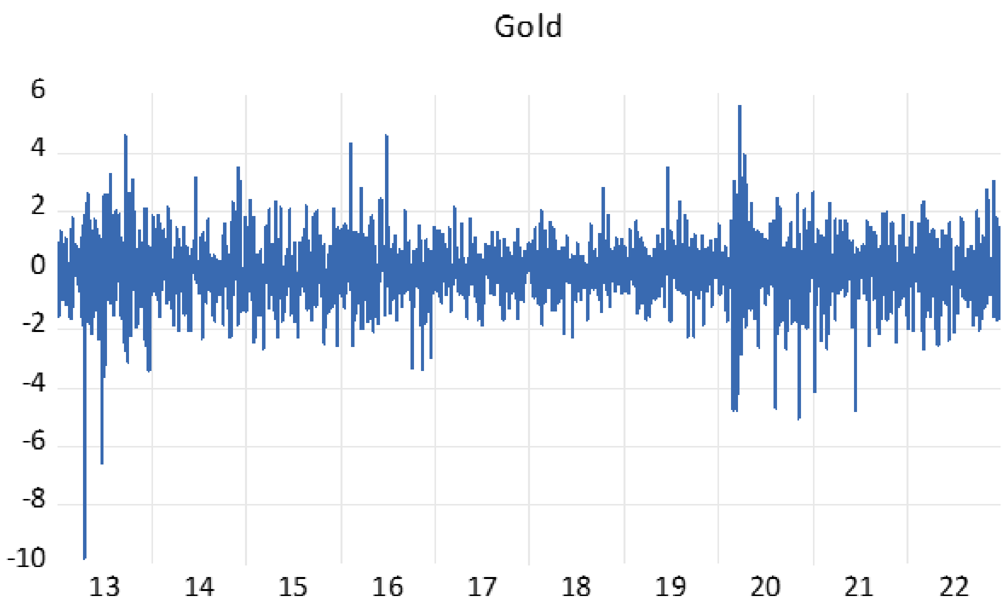
For the rest of the time period of the sample, there is no evidence of strong connectedness among asset classes.This shows that global events such as pandemis situation effects the investors' behaviour which is reflected on the prices of the assets.When there is situation of fear and uncertainity, the investors tend to behave in risk averse manner and vice versa.

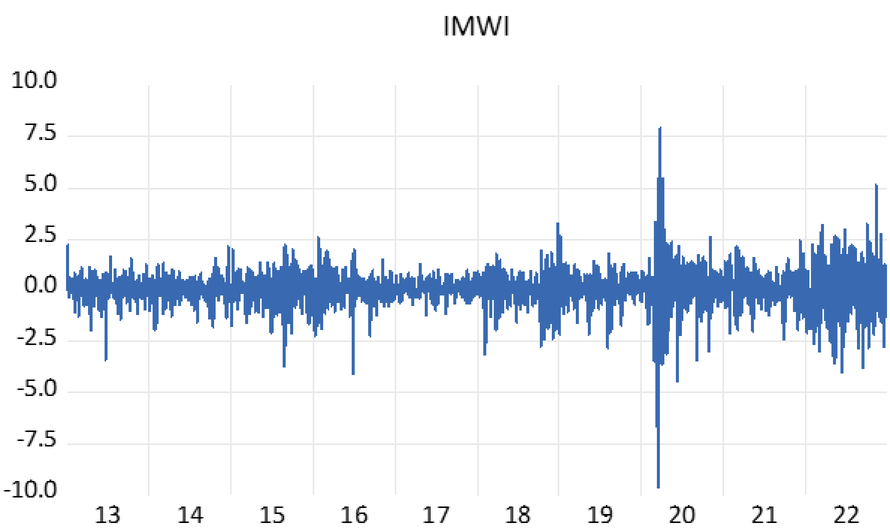
Similarly, for the period of 2015-2016, a specific deviation from the normal pattern could be observed for all the asset classes.A sudden decline is evident for almost all the asset classes during timme period 2015-2016.

This sudden change or deviation from the normal returns pattern could be identified as the result of oil crises.The crises hit the global financial and economic markets, and a situation of uncertainity and unpredictibility was created.The impact could be seen in the form of deviation in the returns.




GCEI
15
10
5
0
-5
-10
-15
13 14 15 16 17 18 19 20 21 22


Gold
6
4
2
0
-2
-4
-6
-8
-10
13 14 15 16 17 18 19 20 21 22


IMWI
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
13 14 15 16 17 18 19 20 21 22

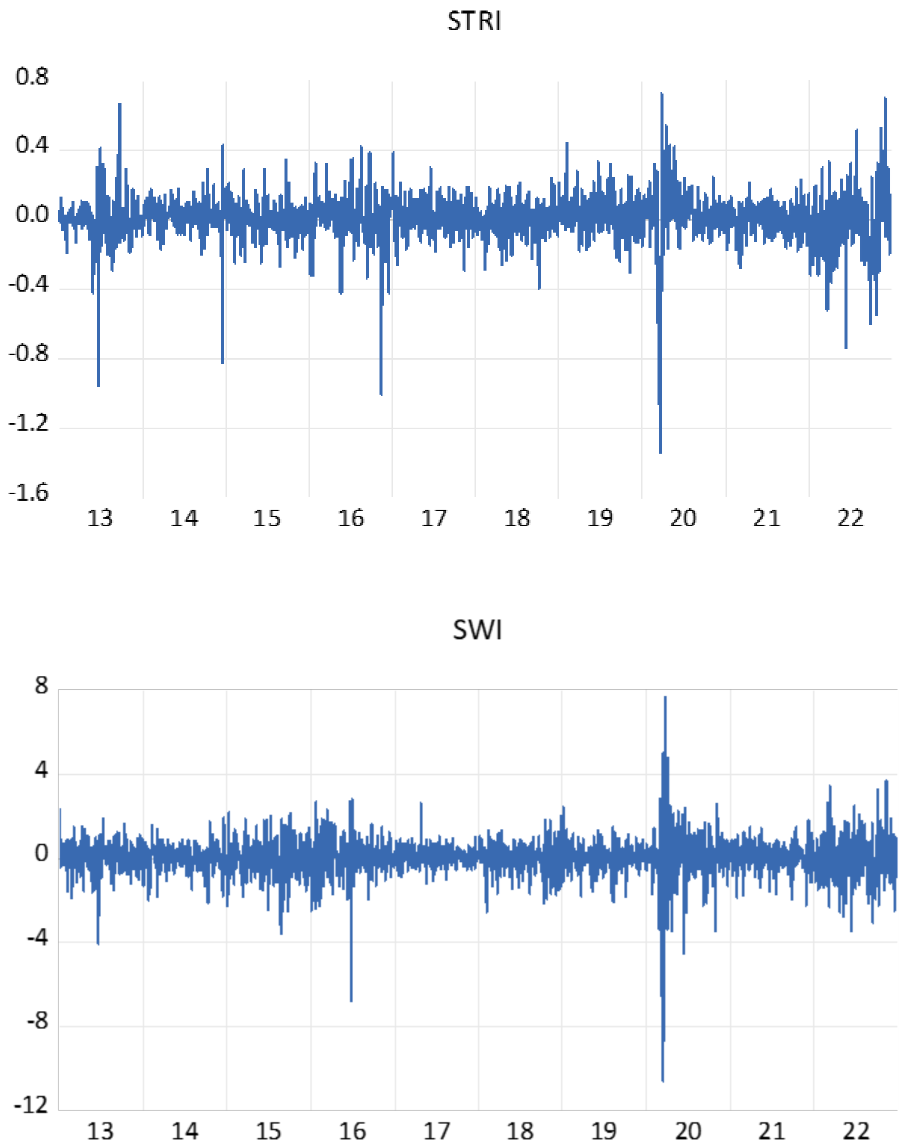


FIGURE 3.3: Time-varying Returns Full Sample [Jan2013-Dec2022]

Green Finance and its Connectedness with other Sustainable Asset Classes during Pre-Covid Sample Period [Jan 2013-Dec 2019]

Table 3.13 shows the descriptive statistics of the log returns of all the variables for the pre-COVID sample. Overall, all the assets have positive average returns. Islamic investments depict the highest returns and highest volatility whereas, Green bonds show the lowest positive returns.

Whereas, Shariah compliant investments show the lowest volatility. Kurtosis and skewness results depict that all the variables are asymmetric as well as leptokurtic.

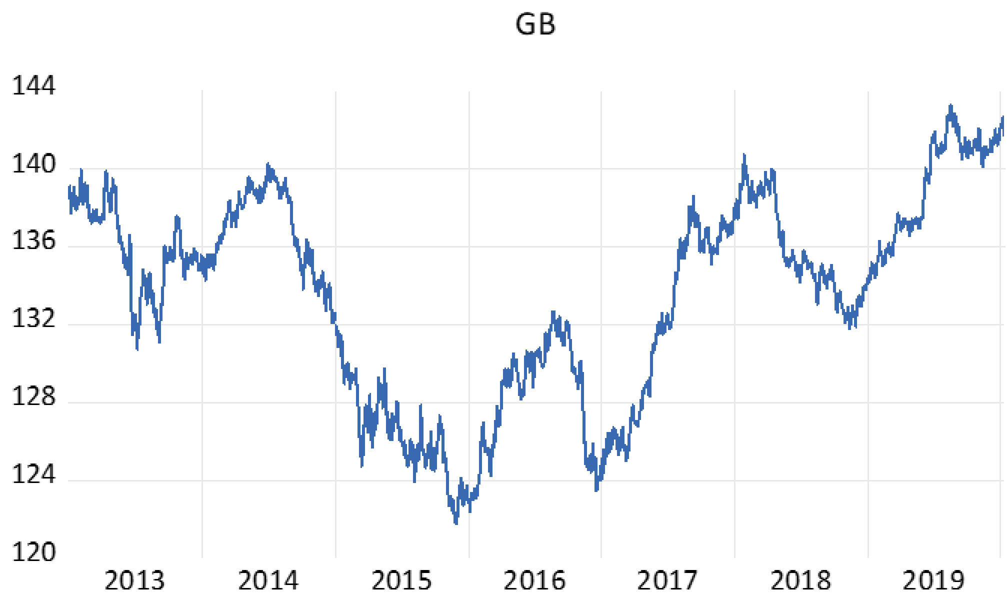
The ADF test confirms the stationarity of the variables whereas the Jarque-Bera test rejects the normality of the variables.

Figure 3.4 represents the price dynamics of all the investment options (green, sustainable, Islamic, and gold) for the pre-COVID. It could be noticed that all the assets show separate price changing pattern for the pre-COVID sample period.

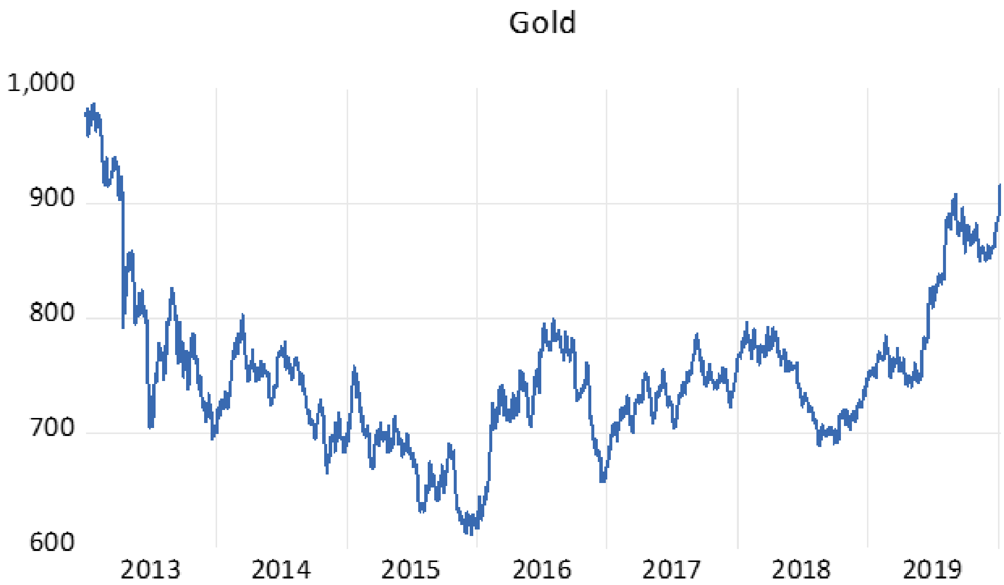
Afterwards, a gradual increase could be noticed until end of 2019. Sustainable and Islamic investments show an increase in the prices after 2015-2016 oil crises whereas green bonds and clean energy investments show a mixed trend with crests and troughs throughout the sample period.These time varying patterns show inconsistency and independence in the behavior of all asset classes.

These results show that these assets are not connected to each other in the sample period.Such independence in the behavior of asset clasees could be very helpful to the investors to get portfolio diversification benefits.Investors prefer to add such investment options in their porfolios that are less connected with each other, so that maximum diversification could be achieved.

The findings depict that before pandemic all the asset classes were behaving in an independant manner.Where some assets are showing price hikes and others are showing crests, indicating an independant movement pattern.An interesting trend is followed in oil crises situation where the investors reacted to the crises situation with uncertainity, hence a very turbulent price dynamics is observed.




GCEI
850
800
750
700
650
600
550
500
450
2013
2014
2015
2016
2017
2018
2019


Gold
1,000
900
800
700
600
2013
2014
2015
2016
2017
2018
2019

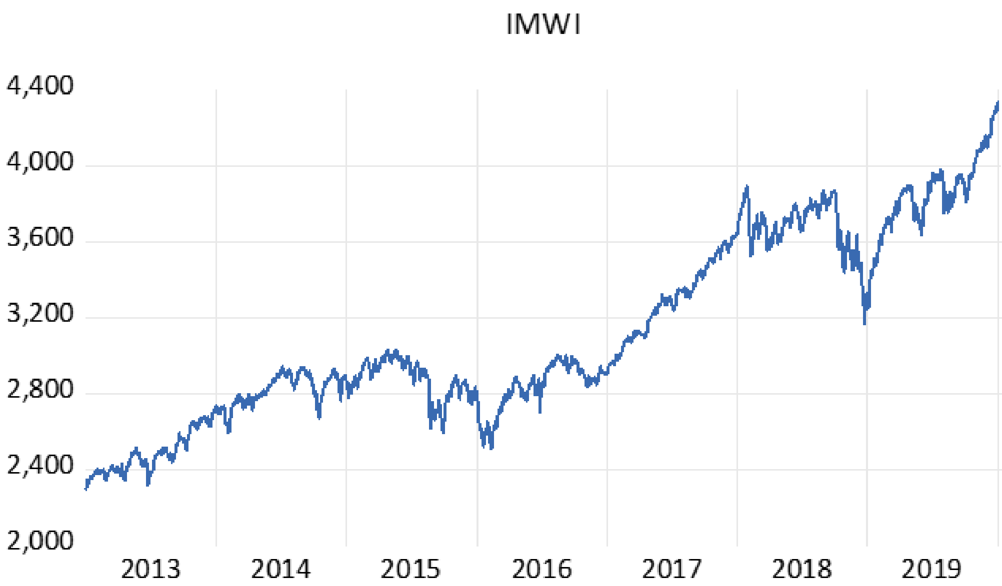

IMWI
4,400
4,000
3,600
3,200
2,800
2,400
2,000
2013
2014
2015
2016
2017
2018
2019

FIGURE 3.4: Time-varying Price Dynamics pre-COVID [Jan2013-Dec2019]

Furthermore, Figure 3.5, depicts the volatility clustering among the time-varying returns of all the assets for the pre-COVID sample.

The time-varying dynamics show that there is a significant decline in returns during the 2015-2016 oil crises period for all the asset classes. The is no specific pattern of spikes or declines for the rest of the pre-COVID sample period indicating that all the assets responded in a similar manner to the oil crises situation.The investor's behaviour is based on their perception and uncertainity of the future.

Conditions like global pandemics or crises tend to be situations of uncertainity.An interesting trend is followed in oil crises situation where the investors reacted to the crises situation with uncertainity, hence a very turbulent price dynamics is

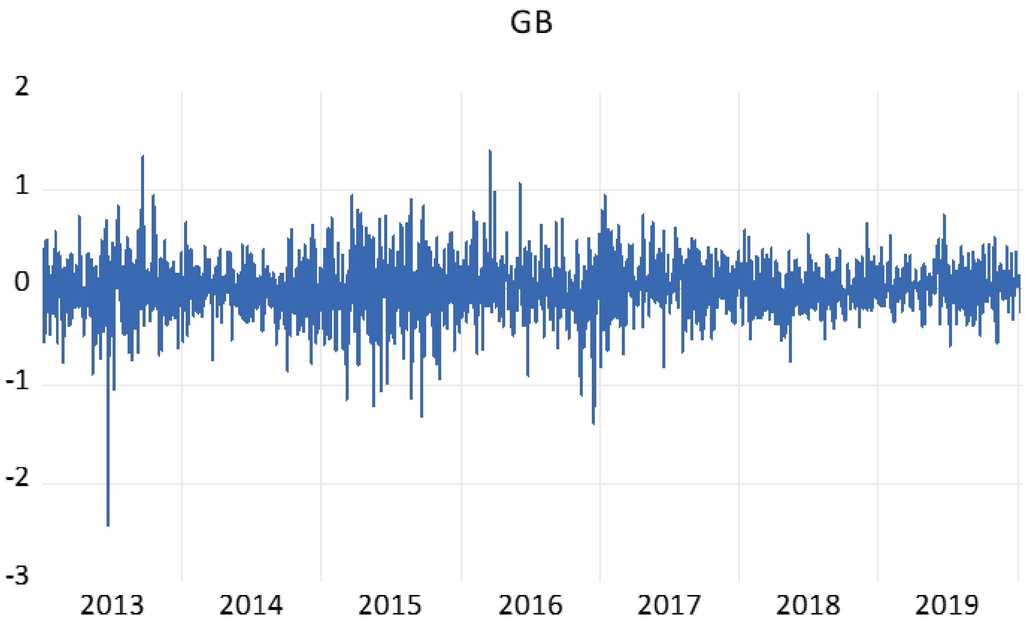
Table 3.13: Descriptives [Jan2013-Dec2019]

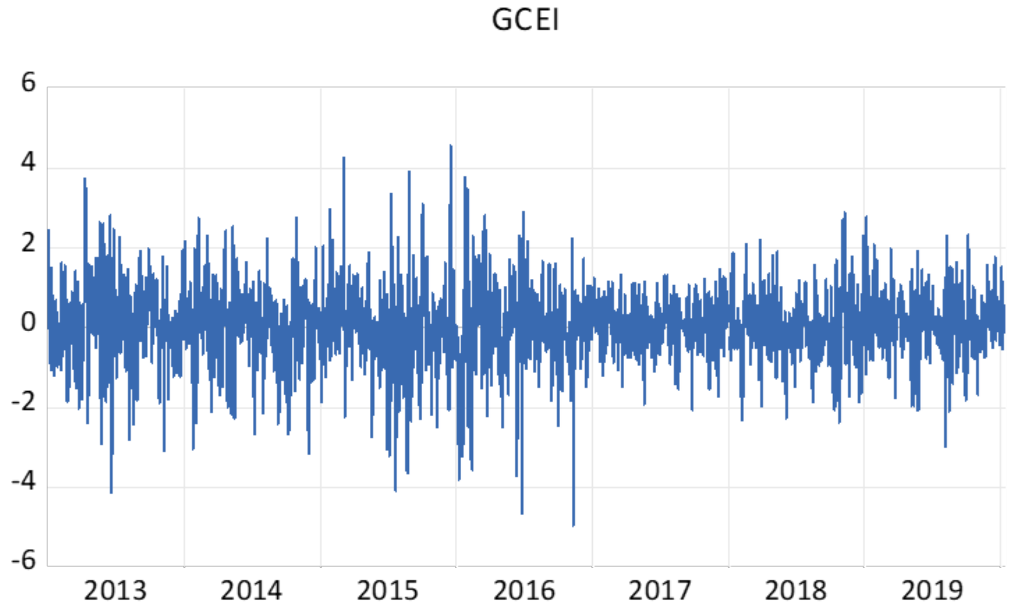
	IMWI	STRI	SWI	GBI	GCEI	GOLD
Mean	0.034996	0.014706	0.025424	0.001503	0.027360	-0.00486
Median	0.057273	0.016416	0.043401	0.007312	0.069603	0.000000
Max	3.289147	0.672831	2.815197	1.402702	4.558550	4.610318
Min	-4.08307	-1.0051	-6.81875	-2.42391	-4.96441	-9.81123
Std. Dev.	0.679320	0.109586	0.731873	0.296414	1.037594	0.916627
Skewness	-0.63068	-1.22134	-0.79678	-0.4227	-0.20363	-0.71393
Kurtosis	6.414687	16.17488	9.032568	6.968826	4.914996	13.48379
JB	1012.605	13585.50	2975.001	1256.927	292.2720	8545.404
ADF	1012.605	13585.50	2975.001	1256.927	292.2720	8545.404

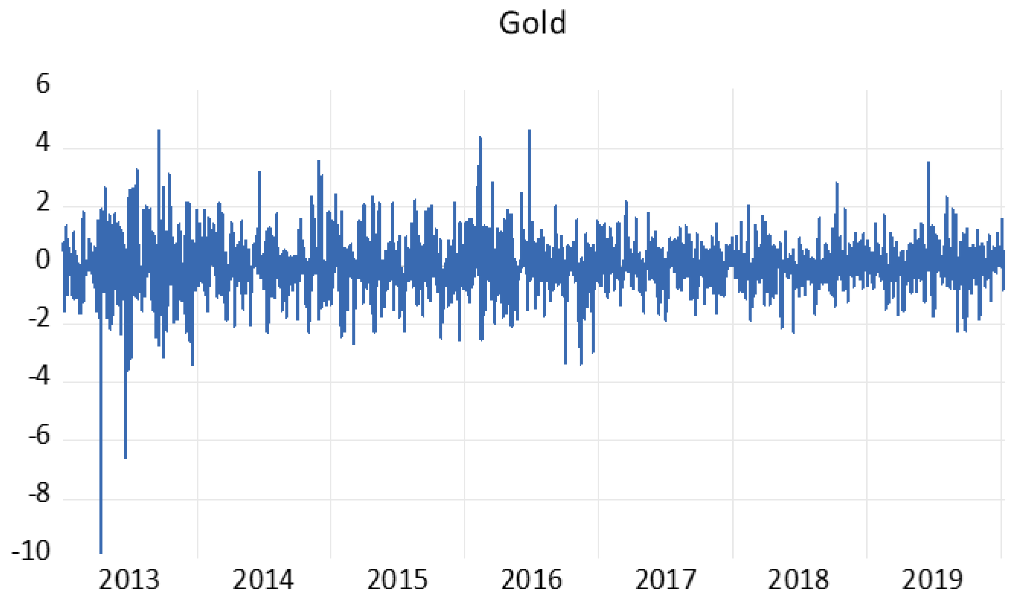
GB= Green bonds, SWI=Socially responsible investments, Gold = gold, IMWI=Islamic investments, STRI=Shariah compliant investments,GCEI= Clean energy investments.

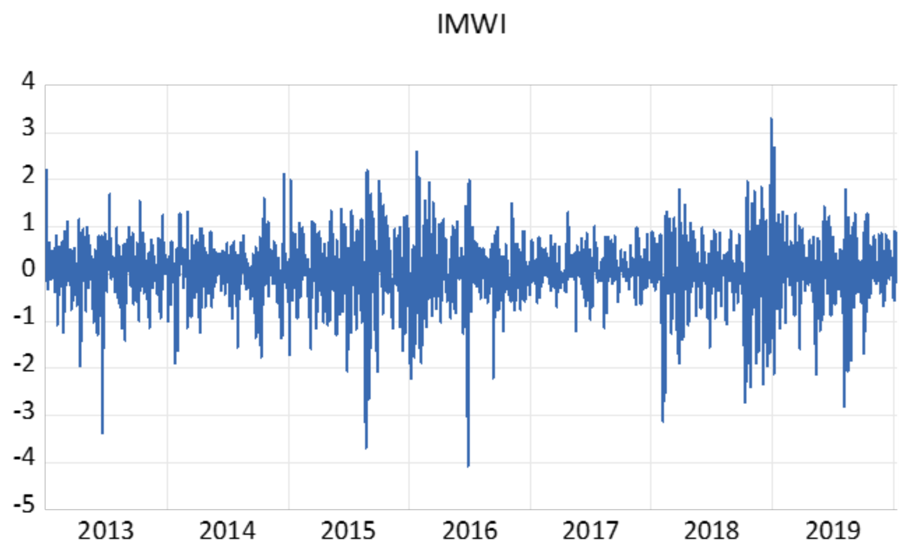
observed. The unpredictable patterns in the pandemic conditions do not capture the actual market situation,hence overall trend should be considered while making investment decisions.

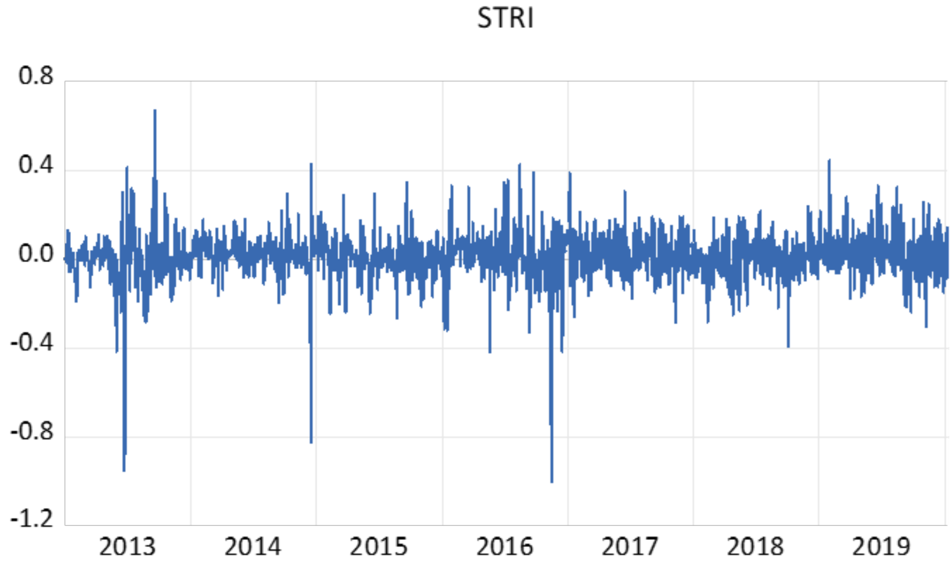
Further analysis of these asset classes is need to confirm the spillover and volatility of all these asset classes in a comprehensive manner.And to confirm the patterns depicted in the time-varying returns and prices.Furthermore, the comparison with other sample periods will be helpful in exploring the effect of time dynamics over connectedness among these asset classes aswell.




GCEI
6
4
2
0
-2
-4
-6
2013
2014
2015
2016
2017
2018
2019


Gold
6
4
2
0
-2
-4
-6
-8
-10
2013
2014
2015
2016
2017
2018
2019


IMWI
4
3
2
1
0
-1
-2
-3
-4
-5
2013
2014
2015
2016
2017
2018
2019



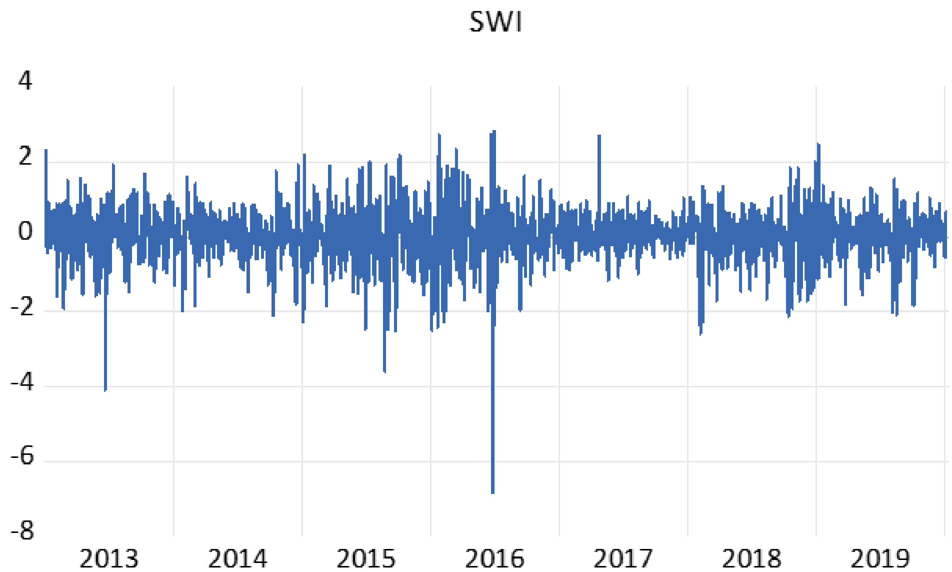


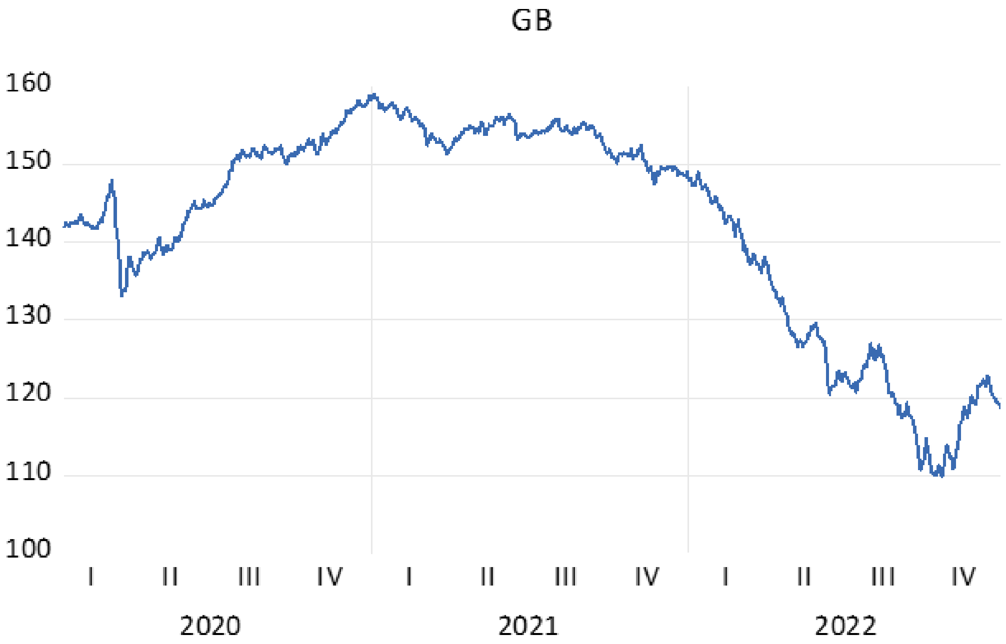
FIGURE 3.5: Time-varying Returns pre-COVID [Jan2013-Dec2019]

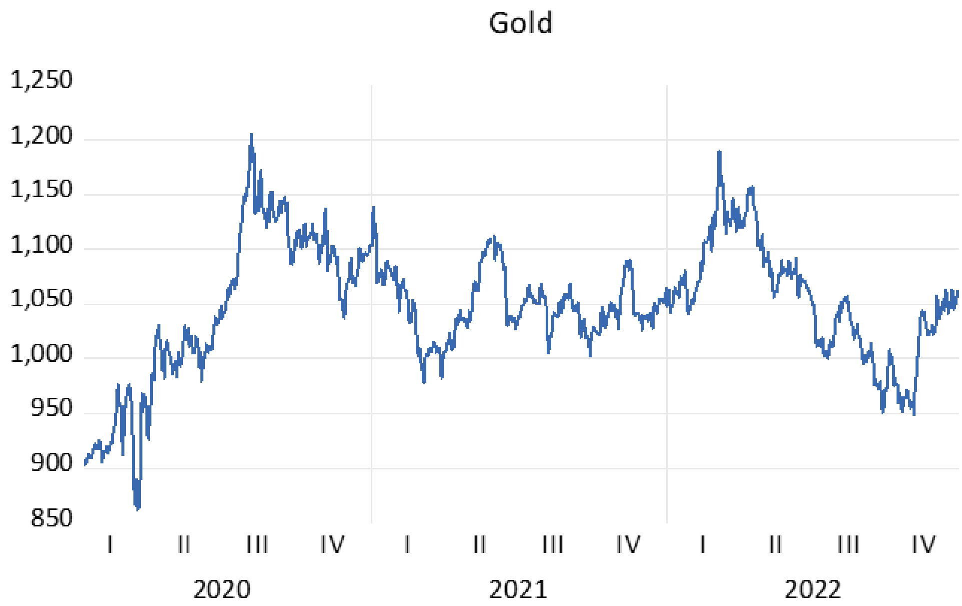
3.3.3 Green Finance and its Connectedness with other Sustainable Asset Classes during COVID Period [Jan 2020-Dec 2022]

Table 3.14 shows the descriptive statistics of the log returns of all the variables for COVID sample. Overall, all the assets have positive average returns except GBI. GCEI depicts the highest returns and highest volatility whereas, Gold shows the lowest positive returns. Whereas, STRI shows the lowest volatility. Kurtosis and skewness results depict that all the variables are asymmetric as well as leptokurtic.

The ADF test confirms the stationarity of the variables whereas the Jarque-Bera test rejects the normality of the variables.

Figure 3.6, represents the price dynamics of all the investment options (green, sustainable, Islamic, and gold) for the COVID sample. All the assets are following a similar trend at the beginning of COVID-19 where a decline in price of all the asset classes could be noticed. A downward trend is seen in all the assets except gold during early 2020, followed by an upward trend till the end of 2022, followed by a downward trend, whereas gold shows a different trend during the COVID-19 outbreak i.e., a spike in prices in early 2020 and 2022.




Gold
1,250
1,200
1,150
1,100
1,050
1,000
950
900
850
I II III IV I II III IV I II III IV
2020
2021
2022


IMWI
7,000
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
I II III IV I II III IV I II III IV
2020
2021
2022


STRI
205
200
195
190
185
180
175
I II III IV I II III IV I II III IV
2020
2021
2022

FIGURE 3.6: Time-varying Price Dynamics during COVID [Jan2020-Dec2022]

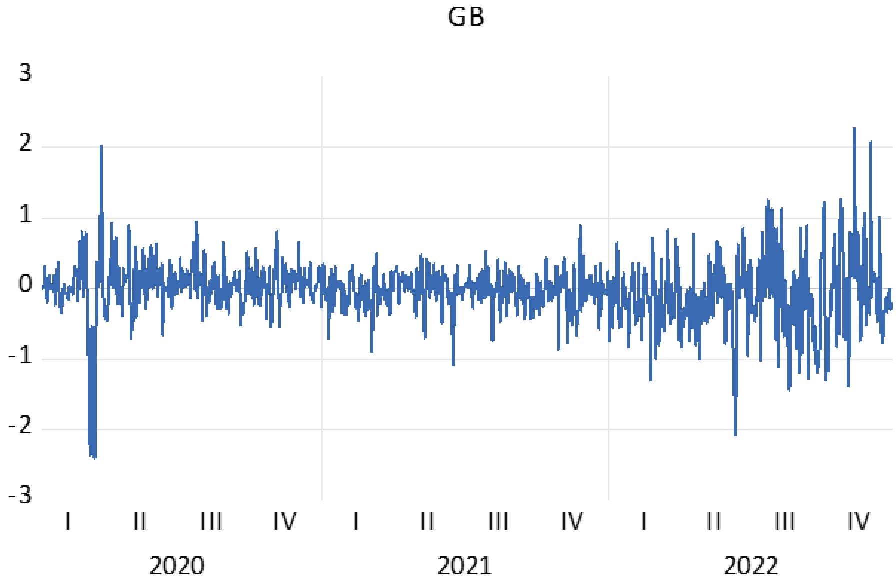
TABLE 3.14: Descriptives COVID [Jan2020-Dec2022]

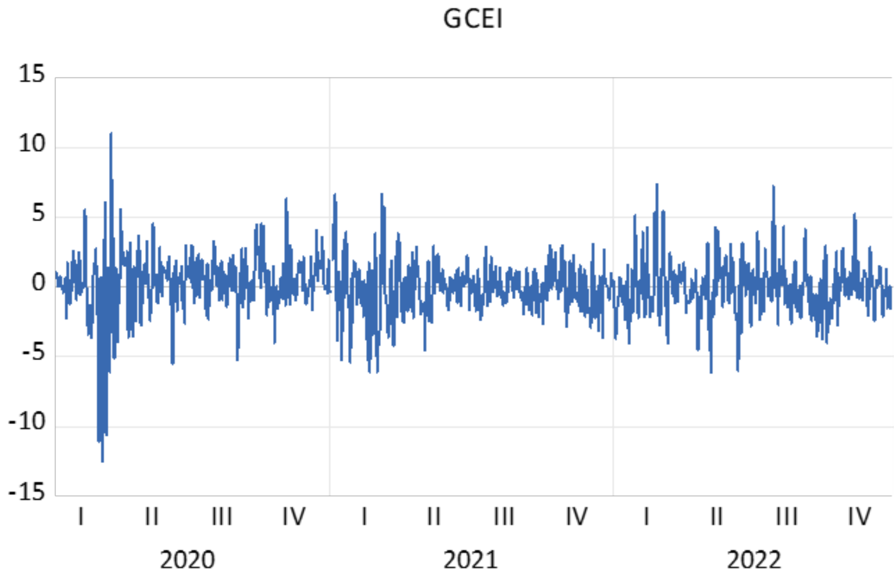
	IMWI	STRI	SWI	GBI	GCEI	GOLD
Mean	0.017742	0.001410	0.013746	0.017066	0.071831	-0.021
Median	0.069699	0.010527	0.043627	0.028157	0.106562	-0.006
Max	7.915943	0.729341	7.693916	5.601162	11.03300	2.271
Min	-9.638563	-1.33983	-10.6051	-5.05641	-12.4971	-2.409
Std. Dev.	1.338499	0.163617	1.210560	1.072745	2.129622	0.448
Skewness	-0.740463	-1.47312	-1.1782	-0.28254	-0.43269	-0.299
Kurtosis	12.06170	14.72084	17.44901	7.237035	7.861204	7.455
Jarque-Bera	2820.789	4886.875	7171.012	611.3433	815.7206	676.1
ADF	-8.28***	-12.12***	-8.15***	-28.57***	-17.03***	-22.4**

GB= Green bonds, SWI=Socially responsible investments, Gold = gold, IMWI=Islamic investments, STRI=Shariah compliant investments,GCEI= Clean energy investments.

Furthermore, Figure 3.7 depicts the volatility clustering among the time-varying returns of all the assets for the full COVID sample.

There is significant volatility in returns of all the assets during the early 2020 period which is the peak of COVID-19. The returns depicts that all the assets have responded to global pandemic situation. Later, all the assets show a less volatile behavior until the end of 2022.


GB
3
2
1
0
-1
-2
-3
I
II
III
IV
I
II
III
IV
I
II
III
IV
2020
2021
2022


GCEI
15
10
5
0
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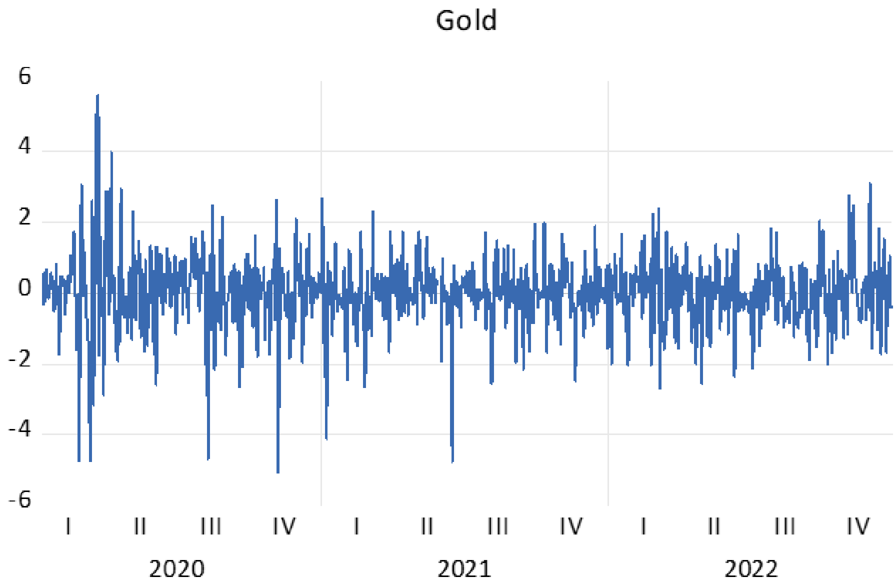
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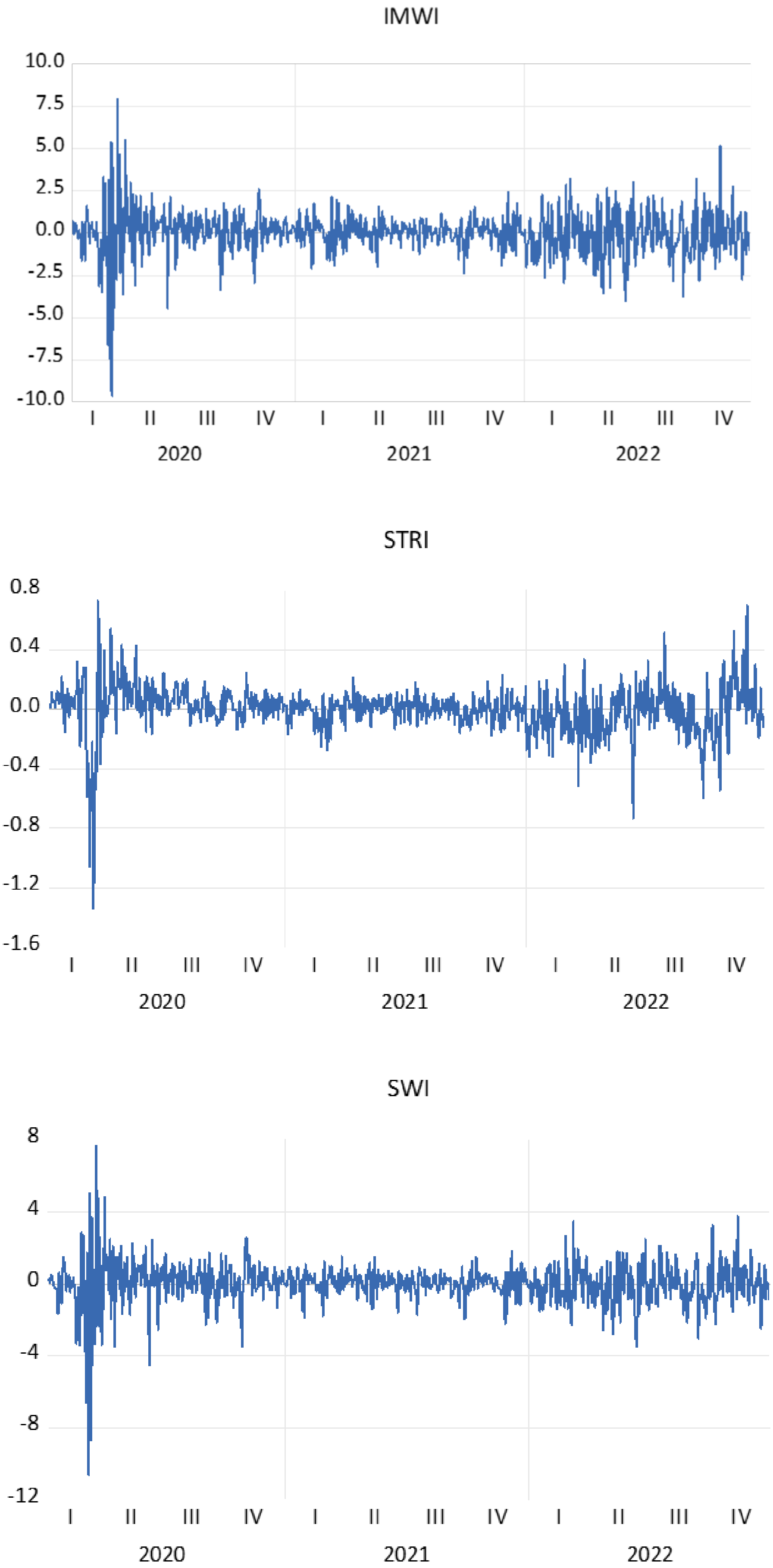


FIGURE 3.7: Time-varying Returns during COVID [Jan2020-Dec2022]

Chapter 4

Results and Discussion

4.1 Impact of Green Finance, Renewable Energy, and Carbon Finance on Environmental Sustainability

To examine the effect of green finance, renewable energy, and carbon finance on environmental sustainability, the model described by Eq. 4.1 is used.In the equation given below, explanatory variables are green finance (GFG) index, carbon finance (CF), and renewable energy (REG) and explained variable is $\ln EQ_{i,t}$.

$$\ln EQ_{i,t} = \beta_1 \ln EQ_{i,t-1} + \beta_2 GFG_t + \beta_3 \ln CF_t + \beta_3 REG_{i,t} + \epsilon_{i,t} \tag{4.1}$$

In the above equation, $\ln EQ_{i,t}$ represents environmental sustainability, $EQ_{i,t-1}$ is the lagged term of environmental sustainability, $\beta_i (i = 1, ..., 4)$ shows the coefficient of each variable, $GFG_{i,t}$ denotes green finance index, $\ln CF_{i,t}$ depicts carbon finance, whereas $REG_{i,t}$ measures renewable energy. The results from GMM estimation displayed in Table 4.1 (model 1) depict that the Sargan test has a p-value of $0.1123 (> 0.05)$; hence, the null hypothesis cannot be rejected.

The coefficients of green finance and renewable energy are significant ($\beta_{gfg} = -0.2577$, $\beta_{reg} = -0.2716$, $p-value < 0.05$). Here, the negative sign indicates that if green finance increases by 1%, it causes a reduction in CO_2 by 0.25%. Similarly, with 1% increase of renewable energy, there is 0.27% reduction in CO_2 emissions resulting in environmental sustainability. These results are in consistence with the prior literature and theory (Huang & Chen, 2022; Chin et al., 2022; Bekun et al., 2019; Zhou et al., 2022; Tong et al., 2022; Usman et al., 2022), indicating the importance of these variables in environmental sustainability.

Further, the renewable energy coefficient is significant, which emphasizes its importance. Its negative sign depicts the inverse relationship with CO_2 emissions portraying that renewable resources help in emission reductions and hence aiding the process of environmental sustainability. These results resonate with recent studies(Usman et al., 2022; Zoundi, 2017; Liao et al., 2023). The significant results of green finance index are in lieu with Mohsin et al. (2021), who formulated a low carbon finance index using several indicators to study climate mitigation supporting the inclusion of carbon finance in green finance index.

Carbon finance fails in reduction of CO_2 emissions. A positive significant coefficient of carbon finance indicates a rise in CO_2 emissions with the introduction of carbon finance. The additional cost of carbon credits not only fails to control CO_2 emissions but opens the door to continue with practices that are damaging to environmental sustainability.

These results lead to a new debate as the carbon finance is not positively affecting the environmental sustainability and not helping in CO_2 emissions reductions. This behavior of carbon finance may be Cobra Effect.

The cobra effect occurs when an attempt to solve a problem only makes the problem worse. It is a strong concept referring to the outcome that is opposite to the intended results of the action (Warczak, 2020). The term originated from British colonial rule in India. During the British rule in India, the government was concerned with growing number of cobras in the region and as a solution decided to proposed to give bounty over every dear cobra that is brought to the government by local residents.

Initially, the idea worked very well and lot of dead cobras were brought to the government. But soon the locals realized that breeding cobras for the purpose of bounty was more profitable. As soon as the government realized this situation, the bounty offering program was cancelled. Hence all cobras that were bred for the incentive purposes were useless to the locals hence they were freed in the wild. This increased the number of cobras in Delhi. Hence the ideology of Cobra effect was emerged.

The cobra effect perspective has been tested in various empirical studies in economics and other domains (Theerthaana & Arun., 2021; Bajo-Buenestado & Borrella-Mas, 2019) suggesting that it must be adapted in future studies to confirm the presence of agency issues and cobra effect in carbon credit markets aswell. If the additional cost of carbon is being transferred to the end users, then it will not influence the producers to reduce their CO_2 emissions triggering a cobra effect.

The difference in the results of carbon finance and green finance supports that these two concepts have some differences. Green finance practices have been adapted by relatively large number of countries hence its significant results towards sustainability are supported by several recent studies.

Carbon finance has not been extensively adapted by all the countries yet as the convergence options towards environmentally sustainable ones is a relatively new idea and different countries will take time to make a shift.The idea of purchasing carbon credits is not well adapted globally yet, only few developed econoies are trading in carbon credits

These results provide insight to further investigate carbon finance in. Kumar et al., (2022) confirm that most of the studies in sustainable finance are more focused on green finance than carbon finance. Further, available studies are focused on developed economies leaving a gap in literature to extend the studies.

This study makes an effort to cover a large sample with different stages of development so that the results add to the existing literature by extending the research of carbon finance and confirming that although green finance and carbon finance share same theme but they also have some differences between them as well which are understudied providing a research direction for future studies to confirm the results.

To test the robustness of GMM technique, the models are tested by using panel DOLS. Table 4.1 (Model 2) shows the findings of dynamic OLS which are in consistence with the results of GMM methodology. All the models and variables show significant impact of green finance and renewable energy on decreasing carbon dioxide emissions suggesting the robustness of GMM methodology.

TABLE 4.1: GMM Results

Variables	**Model No 1**	**Model No 2**
LnEQ(-1)	0.7293***(12.048)	0.9887***
LnCF	0.0322**(2.1935)	-0.0140**
GFG	-0.2577***(-6.705)	-0.2040***
REG	-0.2716**(-2.0278)	0.0528**
Sargan Test	0.1123	
AR(1)	0	
AR(2)	0.0131	

Notes: $***p < 0.001, **p < 0.05, ***p < 0.01$. $\ln EQ(-1)$=lag term of environmental sustainability, $\ln CF$=carbon finance, GFG=green finance index, REG=renewable energy

4.2 Moderating Role of Environmental Regulations between Green Finance and Environmental Sustainability

The equation below enquires about the moderating role of environmental regulations on environmental sustainability.

$$\begin{aligned} \ln EQ_{i,t} = \beta_1 \ln EQ_{i,t-1} + \beta_2 GFG_{i,t} + \beta_3 ER_t \\ + \beta_4 GFG \times ER + \beta_5 GDPgr_{i,t} + \epsilon_{i,t} \end{aligned} \tag{4.2}$$

Table 4.2 (model 1) shows the GMM estimation results. The coefficient of interaction term is significant ($\beta = 5.7068, p - value < 0.05$), and the negative sign indicates that the increase in environmental regulations regarding green finance causes a reduction in CO_2 emissions. These results depict that the initiation of NDCs is vital in improving environmental sustainability by urging the countries to formulate policies and initiate projects that help in reducing CO_2 emissions. By adapting these policies, countries can avoid environmental damage by converging to green projects. Industries and organizations could be streamlined with the help of uniform policies to change their business practices towards environment friendly manner.

Shift from fossil fuel to renewable energy, water purification process, less labor-intensive work processes, going electronic and using less paper for inter departmental communications, reuse, reduce and recycle the recyclable materials are some efficient production processes could be some of the mechanisms to follow a sustainable path.

These findings confirm the importance of NDC policies. A global transition towards green finance is the outcome of such policies, which enhance environmental sustainability by reducing harmful emissions. These findings are in coherence with recent studies emphasizing the importance of policies and regulations for sustainability (Dogan et al., 2022a; 2022b; Yang et al., 2022; Usman, 2022; Zhao et al., 2019).

The sooner all economies will adopt these environmental regulations and abide by them, the better for improving climatic health.The results confirm the importance and significance of factors like green finance and environmental regulation towards combating environmental degradation.

Hence avenues like the governments, international forums, stakeholders, law enforcing institutions have the responsibility to work in collaboration , and make sure that such policies are not only adapted by the countries but also implemented effectively to gain their main purpose.

To test the robustness of GMM technique, the models are tested by using panel DOLS. Table 4.2 (Model 2) shows the findings, which are in consistence with the results of GMM methodology. All the models and variables show significant results suggesting the robustness of GMM methodology.

4.3 Impact of Panel EKC Model and Green Finance on Environmental Sustainability

For a valid U-shape EKC curve, the condition $\beta_1 > 0$ and $\beta\alpha_2 < 0$ should be met. Only under this condition, the inverted U-shape curve is valid, and the turning

TABLE 4.2: GMM Results for Moderation analysis

Variables	**Model No 1**	**Model No 2**
LnEQ(-1)	0.7918***(19.5807)	0.9939***
GFG	5.6784***(4.4433)	1.6206**
ER	1.0959***(4.4955)	0.3278***
GFG*ER	-5.7068***(-4.4506)	-1.756***
GDPgr	0.0103***(10.4827)	0.0069***
Sargan Test	0.1041	
AR(1)	0	
AR(2)	0.938	

Notes: ***$p < 0.001$, **$p < 0.05$, ***$p < 0.01$. ln$EQ(-1)$=lag term of environmental sustainability, GFG=green finance index, ER=environmental regulations, $GDPgr$= GDP per capita.

point could be calculated by $Y = \exp(-\beta_1/2\beta_2)$. The equation for our panel EKC model is as follows.

$$\ln EQ_{i,t} = \beta_1 \ln EQ_{i,t-1} + \beta_2 GDPgr_{i,t} + \beta_3 GDPgr^2_{i,t} + \beta_3 GFG_t + \epsilon_{i,t} \tag{4.3}$$

The results from Table 4.3 (model 1) confirm the EKC hypothesis for our panel data. The GMM estimation results show that Sargan test has a $p-value$ 0.2579($>$ 0.05); hence, the null hypothesis that instruments are exogenous cannot be rejected. The instruments used are the second lag of CO_2 emissions, the second lag of GDP per capita, and the second lag of renewable energy.

The Arelleno-Bond tests for autocorrelation AR (1) and AR (2) are also conducted, which have a null hypothesis of no autocorrelation. The coefficient for green finance index is significant and negative, indicating an inverse relation with CO_2 emissions, i.e., if green finance increases, the level of CO_2 emissions decreases.

The coefficients of economic activity and squared terms are significant and meet the condition of $\beta_1 > 0$ and $\beta_2 < 0$ hence proving the validity of U-shaped curve in the panel dataset of 70 countries, which implies that initially, the CO_2 emissions increase as the economic activity increases but after a certain level the increase in economic activity causes a decrease in environmental degradation.

The coefficients are significant and coherent with the literature (Li et al., 2022; Khan et al., 2022; Qalati et al., 2023; Saleem et al., 2022), i.e., CO_2 emissions increase with the GDP per capita during the early stage of economic development and start declining afterward. The green finance indicator shows a significant and negative coefficient confirming its importance in the EKC fitting towards minimizing environmental degradation by reducing CO_2 emissions.

These findings indicate that with an increase in economic development and introduction of green finance in different economies we experience and reduction in CO_2 emissions. The inverse and significant relationship between green finance and CO_2 emissions in the EKC fitting indicate that countries must follow the sustainable path towards economic growth and development to help sustain the environment.These results confirm that with the econoies relying on green invesments for economic growth, the negative effective on environment would be lessened.

Hence the adaptation of green investment and energy options, countries can not only get a better economic growth but on the other hand, climate mitigation can also be achieved. The earlier work exploring the role of green finance in the EKC fitting is missing creating a need to explore this dimensionin detail.This gap contributes to the novelty of this idea and positive results emphasize on its practical implications.

To test the robustness of GMM technique, the models are tested by using panel DOLS. Table 4.3 (Model 2) shows the findings of the dynamic OLS, which are in consistence with the results of GMM methodology and proving the role of green finance in EKC. All the models and variables show significant results suggesting the robustness of GMM methodology.

4.4 Dynamic Connectedness among Green Finance, Sustainable Investments and Islamic Investments Full sample [Jan 2013-Dec 2022]

Table 4.4 explains the average dynamic connectedness among all the asset classes for the complete sample period. The total dynamic connectedness index depicts a value of 49.80% indicating that the interdependence among all the returns is not significantly high. The results also indicate that GBI is not a transmitter of net

Table 4.3: GMM Results EKC Model

Variables	**Model No 1**	**Model No 2**
LnEQ(-1)	0.70286***(14.0045)	0.9935***
GFG	-0.06515***(-2.5183)	-0.1106***
GDPgr	0.0093***(6.941)	0.0073***
GDPgr2	-0.00044***(-2.0354)	-0.00011***
Sargan Test	0.2579	
AR(1)	0.0007	
AR(2)	0.5869	
Turning Point	$39,362	

Notes: $^{***}p < 0.001$, $^{**}p < 0.05$, $^{***}p < 0.01$. $\ln EQ(-1)$=lag term of environmental sustainability, GFG=green finance index, $GDPgr$= GDP per capita.

volatility but net recipient (-21.24%). Similarly, clean energy stocks (-2.92%) and Shariah' complaint investments (-20.26%) are net recipients of shocks. Gold is the net transmitter of shocks to all the other asset classes (22.38%) which indicates that gold is a good predictor of all other asset classes.

Table 4.4: Averaged dynamic connectedness table full sample [Jan2013-Dec2022]

	GB	SWI	IMWI	GCEI	STRI	Gold	FROM
GB	58.55	7.48	4.77	3.79	7.31	18.1	41.45
SWI	4.67	40.65	34.82	16.82	1.83	1.2	59.35
IMWI	2.61	34.59	41.33	18.3	1.86	1.31	58.67
GCEI	2.4	20.39	22.98	51.15	1.94	1.14	48.85
STRI	9.63	5.96	6.43	5.04	65.82	7.11	34.18
Gold	0.91	1.28	1.34	1.97	0.98	93.51	6.49
TO	20.22	69.7	70.34	45.93	13.92	28.87	248.98
Inc.Own	78.76	110.35	111.68	97.08	79.74	122.38	cTCI/TCI
NET	-21.24	10.35	11.68	-2.92	-20.26	22.38	49.80/41.50
NPT	1	4	5	3	0	2	

GB=Green bonds, SWI=socially responsible investments, IMWI=Islamic investments, STRI=Shariah compliant investments, Gold = gold

The total dynamic connectedness shown in Figure 4.1 demonstrates the total connectedness index over the sample period based on TVP-VAR approach. It can be seen that the connectedness is varying in different time periods. A significantly high level of connectedness (around 85%) could be seen among all assets during 2020. This spike could be explained by COVID-19 outbreak where all the assets responded similarly to this global pandemic.

The increase in covid cases, increased level of unemployment and policy changes caused sudden changes in financial decisions of investors (Bossman, 2021) could be attributed to increased connectedness. A reduction in connectedness could be seen during the year 2015, this trough could be associated with the 2015-2016 global oil crisis where all the assets responded separately to the global economic crisis due to the event.

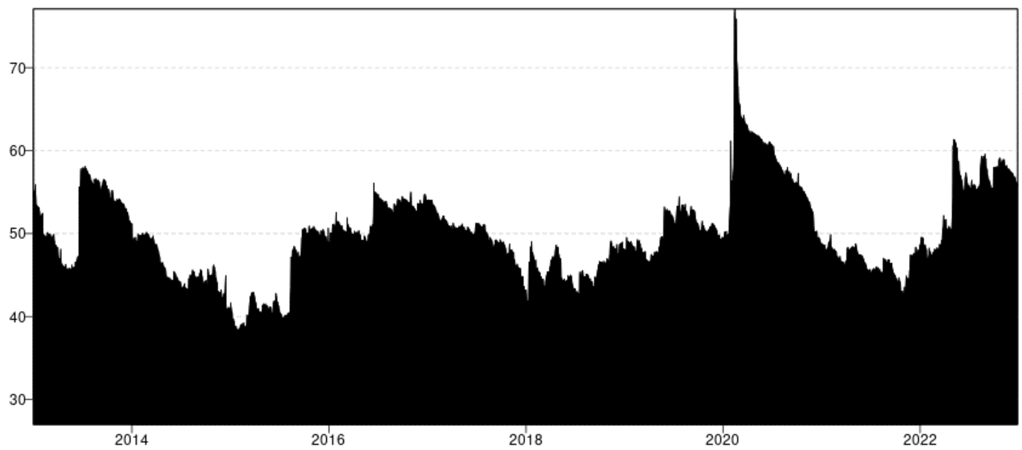
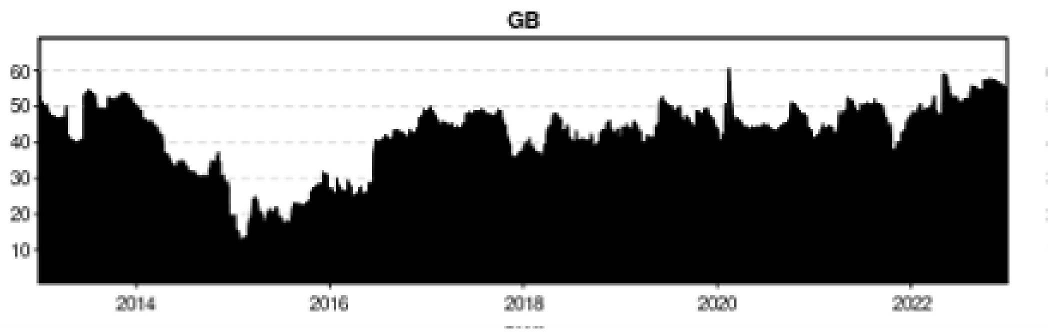


FIGURE 4.1: Total Dynamic Connectedness Full sample [Jan2013-Dec2022]

Figure 4.2 depicts the return spillovers FROM each of the assets to the system. A high spillover from the assets toward the network could be seen except for gold.

The period of 2020 shows a spike in spillover from all the assets to the system depicting that they show similar behavior in the global pandemic situation.

This similarity in behavior could be a response to pandemic and uncertainity associated with it.All the asset classes are generally showing a high level of spillover from others during the uncertain period of pandemic The general trend shows that gold is not a receiver of spillovers and acts differently than the rest of the assets but during the pandemic time, it also recieves spillover from the system.



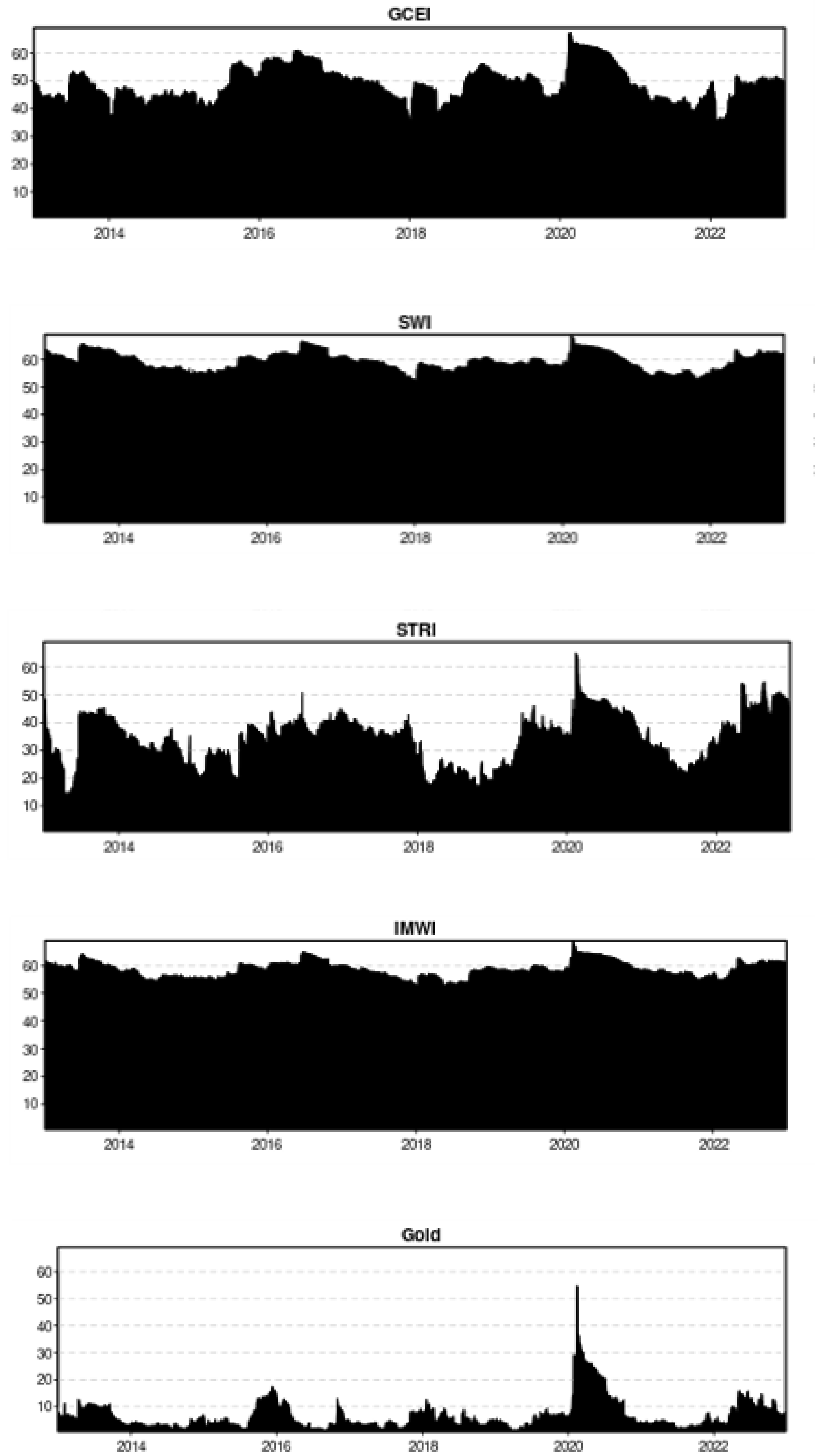


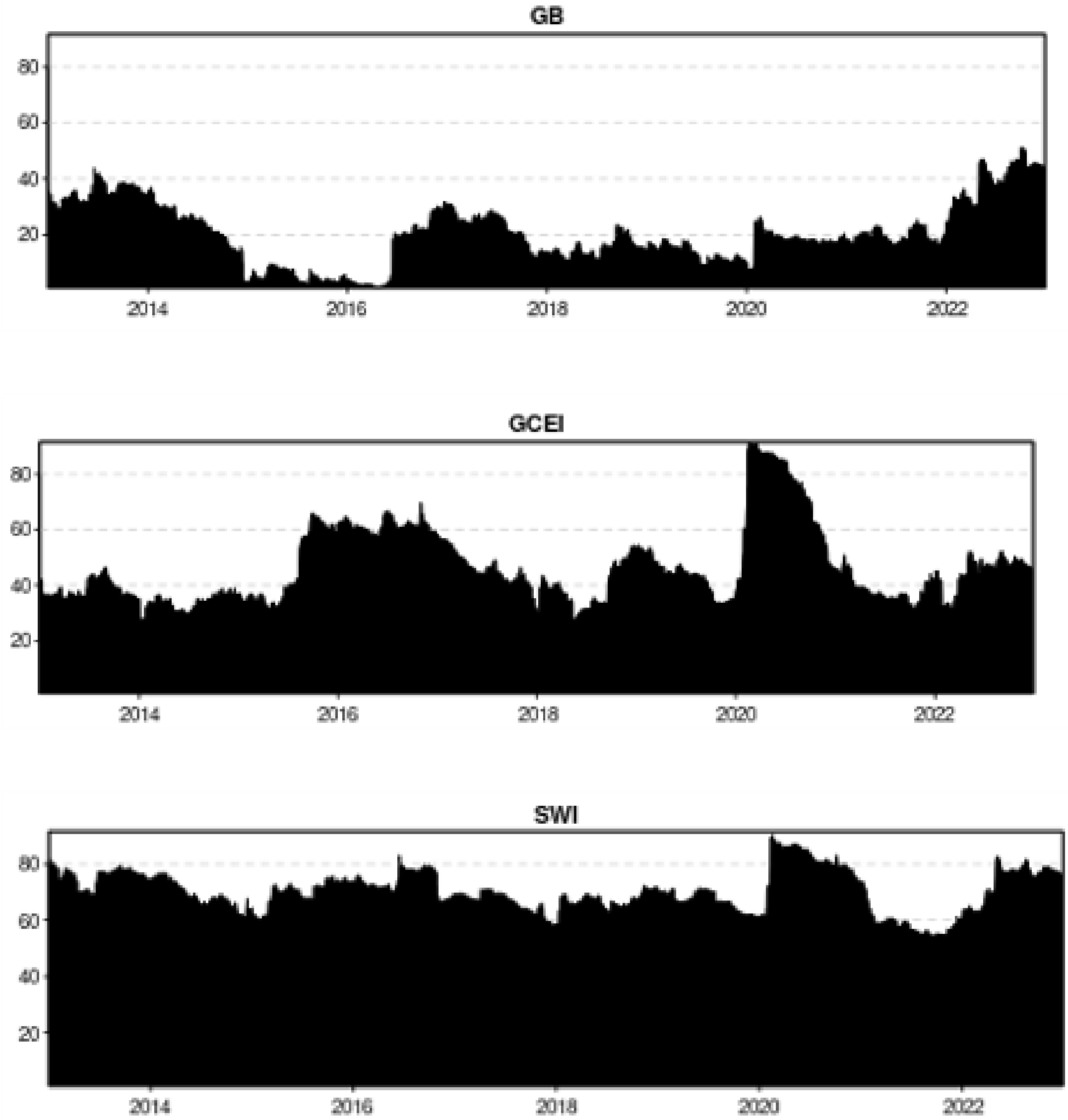
FIGURE 4.2: Directional connectedness FROM others. Full sample [Jan2013-Dec2022]

The return spillovers from the system TO the variables are shown in Figure 4.3. The results show a high spillover from the system to sustainable investments and

Islamic investments in the time-varying dynamics.Whereas, other variable show varying dynamics over time.These spillover indicate a relatively less connectedness among variables as their patterns are not similar.

The return spillover to the Shariah' compliant investments, clean energy investments and gold from market depicts an abrupt hike in the COVID 19 period specially during 2020. Some asset classes do not show any spillovers to other assets throughout the full sample, but a spike in spillover to others is seen during 2020s.

These trends depict that the level of connectedness increased in the pandemic situation. The figure also exhibits a decoupling trend of gold and green bonds from the system except for the COVID 19 period, explaining that there is low connectedness between system and these variables.



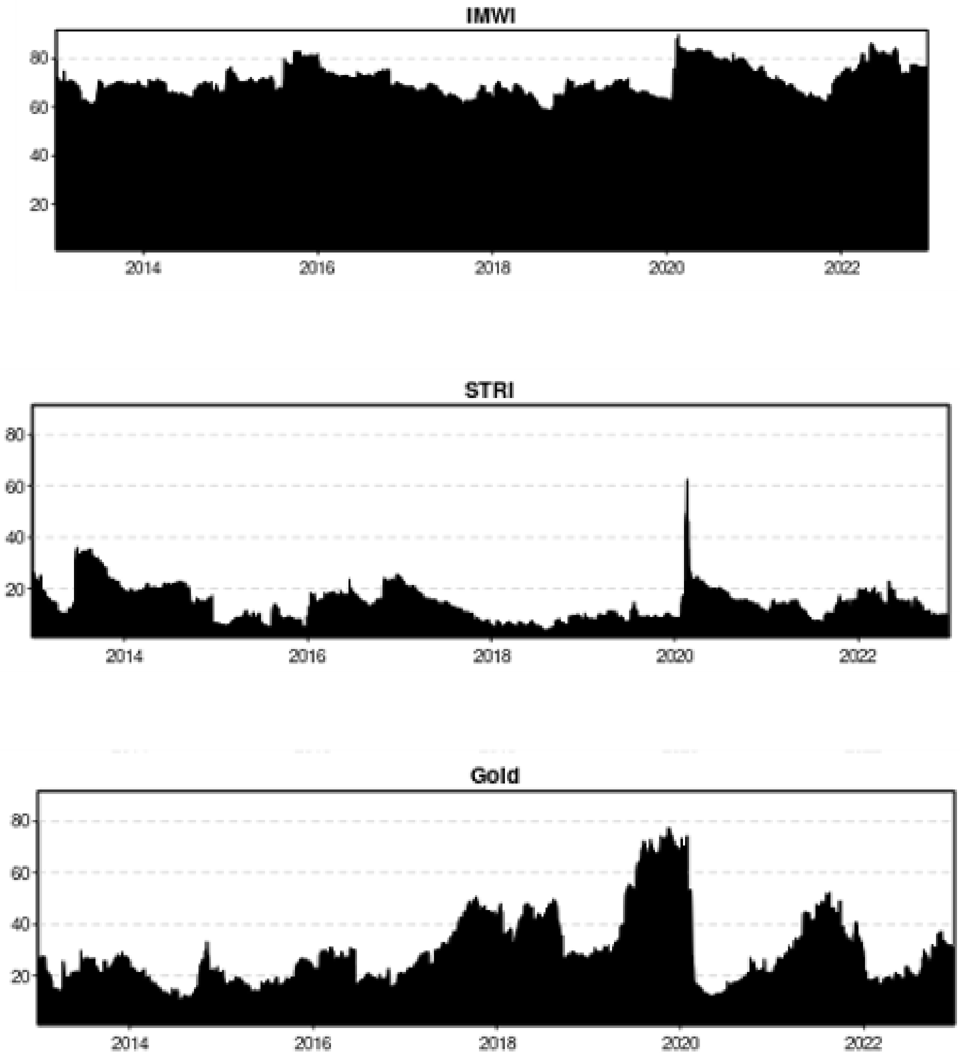
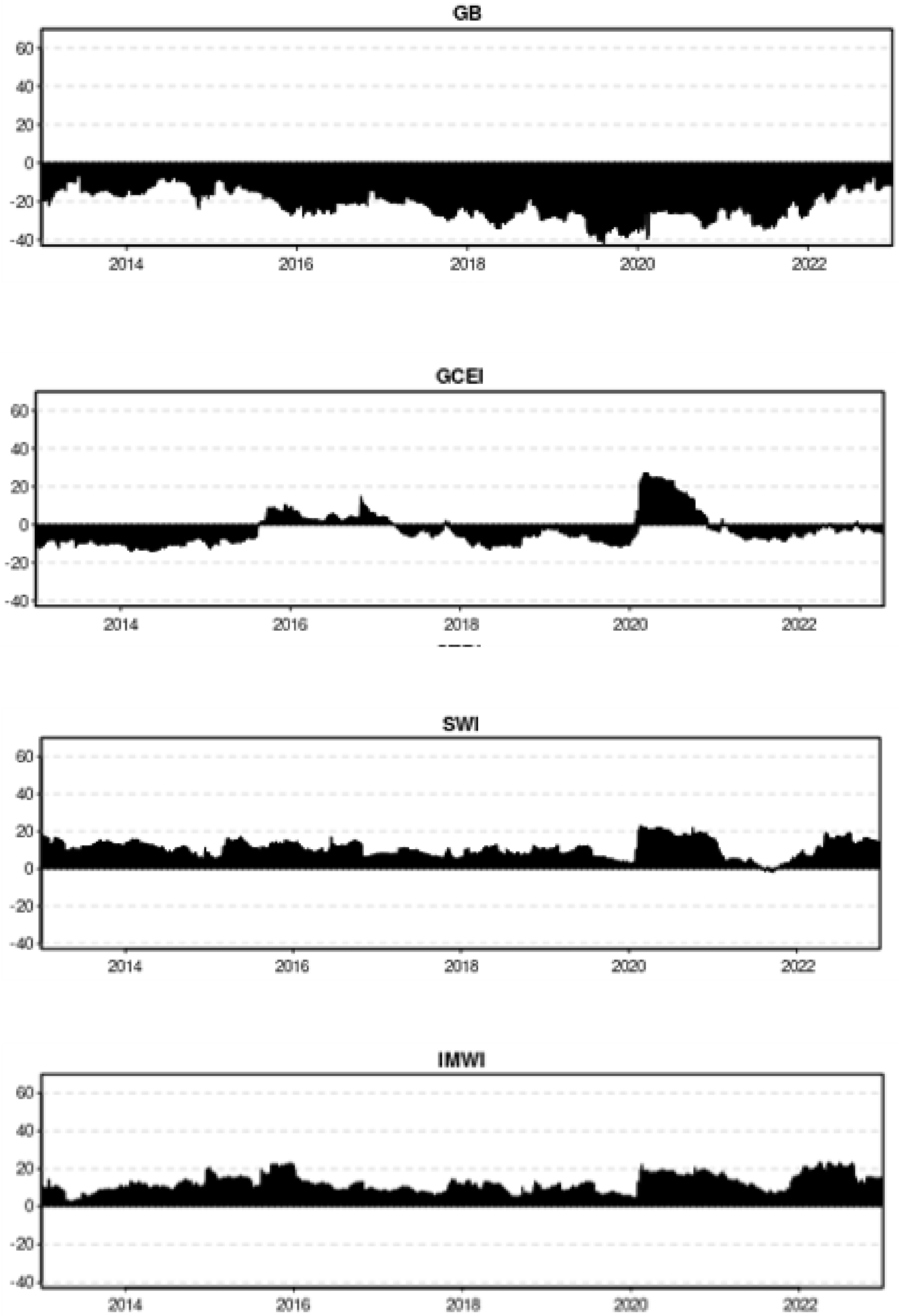


FIGURE 4.3: Directional connectedness TO others. Full sample [Jan2013-Dec2022]

Figure 4.4 depicts the net directional connectedness of all the asset classes in the complete sample period. The net directional connectedness of each market represents the difference in the shocks transmitted and received. The positive (negative) time-varying values of the market corresponds the net transmission (reception) of shocks along the time period.

Gold is a net transmitter of shock throughout the time-varying pattern except for 2020 where it behaves as a net receiver of shock due to COVID 19. Green bonds and Shariah compliant investments seem to have a persistent behavior as net recipient of shocks during the time-varying pattern. Whereas, sustainable and Islamic investments show a pattern of net transmission throughout the time-varying period.

On the other hand, clean energy investments behave as net receiver till 2015, where it changed role and acts as a net transmitter for a short time period, this shift in behavior could be traced to the global oil crises of 2015-2016, after the oil crises clean energy moves back to be the net recipient of shocks till the COVID-19 in 2020.



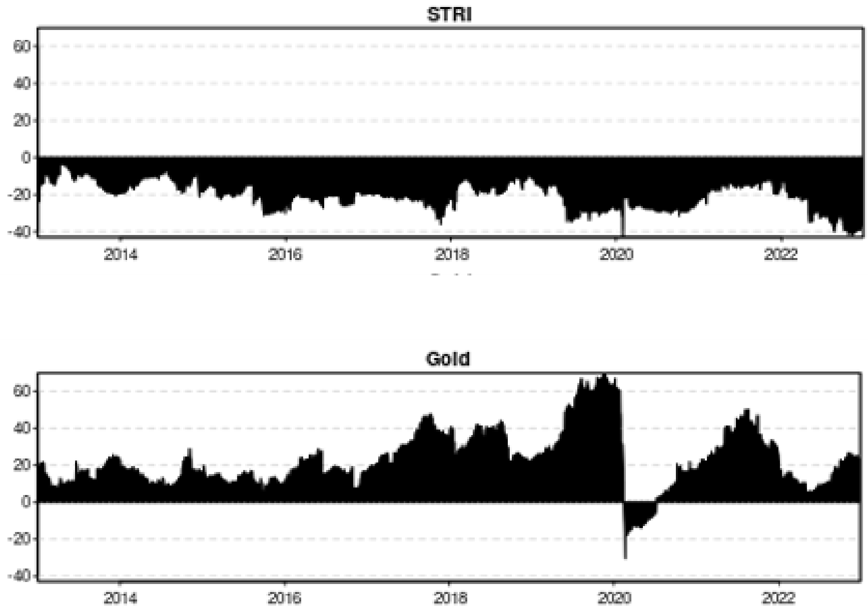


FIGURE 4.4: Net directional connectedness Full sample [Jan2013-Dec2022]

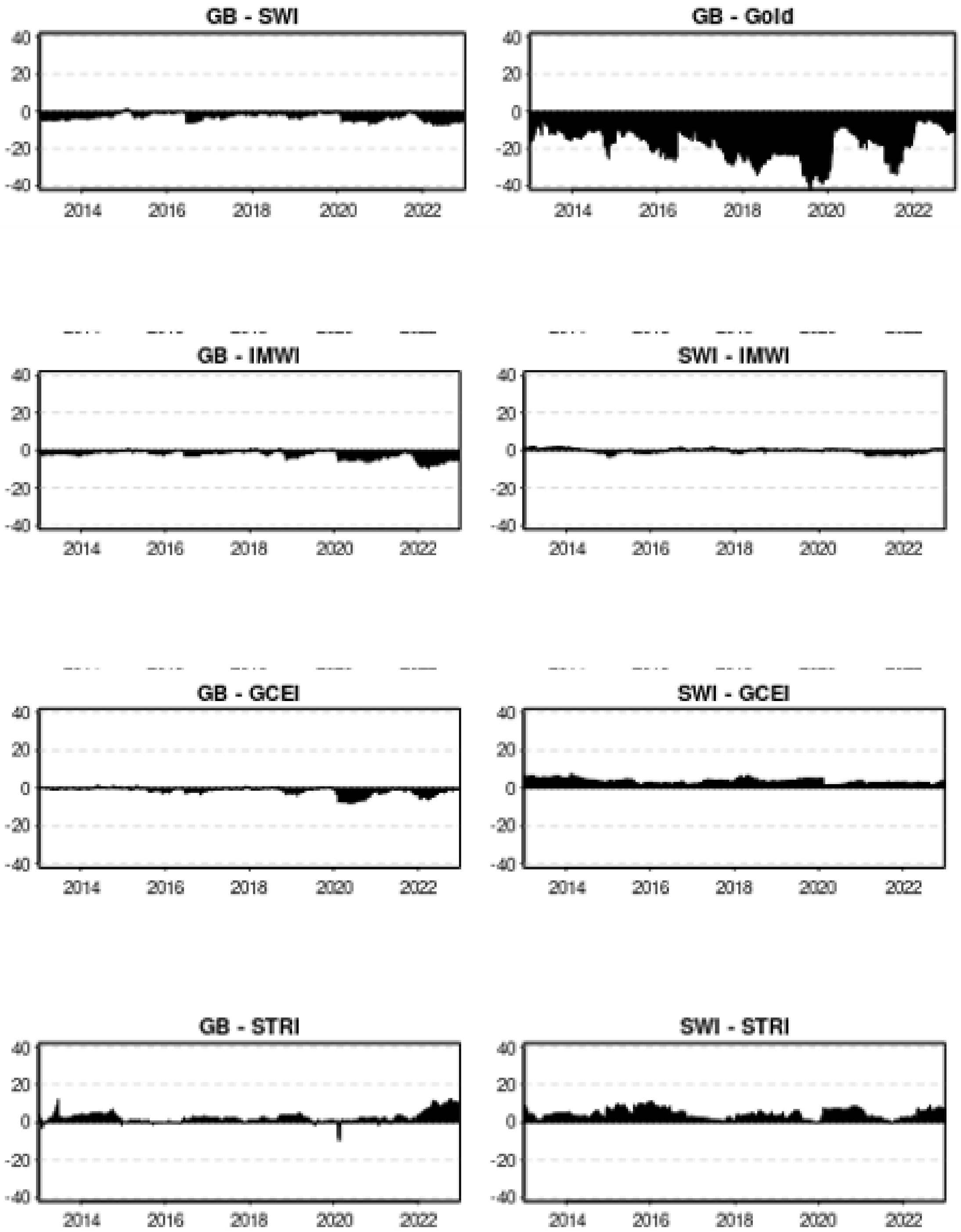
Finally, net pairwise connectedness is shown in Figure 4.5. We observed that the magnitude of spillover overall increased during the COVID-19 period. The results depicted confirm the aforementioned results that green bonds are the net recipient of shocks throughout the time period. The plots show the net receiver pattern of green bonds with other asset classes such as, sustainability investments, clean energy stocks, Islamic stocks and Gold.

The additional information provided while analyzing other asset classes is very interesting as sustainability investments, and Islamic stocks both transmit shocks to clean energy investments explaining that sustainability markets and Islamic markets have impact on clean energy indices. Furthermore, these inversely symmetric relationships could be used in future to articulate the hedging strategies focusing on the recipient-transmitter relationships.

The above results show a complete analysis of spillovers among all the asset classes and depicting practical implications regarding all the asset classes under consideration i.e. green finance, Islamic finance and sustainable investments in the time-varying pattern with periods of economic crises such as 2015-16 oil crises and 2020 pandemic.

Policy makers and investors can use the information for diversification strategies as our results depict that although all these assets aim for sustainable environment but have different dynamics. Investors could get a well diversified portfolio which will not only manage risk and give returns, but is also environment friendly and help in contributing towards attaing a better environment.

The Net pairwise connectedness results depict some interesting findings for the investors.Almost all the pairs of asset classes show very less to negative connectedness, making them very good options to use as portfolio diversifiers and investors benefit from them.



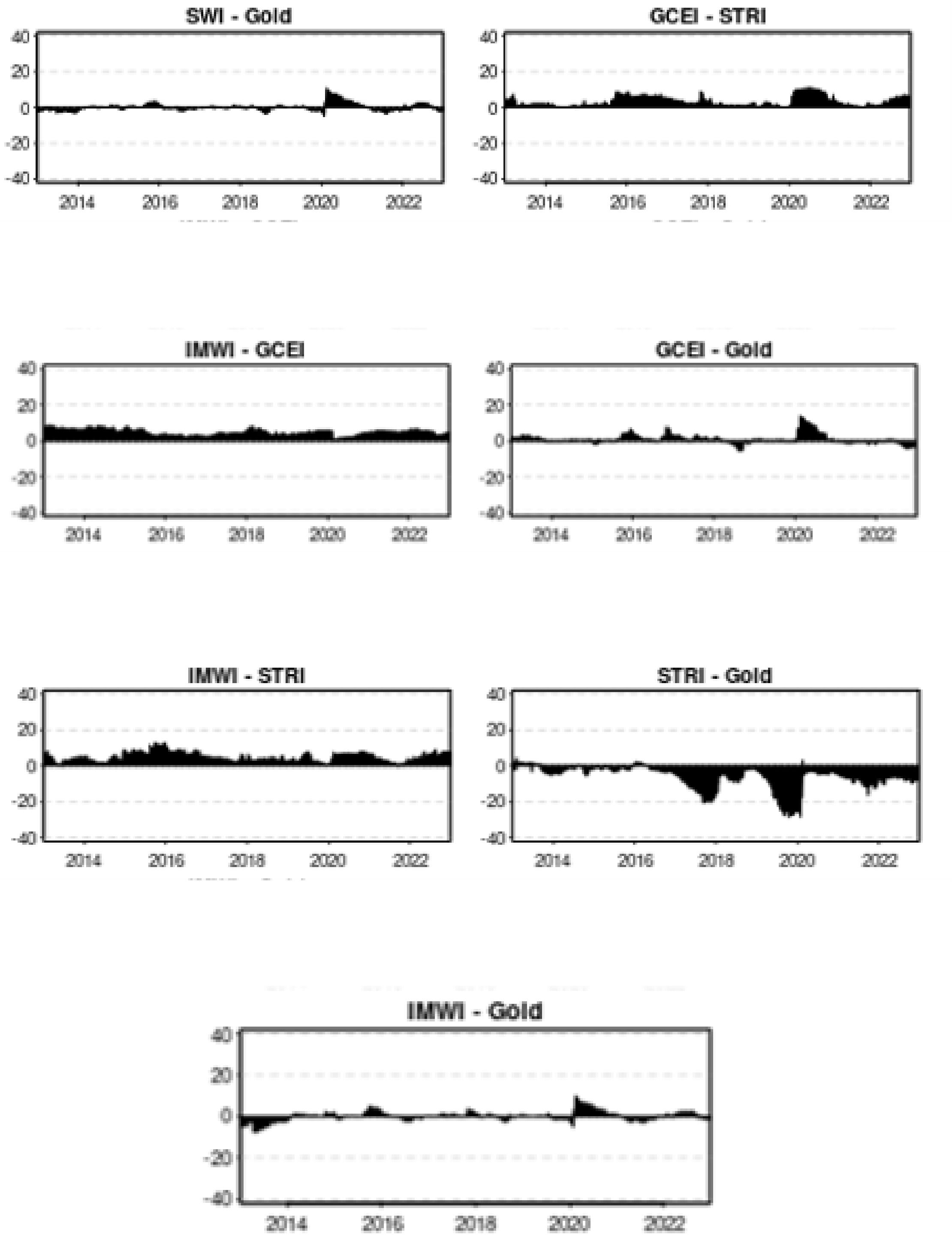


FIGURE 4.5: Net connectedness pairwise Full Sample [Jan2013-Dec2022]

The network plot of the full sample is shown in (Figure 4.6).

The network plot depicts that dynamic connectedness among all asset classes is weak.These weak linkages among assets provide diversification oppurtunities to the investors. Any strong linkages could not be identified among all the investment options. Only few assets,such as, shariah' compliant investments and Gold show linkages with other options.These results provide basis for investment in green,sustainable and Islamic asset classes to get diversification benefits alongwith environmental sustainability.

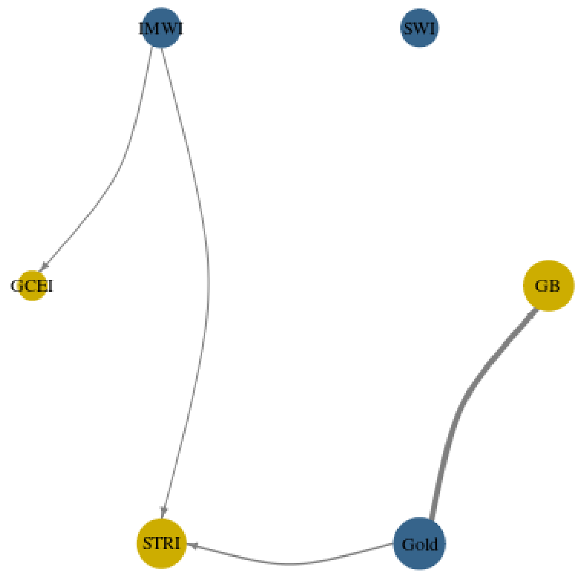


FIGURE 4.6: Network Plot [Jan2013-Dec2022]

4.5 Dynamic Connectedness among Green Finance, Sustainable, and Islamic Investments (Pre-COVID Analysis) [Jan 2013 - Dec 2019]

Table 4.5 explains the average dynamic connectedness among all the asset classes for the pre-COVID time period. The starting date of COVID-19 sample period is taken as January 13, 2020 as used by (Yousaf et al., 2022) and the same cut-off dates are used as done by (Bouri et al.,2021). The total dynamic connectedness index for pre-COVID depicts a value of 48.45%. These results indicate that the interdependence among all the returns have not been significantly high in the pre-COVID. The total dynamic connectedness is same for pre-Covid as for the whole sample. It depicts that the only varying factor might be the global pandemic. The results from average dynamic connectedness table also indicate that green bonds are not a transmitter of net volatility for pre-COVID state rather act as net recipient (-20.83%).

Similarly, clean energy stocks, (-5.06%) and Shariah' compliant investments, (-18.72.26%) are also showing the behavior as net recipients of shocks.

Gold shows to be the highest net transmitter of shocks to all the other asset classes (24.44%) which indicates that gold is a good predictor of all other asset classes.

Table 4.5: Averaged dynamic connectedness table pre-COVID [Jan2013-Dec2019]

	GB	SWI	IMWI	GCEI	STRI	Gold	FROM
GB	61.26	7.11	3.66	2.82	5.7	19.45	38.74
SWI	4.89	40.61	34.49	16.7	2.26	1.03	59.39
IMWI	2.47	34.55	41.83	17.67	2.21	1.27	58.17
GCEI	2.2	20.69	22.57	51.36	2.23	0.95	48.64
STRI	7.48	6.28	6.75	4.76	67.85	6.88	32.15
Gold	0.87	0.71	0.93	1.62	1.02	94.85	5.15
TO	17.91	69.34	68.4	43.58	13.43	29.59	242.24
Inc.Own	79.17	109.95	110.23	94.94	81.28	124.44	cTCI/TCI
NET	-20.83	9.95	10.23	-5.06	-18.72	24.44	48.45/40.37
NPT	1	4	3	3	0	4	

GB=Green bonds, SWI=socially responsible investments, IMWI=Islamic investments, STRI=Shariah compliant investments, Gold = gold

The total dynamic connectedness shown in Figure 4.7 demonstrates the total connectedness index for the pre-COVID period based on TVP-VAR approach.

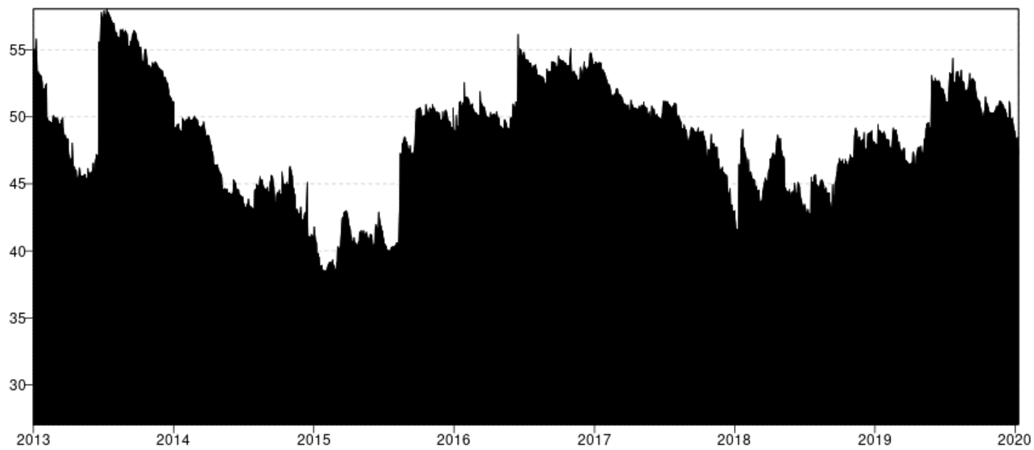
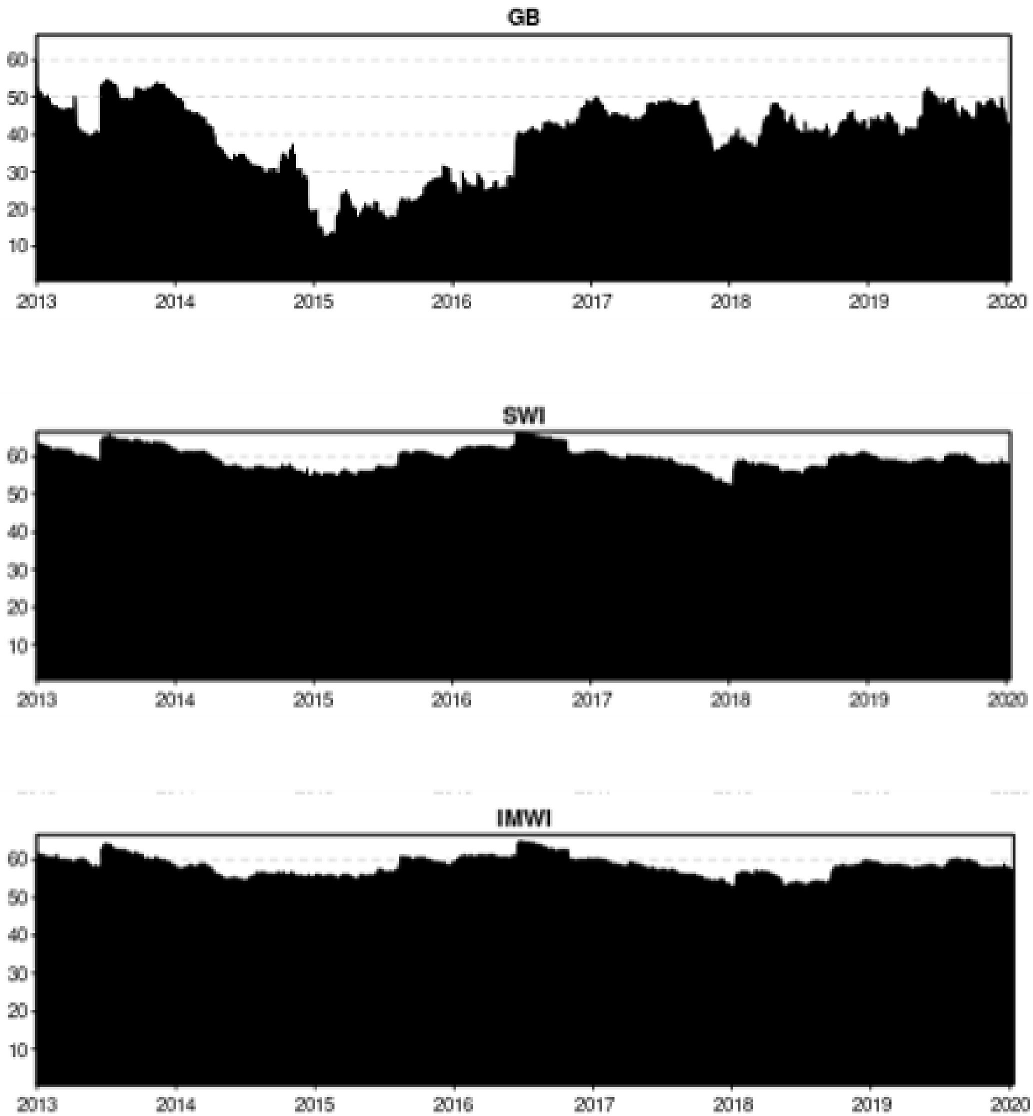


Figure 4.7: Total Dynamic Connectedness Pre-Covid [Jan2013-Dec2019]

It can be seen that the connectedness is fluctuating in 2015 and going down till 37% due to oil crises, but for the rest of the time periods all the asset classes show time-varying increase in connectedness implying that investors must constantly revise their portfolios. A significantly high level of connectedness could be seen among all assets at beginning of 2020. This spike could be explained by COVID-19 outbreak where all the assets responded similarly to this global pandemic.

Figure 4.8 depicts the return spillovers FROM other variables to the system in pre-covid dataset. These results are consistent with those of full sample as here a high spillover from the assets toward the network could be seen except for gold.

Assets like Islamic investments and sustainability investments show a considerably high spillover from the system predicting that these assets are acting like recipients of shocks. While green bonds, clean energy and Shariah' compliant investments fluctuating trend as recipients. The general trend shows that gold is not a receiver of spillovers and acts differently than the rest of the assets.



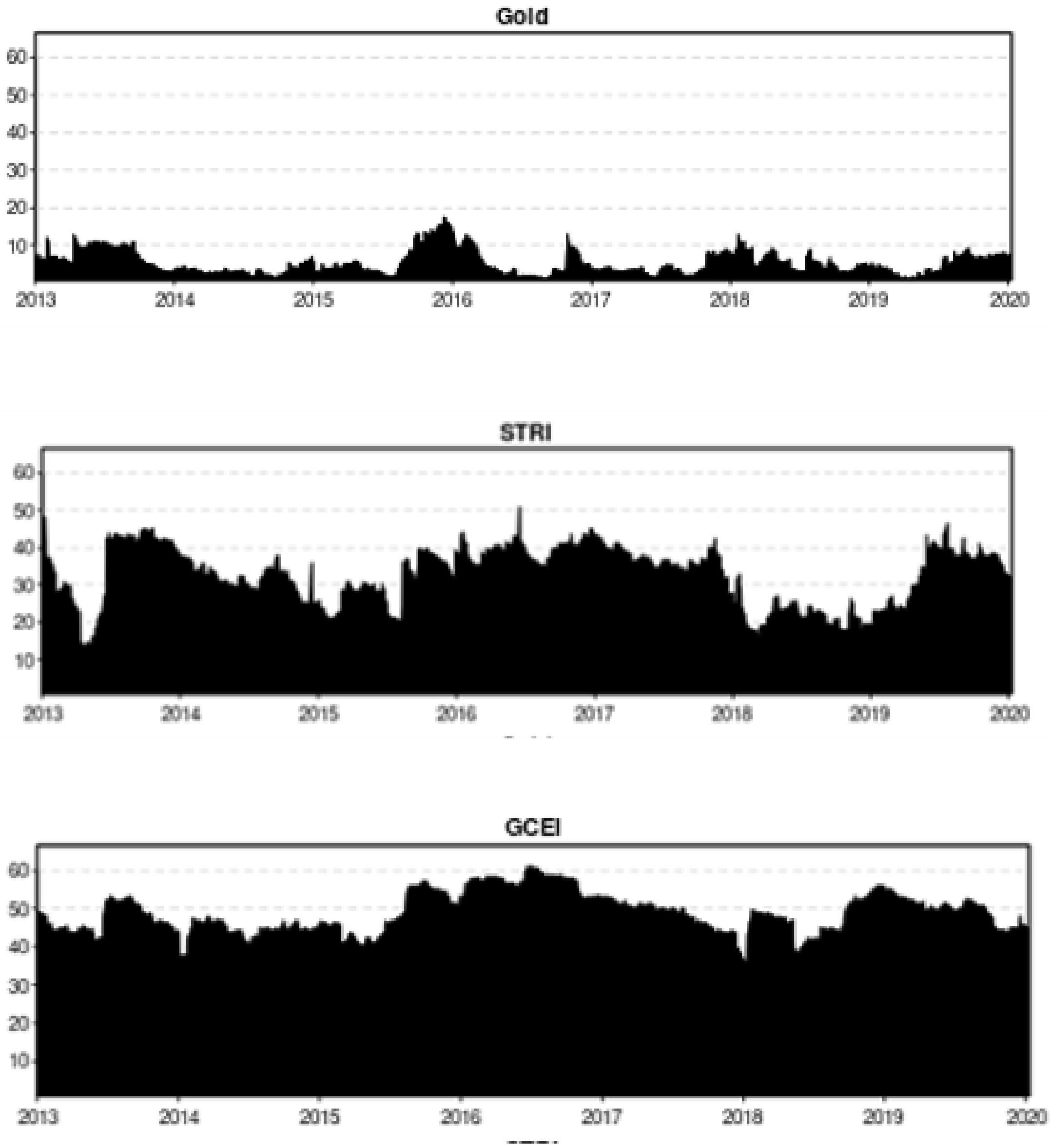
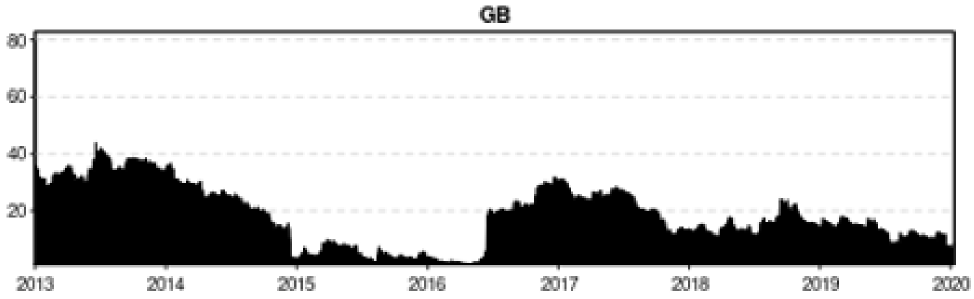


FIGURE 4.8: FROM Others Pre-Covid [Jan2013-Dec2019]

The return spillovers from the system TO variables are shown in Figure 4.9. We observe high spillover from the system to sustainable investments and Islamic investments in the time-varying dynamics. The return spillover to the green bonds, clean energy and Shariah' compliant show that they are weak transmitters of shock. On the other hand, gold shows an abrupt hike in the behavior as transmitter of shocks in late 2019 and at start of 2020 with the appearance and spread of pandemic, bringing uncertainity and panic to the investors.

These weak linkages among assets provide diversification oppurtunities to the investors. Any strong linkages could not be identified among all the investment options.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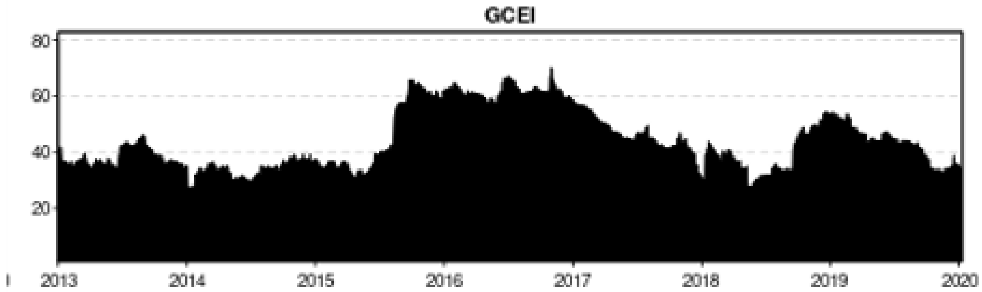
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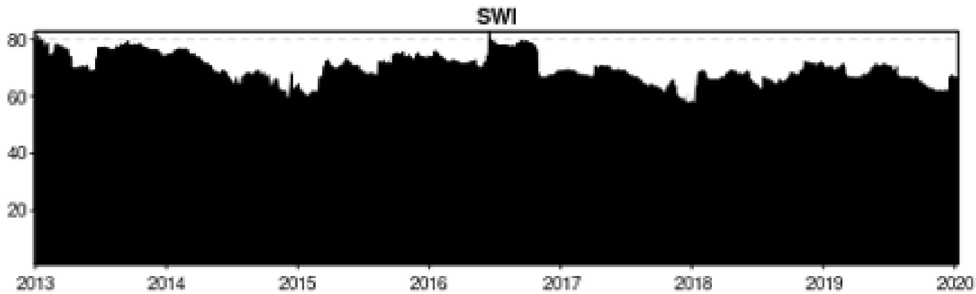
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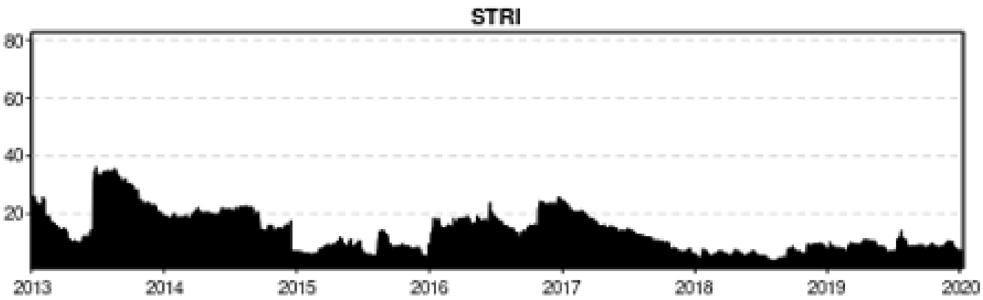
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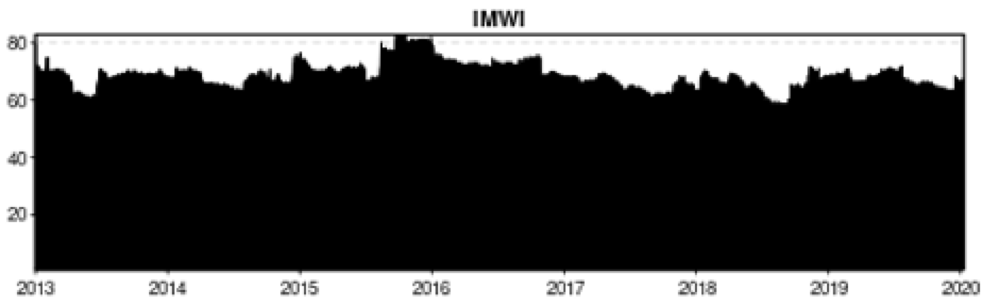
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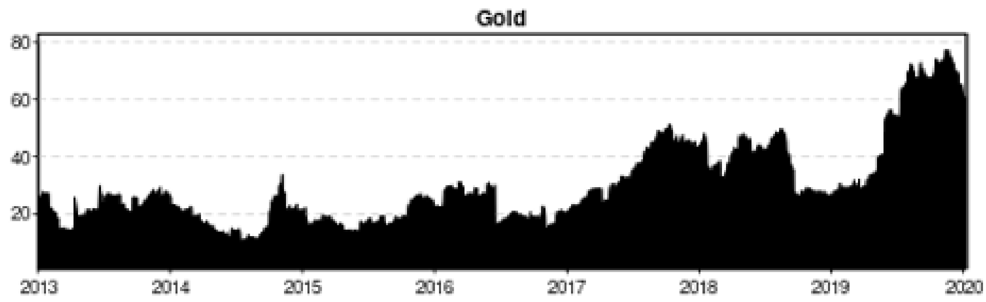


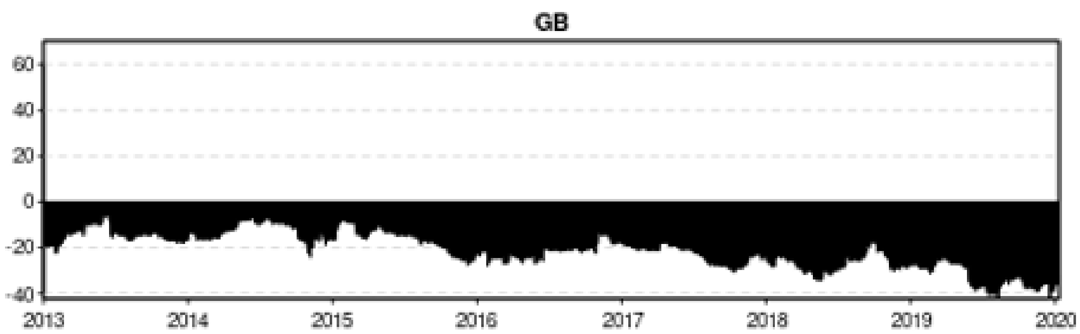
Figure 4.9: TO Others Pre-Covid [Jan2013-Dec2019]

Figure 4.10 depicts the net directional connectedness of all the asset classes in the pre-COVID sample period. The net directional connectedness of each market represents the difference in the shocks transmitted and received. The positive (negative) time-varying values of the market corresponds the net transmission(reception) of shocks along the time period.

On the basis of the above results, it can be concluded that Islamic investments, sustainable investments and Gold act as net transmitters of shock throughout the time-varying pattern.

Whereas, the level of shock transmission by gold has an increasing trend specifically towards the start of pandemic situation. Green bonds and Shariah' compliant investments show a persistent behavior as net recipient of shocks during the time-varying pattern.

Clean energy investments depict a varied pattern where it behaves as net receiver till 2015, where it changed role and acts as a net transmitter for a short time period, this shift in behavior could be traced to the global oil crises of 2015-2016, after the oil crises, clean energy investments move back to be the net recipient of shocks till the COVID-19 in 2020.



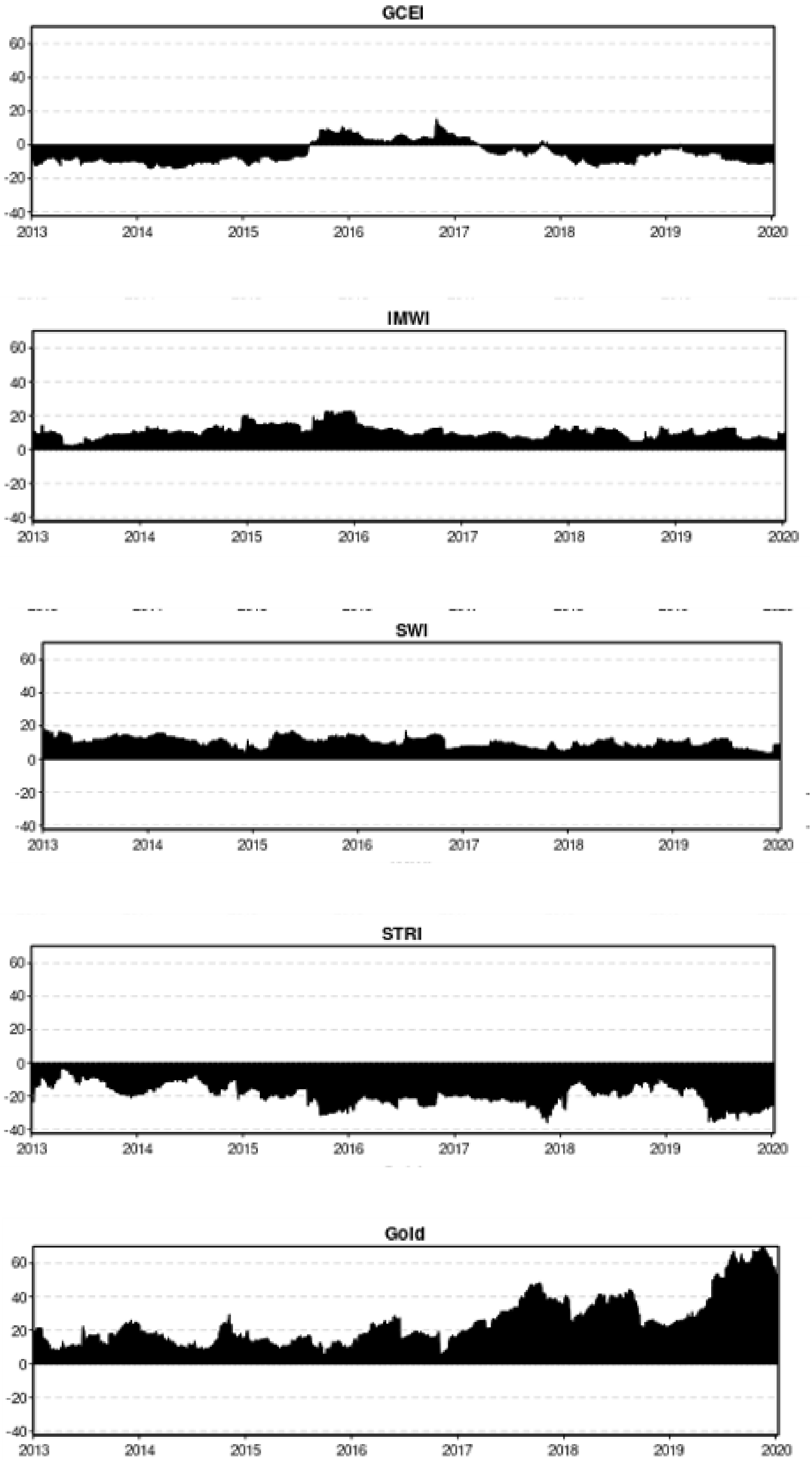
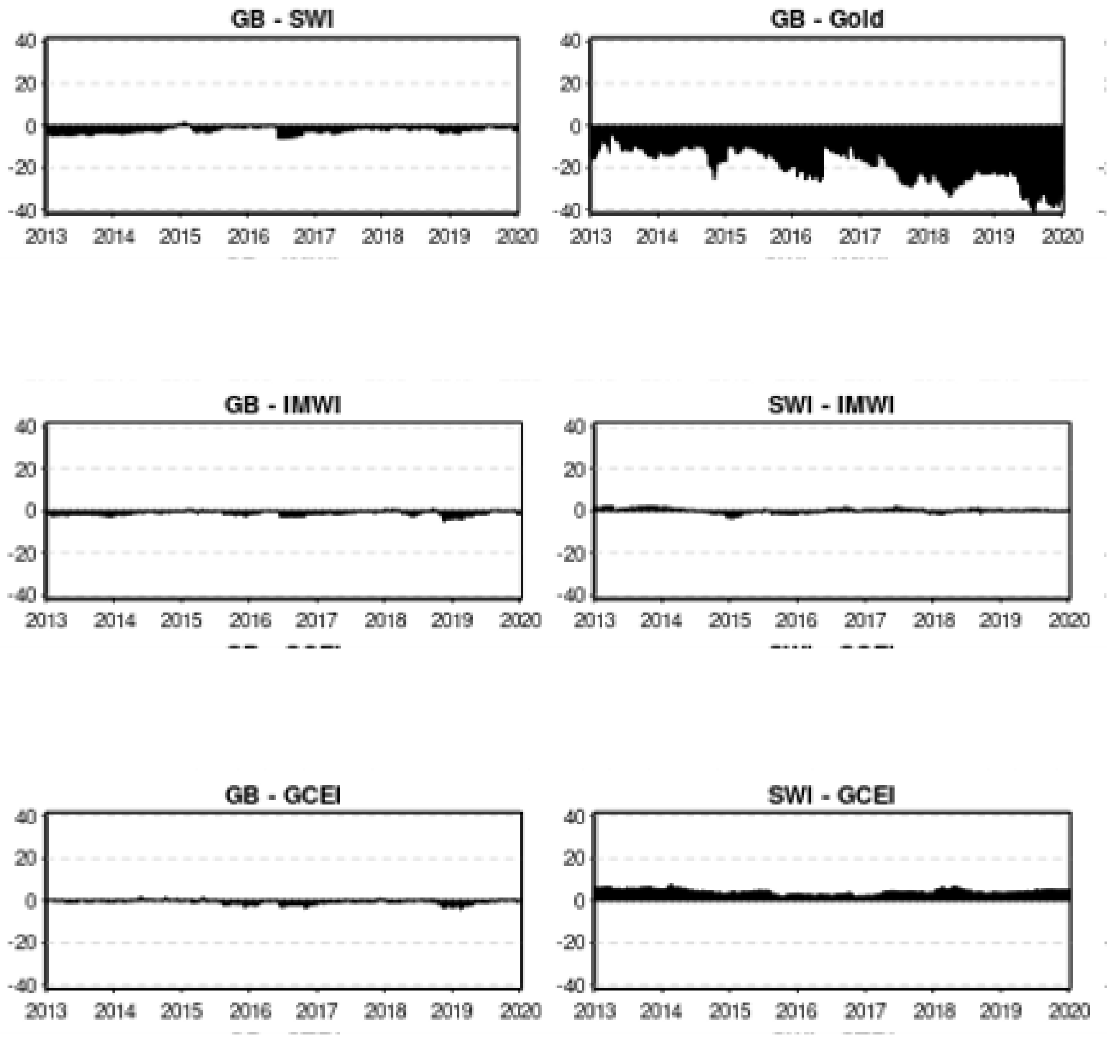
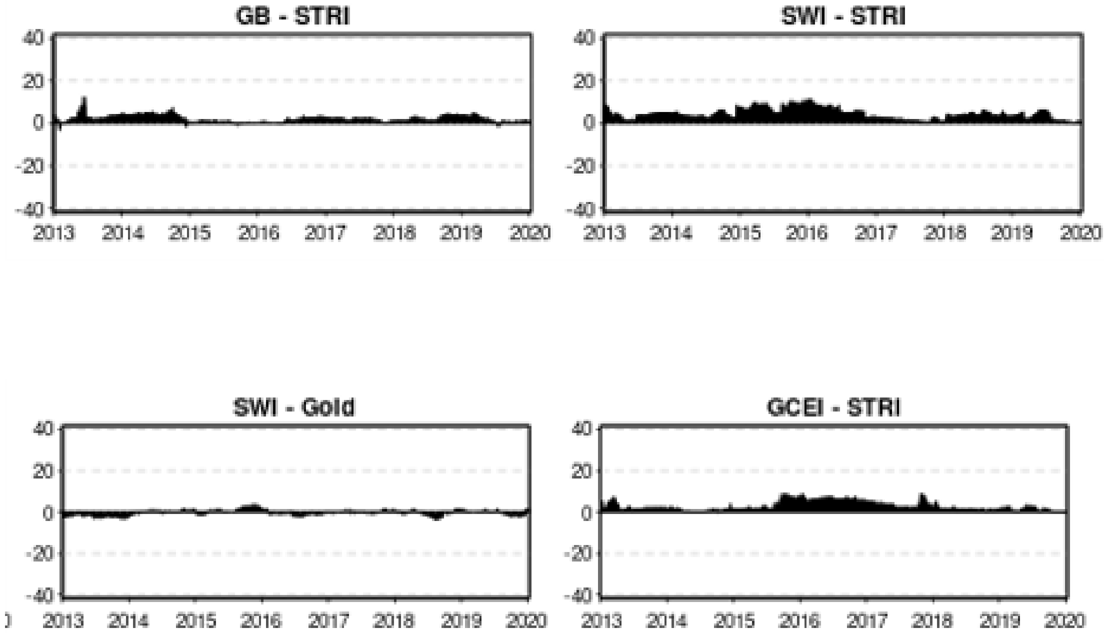


FIGURE 4.10: Net Connectedness Pre-Covid[Jan2013-Dec2019]

Finally, net pairwise connectedness for the pre-Covid sample is shown in Figure 4.11.

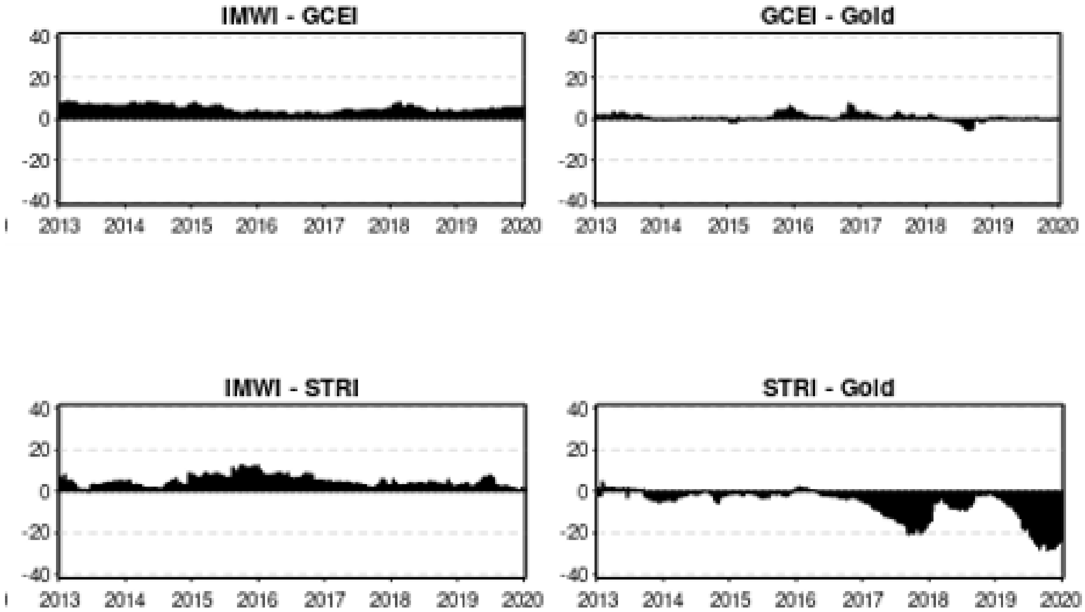
The results confirm the results that green bonds are the net recipient of shocks throughout the pre-COVID time period. The plots show the net recipient pattern of green bonds with other asset classes such as, sustainability investments, clean energy investments and Islamic stocks and Gold. The additional information provided while analyzing other asset classes is very interesting as sustainability investments and Islamic stocks both transmit shocks to clean energy investments explaining that sustainability markets and Islamic markets have impact on clean energy indices. Furthermore, these inversely symmetric relationships could be used to articulate the hedging strategies focusing on the recipient-transmitter relationships. As none of the net pairwise relationship shows strong connectedness, hence these pairs could be potentially better options for portfolio investments.





These results present practical implications regarding green finance, Islamic finance and sustainable investments in the time-varying pattern in the pre-COVID period.

Investors could use the insights provided in the results for optimal risk management and portfolio diversification using green investment options. Investors could achieve a diversified and environment friendly portfolio by using optimal weights and strategies using these assets in their portfolios.



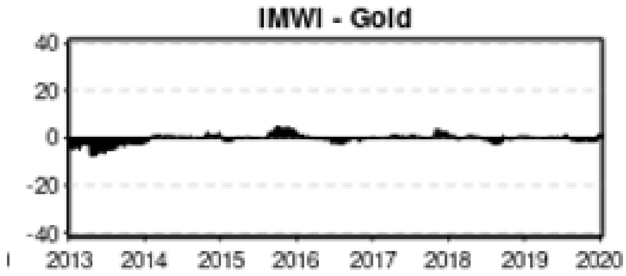


Figure 4.11: Net Pair-wise Connectedness Pre-Covid [Jan2013-Dec2019]

The network plot of pre-COVID sample shows weak connectedness among all variables.It can be clearly noticed that before pandemic, the level of connectivity among these asset classes was very low.Such asset classes could be a better option for portfoilio diversification.

It can also be deducted that there is more connectedness in the full sample network plot, as compared to pre-COVID network plot.This could be due to the changes in the investment patterns during pandemic.

The results indicate that the interdependence among all the returns have not been significantly high in the pre-COVID period.

The total dynamic connectedness is same for pre-Covid as for the whole sample. The total dynamic connectedness is fluctuating in 2015 due to oil crises, but for the rest of the time periods all the asset classes show time-varying increase in connectedness implying that investors must constantly revise their portfolios.

A significantly high level of connectedness could be seen among all assets at beginning of 2020. This spike could be explained by COVID-19 outbreak where all the assets responded similarly to this global pandemic.These strong linkages among assets provide justification that assets behave in similar manner in COVID providing less oppurtunities to the investors. Any strong linkages could not be identified among all the investment options during full sample but pandemic sample shows contrasting results.Strong linkages could not be identified among all the investment options Shariah' compliant investments and Gold show linkages with other options. Clean energy investments and Islamic investments also show a linkage but are not associated to other assets.The network plot for pre-Covid period is shown in Figure 4.12.

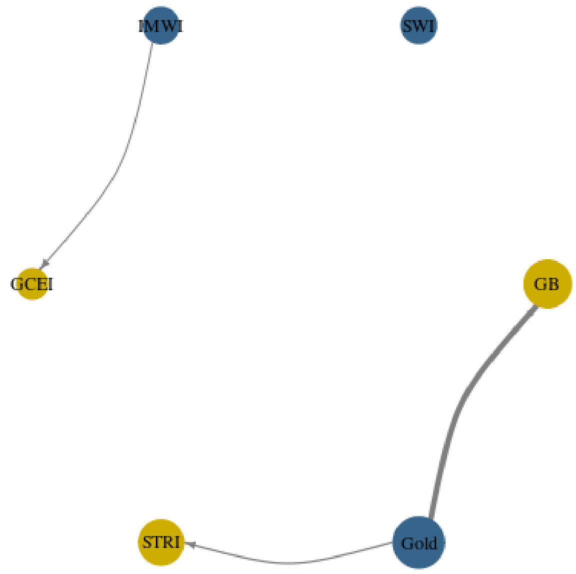


FIGURE 4.12: Network Plot Pre-Covid [Jan2013-Dec2019]

4.6 Dynamic Connectedness among Green Finance, Sustainable Investments and Islamic Investments during Covid [Jan2020-Dec2022]

Table 4.6 explains the average dynamic connectedness among all the asset classes for the COVID-19 sample period. The total dynamic connectedness index depicts that connectedness has increased in the pandemic situation noticeably. The TCI has increased up to 74.27%. These results also indicate that GBI is not a transmitter of net volatility but net recipient (-18.61%).

Similarly, Shariah' compliant investments (-17.65.26%) also continue to show a net recipient behavior as in the pre-COVID sample and full sample. On the other hand, assets such as, clean energy investments which have been showing a net recipient pattern in other two sample periods have shown a minimal transmitting value (2.69%).

In comparison to pre-COVID sample and full sample,the TCI of COVID sample is significantly high.The values of cTCI for other two samples were 48% and 49% respectively.Whereas, TCI of COVID is 74.27%.This increase in TCI shows that global events like pandemic could effect the regular pattern of assets.

TABLE 4.6: Averaged dynamic connectedness table during Covid [Jan2020-Dec2022]

	GB	SWI	IMWI	GCEI	STRI	Gold	FROM
GB	36.32	11.45	10.15	9.48	15.77	16.83	63.68
SWI	6.16	33.07	31.8	16.14	7.65	5.17	66.93
IMWI	5.26	29.96	33.47	18.2	7.57	5.54	66.53
GCEI	5.72	18.87	21.7	39.59	7.89	6.23	60.41
STRI	15.36	14.04	14.26	10.87	32.57	12.9	67.43
Gold	12.57	7.34	7.16	8.41	10.89	53.63	46.37
TO	45.07	81.66	85.07	63.1	49.78	46.67	371.35
Inc.Own	81.39	114.73	118.54	102.69	82.35	100.3	cTCI/TCI
NET	-18.61	14.73	18.54	2.69	-17.65	0.3	74.27/61.89
NPT	0	4	5	3	1	2	

GB=Green bonds, SWI=socially responsible investments, IMWI=Islamic investments, STRI=Shariah compliant investments, Gold = gold

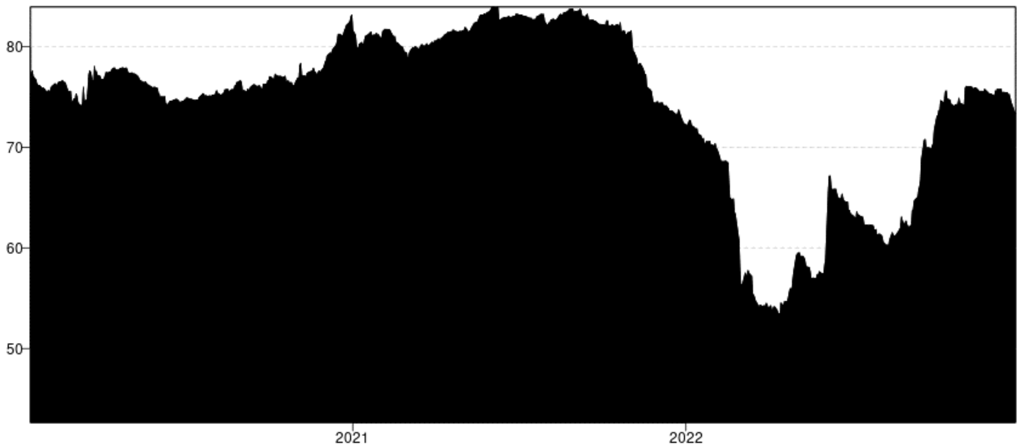
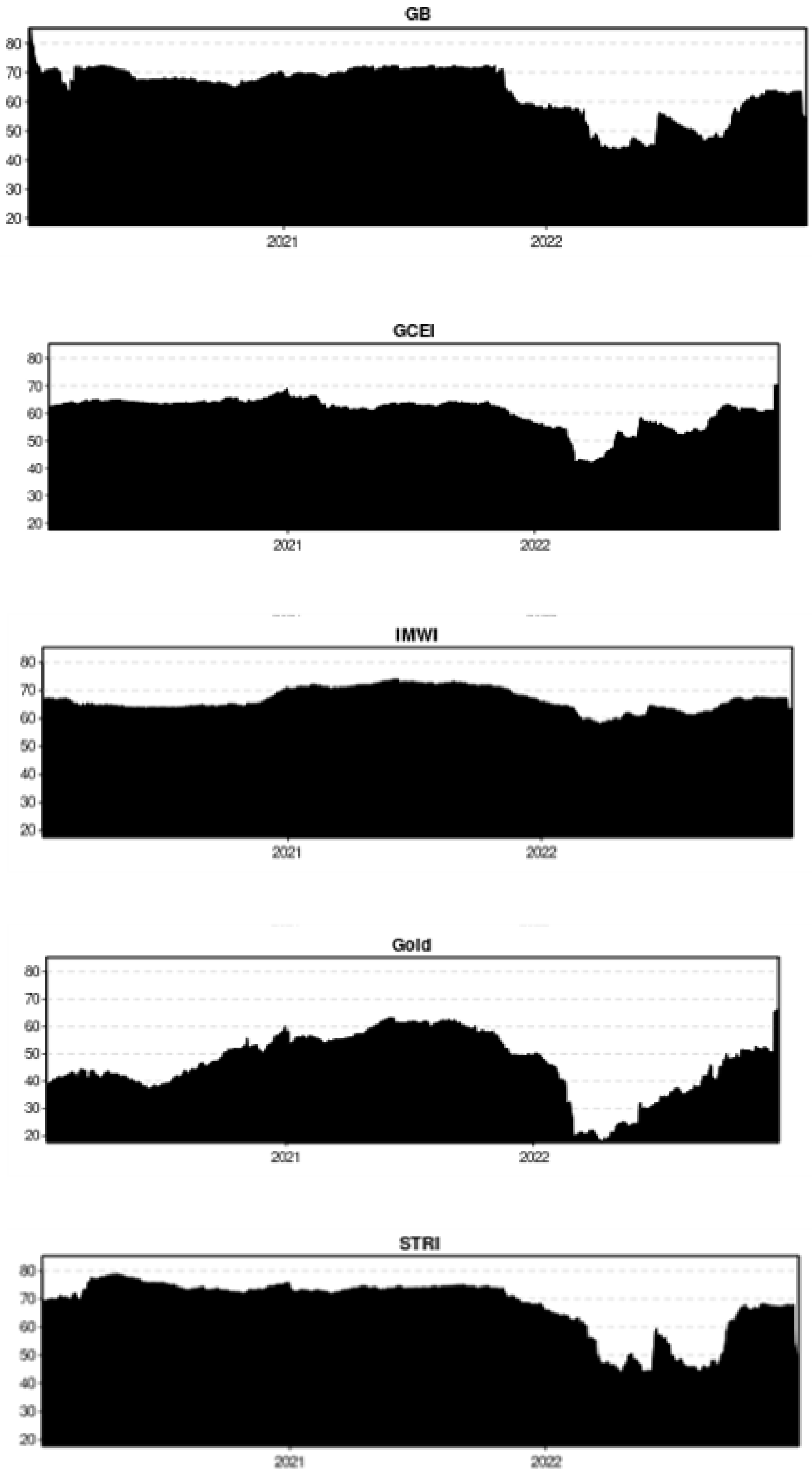


FIGURE 4.13: Dynamic Total connectedness During Covid [Jan2020-Dec2022]

The total dynamic connectedness shown in Figure 4.13 demonstrates the total connectedness index based on TVP-VAR approach for the pandemic period. A significantly high level of connectedness could be seen among all assets. But, a decrease in connectedness can be noticed during the early 2022 as the pandemic was almost diminishing, but with rise of COVID case in China during the later part of 2022, the perception of pandemic was sensed again resulting as a spike in connectedness.

Figure 4.14 depicts the return spillovers FROM each of the assets to the system. The period of pandemic shows a spike in spillover from all the assets to the system depicting that they show similar behavior in the global pandemic situation. The general trend shows that gold is not a receiver of spillovers and acts differently than the rest of the assets but in the covid situation it is also receiving shocks from the system.



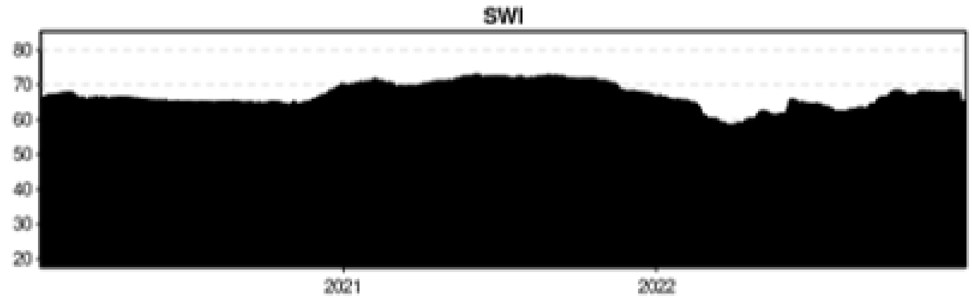
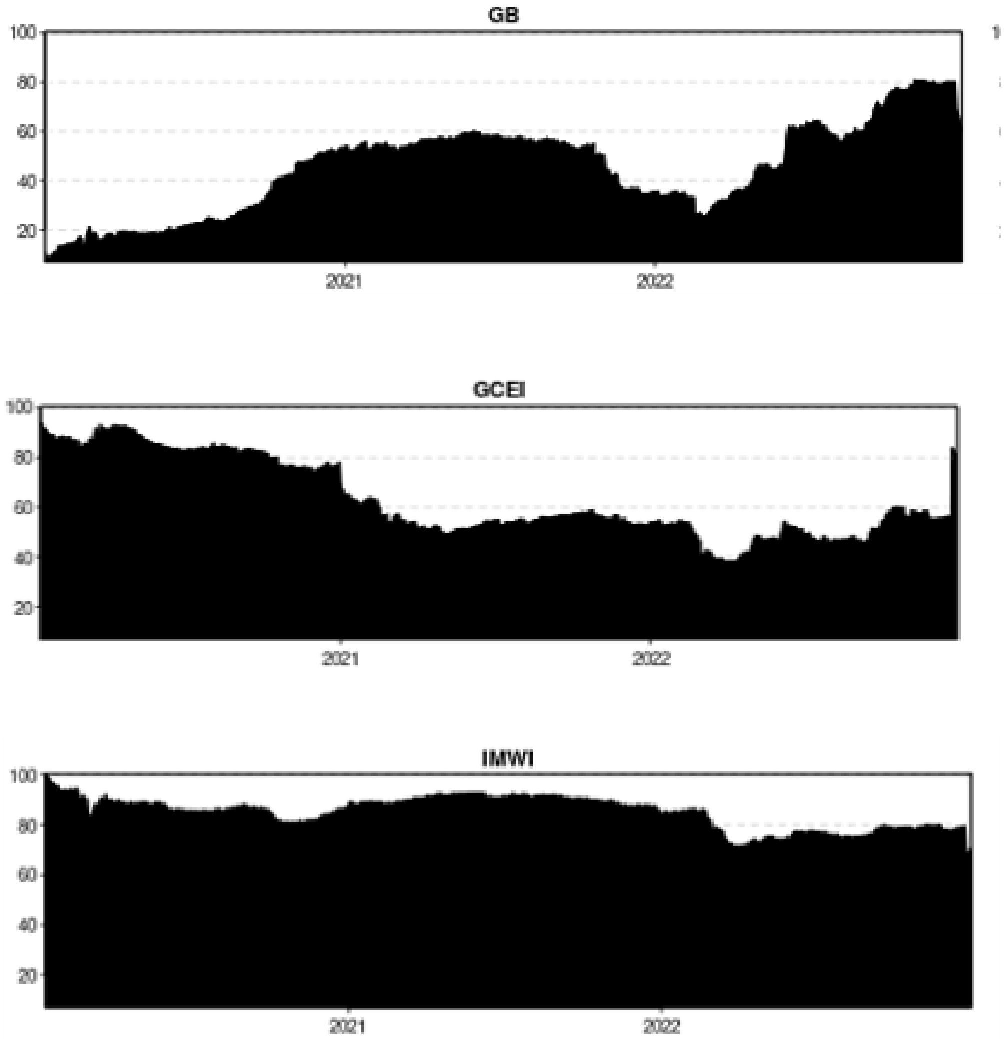


FIGURE 4.14: FROM Others During Covid [Jan2020-Dec2022]

The return spillovers from the system TO the variables are shown in Figure 4.15. We observe high spillover from the system to all the asset classes under the time-varying dynamics of covid period.

The results in the figure also exhibits a decoupling trend of Gold from the system except for the early 2022 period, explaining that there is low connectedness between system and these variables.



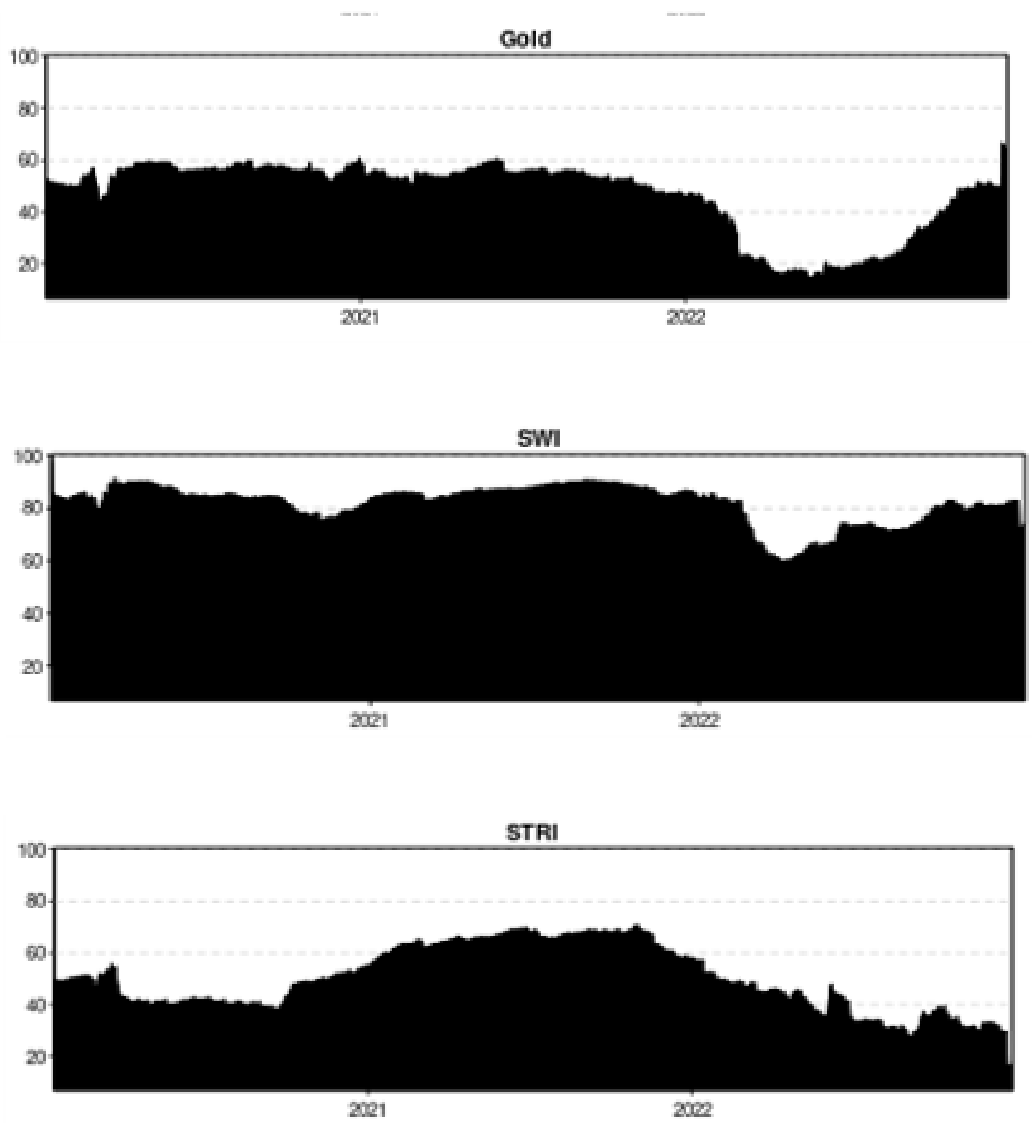
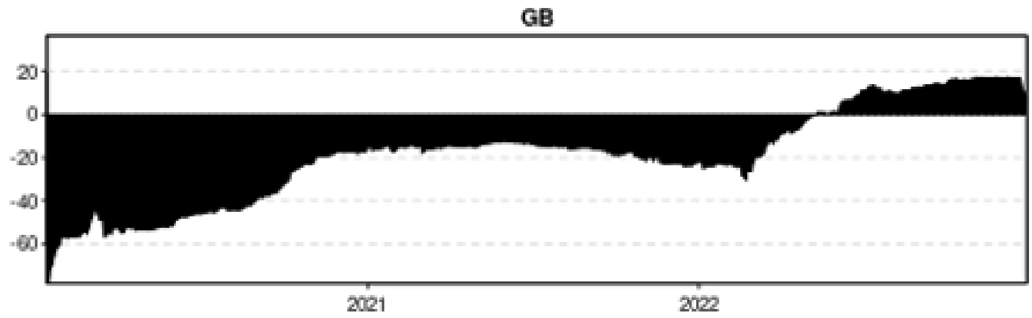


Figure 4.15: TO Others During Covid [Jan2020-Dec2022]

Figure 4.16 depicts the net directional connectedness of all the asset classes in the covid sample period. The results show that gold acts as a net transmitter of shock in the early pandemic period whereas shifts its behavior as a recipient in the late 2022. These results are in contrast to those shown by full sample and pre-COVID sample showing that COVID has affected the behavior of gold as a safe haven during the pandemic.

Green bonds and Shariah' compliant investments seem to have a persistent behavior as net recipient of shocks during the time-varying pattern. Whereas, sustainability investments and Islamic investments show a pattern of net transmission throughout the period. All the assets are depicting different patterens confirming less connectedness and a good options for portfolio diversification.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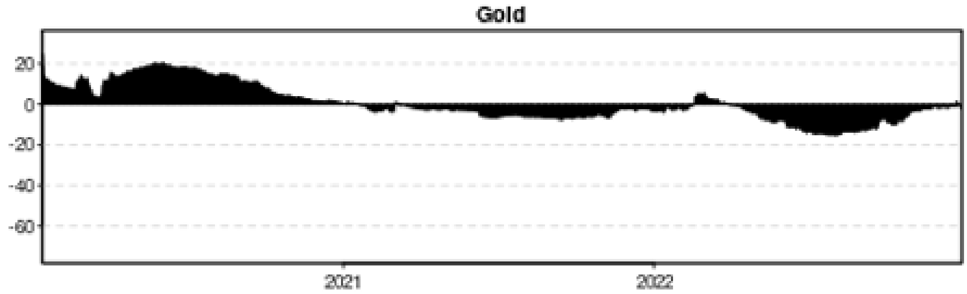
Gold
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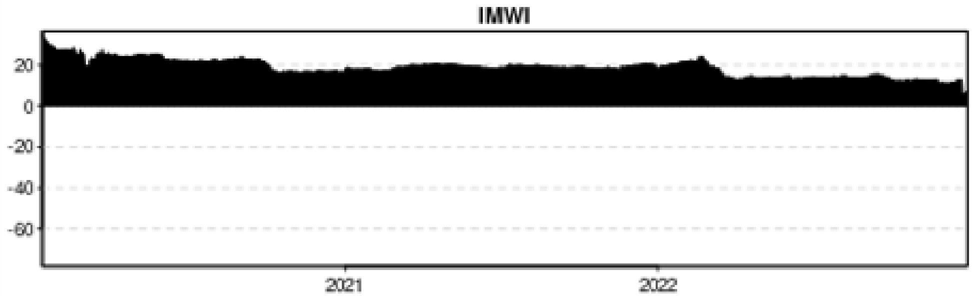
IMWI
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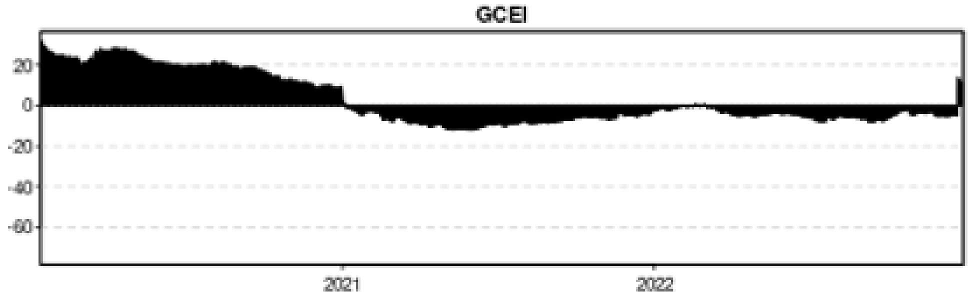
GCEI
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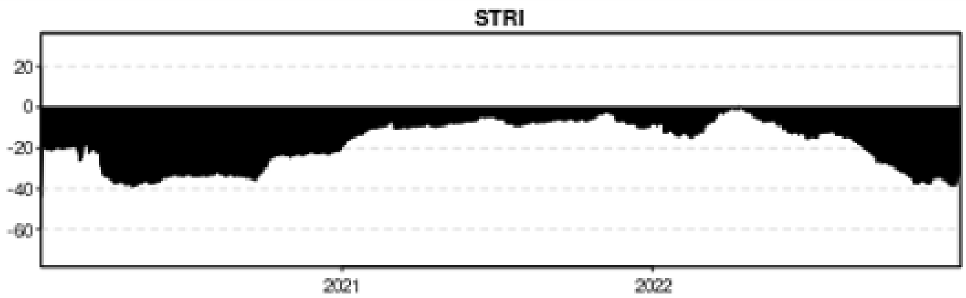
STRI
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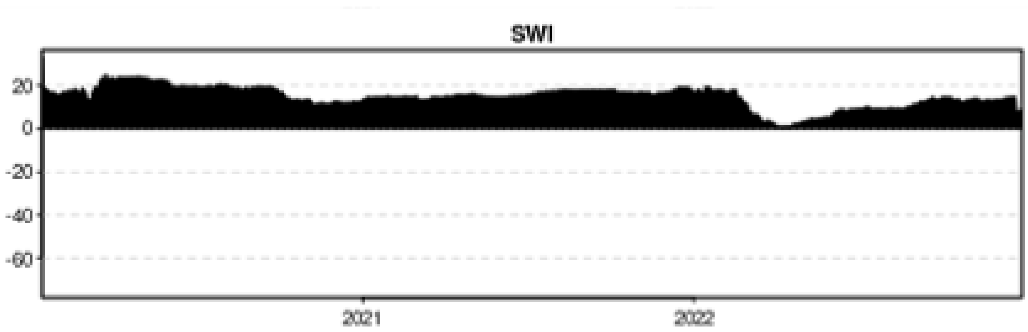
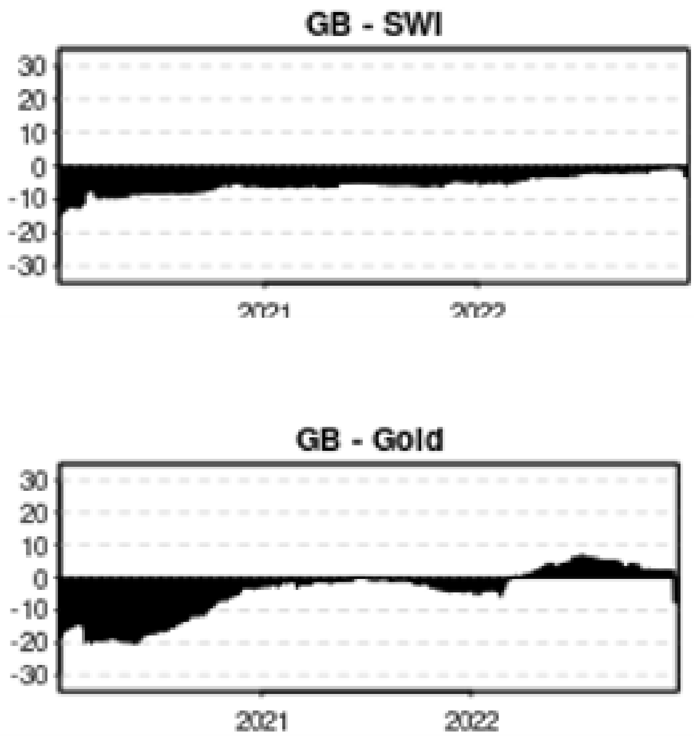
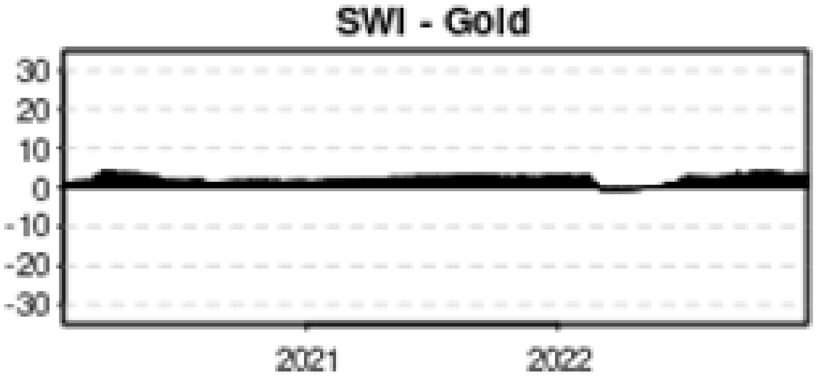


FIGURE 4.16: Net total directional connectedness During Covid [Jan2020-Dec2022]

Net pairwise connectedness is shown in Figure 4.17. The results show that green bonds are the net recipient of shocks throughout the time period until the late 2022 where a spillover can be seen from green bond index towards gold. Also, the magnitude of spillovers could be seen to be greater during the covid sample.

The additional information provided while analyzing other asset classes is very interesting as sustainability investments and Islamic investments transmit shocks to clean energy investments explaining that sustainability markets and Islamic markets have impact on clean energy indices. Furthermore, these inversely symmetric relationships could be used to articulate the hedging strategies focusing on the recipient-transmitter relationships.




SWI - Gold
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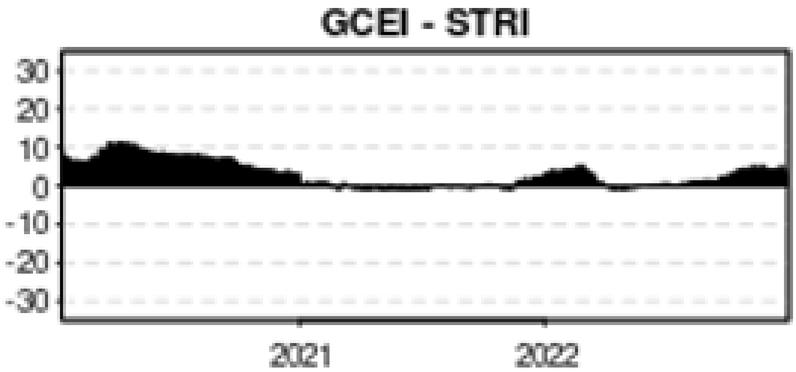
GCEI - STRI
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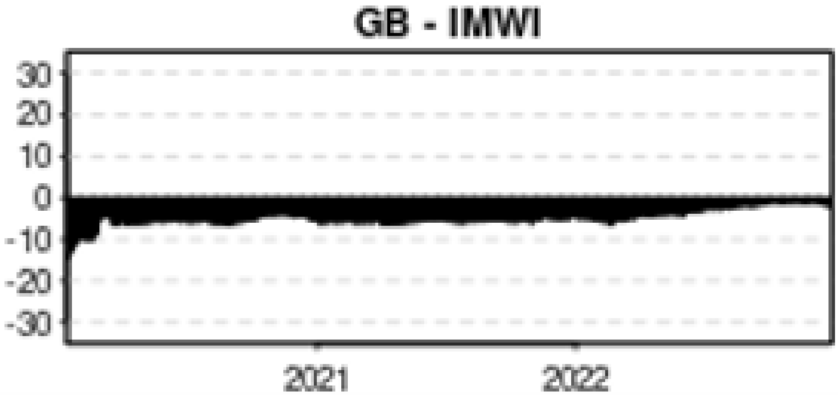
GB - IMWI
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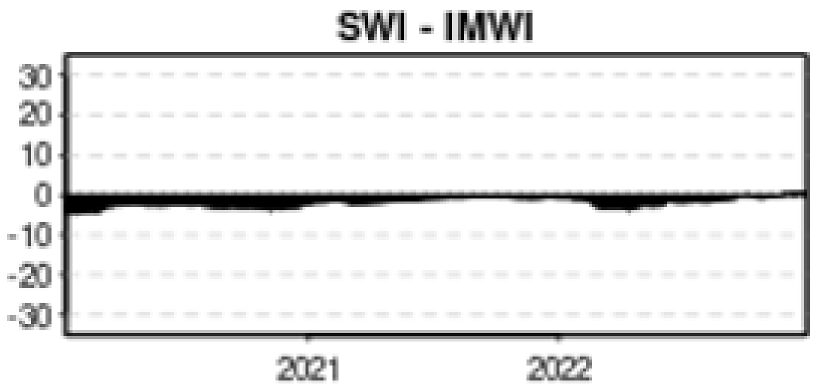
SWI - IMWI
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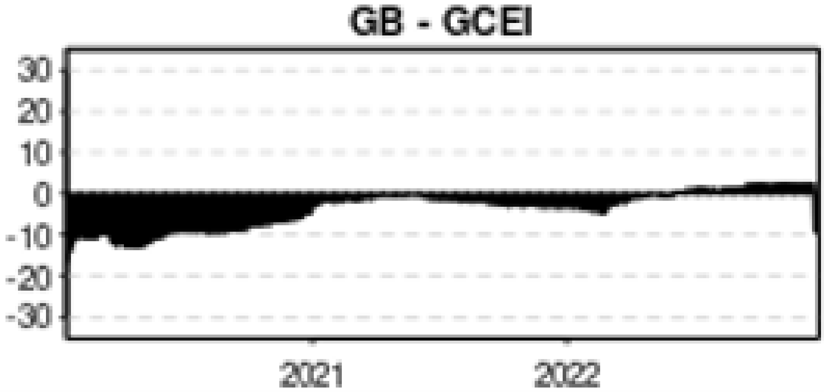
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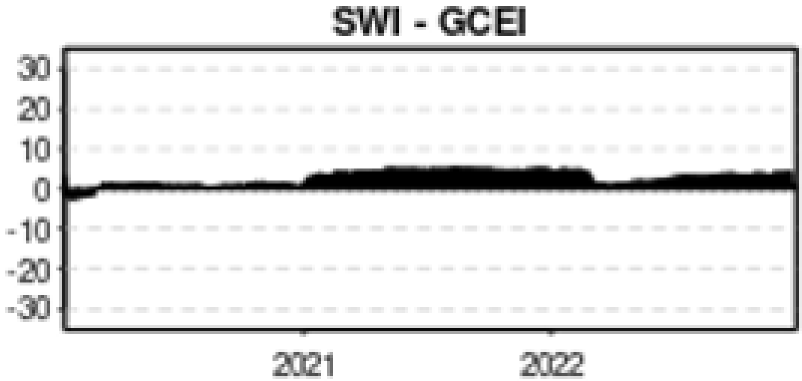
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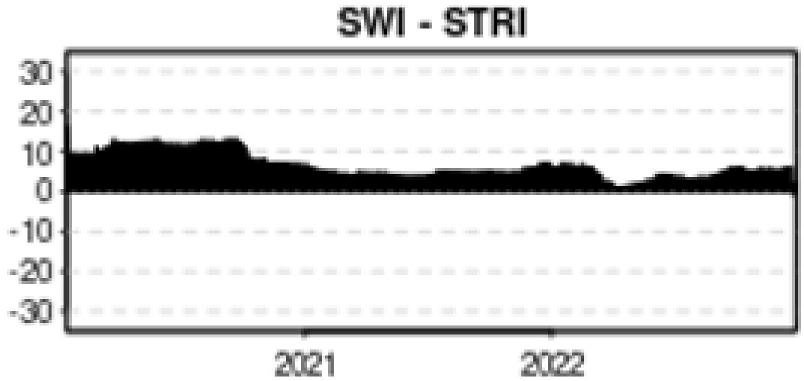
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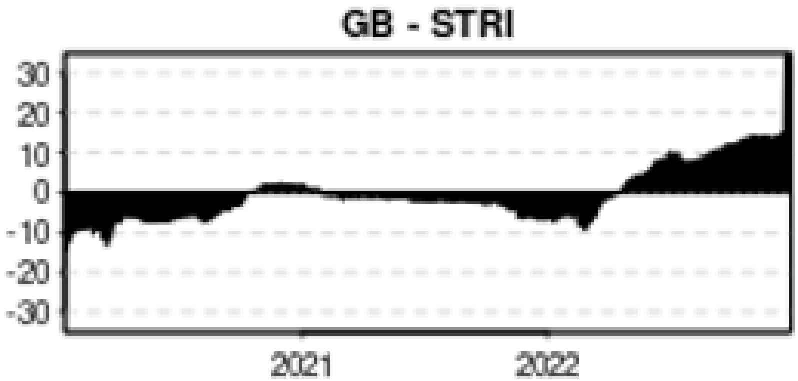
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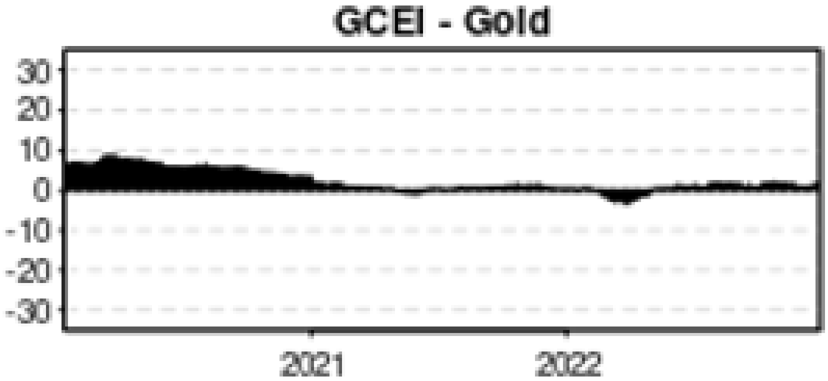
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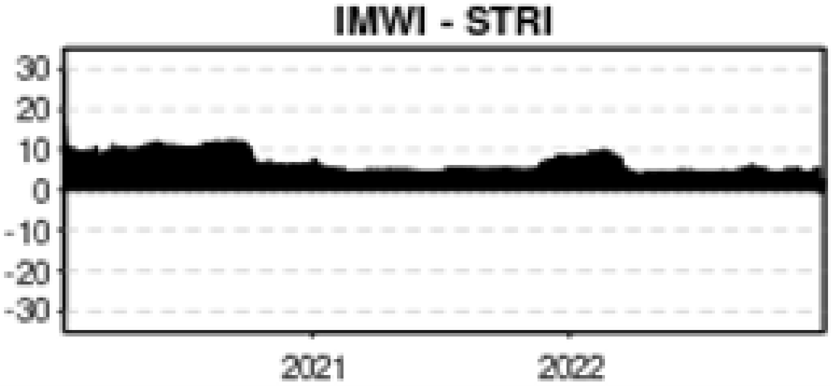
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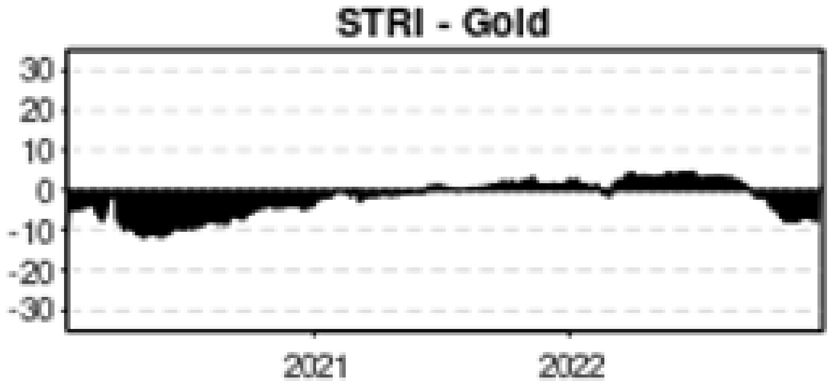
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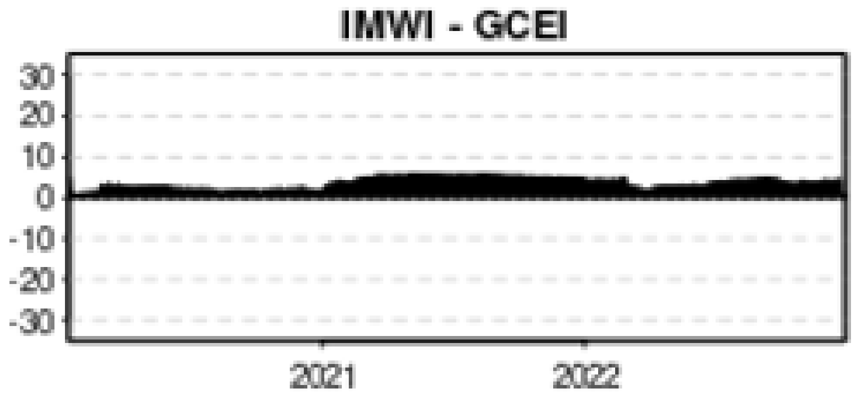
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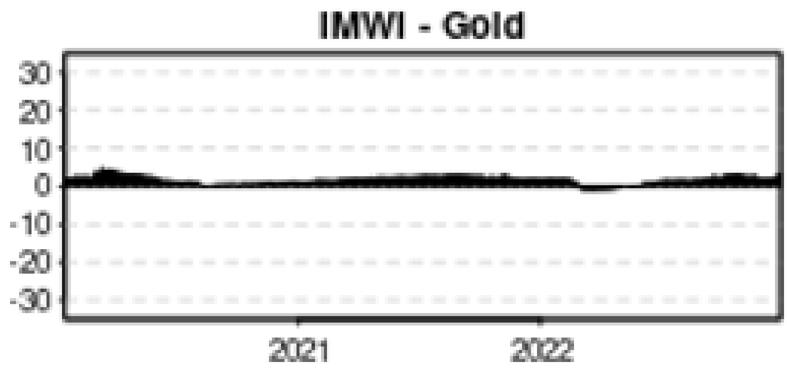

FIGURE 4.17: Net Connectedness Pairwise During Covid [Jan2020-Dec2022]

The above results show that COVID pandemic has led noticeable disruptions in green and sustainable investment markets and the results are in coherence with Bouri et al. (2021) who concluded the same for the global financial markets.These results provide practical implications regarding green finance, Islamic finance and sustainable investments as investment options.Investors could use the insights provided in the results for optimal risk management and portfolio diversification using green investment options. Investors could achieve a diversified and environment friendly portfolio by using optimal weights and strategies using these assets in their portfolios.Alongwith diversification, the green and sustainable investments also help in mitigating environmental degradation

Policy makers and investors can use this information to formulate diversification strategies as the results depict that although all these assets aim for sustainable environment but also show different dynamic behavior in time-varying pattern. Investors could get a better and environment friendly portfolio by formulating diversified portfolios using these assets.

The network plot of the COVID sample shows strong dynamic connectedness among all asset classes.The results of pandemic sample are quite different from those of full and pre-covid samples. As the previous network plots of full sample and pre-COVID sample do not show such strong linkages.These results show that overall these asset classes are not strongly connected and can be used for portfolio diversification.The only high level of connectedness were seen in pandemic due to fear and uncertainity. COVID-19 network plot also confirm these empirical results stated above that all the assets show more connectedness in the pandemic period.

The high level of connectedness among assets in COVID-19 could be associated to uncertainity among investors.Pandemic period caused a state of uncertainity and unpredictibilty among investors, which affected their investment pattern. The network plot is shown in Figure 4.18.

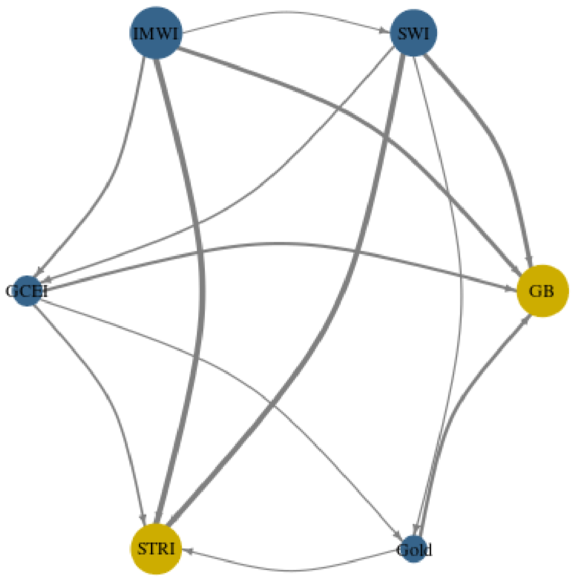

FIGURE 4.18: Network Plot During Covid [Jan2020-Dec2022]

The results of three sample classes i.e full sample, pre-COVID and COVID show that the connectedness among all the asset classes change with the change in sample period.For the full sample period, a relatively low dynamic connectedness (49.8%) could be observed among all variables, indicating that over all these assets do not show connectivity hence proving to be potential diversifiers in a portfolio.

Investors can get diversification benefits by adding these environment friendly, and sustainable investment options in the portfolio.Similarly, in the pre-covid period a relatively low dynamic connectedness (48.4%) among the three sample periods is observed.No strong linkages could be identified aming all the asset classes, and all the assets show a decrease in returns and prices during the 2015-2016 oil crises.

For the sample period of COVID-19, a different trend is witnessed among the assets.All the assets show an increased volatility in returns, also higher connectedness is witnessed in the COVID-19 period which demonstrates that all the assets behave in a similar manner during global pandemic situation.The net connectedness among the assets is increased to 74.27%.The increase in connectedness among asset classes during the COVID period could be associated with the investors' behavioral aspects.

Pandemic apperared to be a phase of uncertainity and panic and this pattern could be witnessed in the investors' investment decisions aswell.The phase of fear and uncertainity in COVID is depicted in the form of high connectivity among asset classes.The results also show that gold acts as a net transmitter of shock in the early pandemic period whereas shifts its behavior as a recipient in the late 2022.

These results are in contrast to those shown by full sample and pre-COVID sample showing that COVID has affected the behavior of gold as a safe haven during the pandemic situation.

The above results extensively explain spillover among green finance, sustainable finance and Islamic investments in the three sample phases. The results from total dynamic connectedness, FROM others to system, TO others from system, net connectedness, Dynamic pairwise connectedness, Net-Pairwise connectedness, dynamic pairwise connectedness and network plots for each sample period are discussed in detail.

On the basis of these results, this study concludes that although green finance, sustainable investments and Islamic investments share same idea of attaining better environment but their mechanisms to attain the goal of environmental sustainability are different. This difference makes all these investment option unique, hence they could not be classified as multiple names of same product. Results suggest that green finance and other asset classes could be used as portfolio diversification tools.

Chapter 5

Discussion and Conclusion

This study aims to extensively analyze the concept of green finance in multi-dimensional aspects i.e. as a mechanism to promote environmental sustainability and as a tool for portfolio diversification. To confirm these attributes of green finance, the study has been divided into two phases.

5.1 Green Finance and Environmental Sustainability

In the first phase, this study empirically analyzes the impact of green finance, carbon finance, renewable energy, economic activity, and environmental regulations on the environmental sustainability of 70 countries from 2012-2020 The sample countries used in this study are chosen on the basis of their agreement towards NDC policies. GMM methodology is used for the analysis to avoid the issue of endogeneity, and the findings of the study are as follows.

First, this study estimates the impact of green finance, renewable energy and carbon finance on environmental sustainability by formulating a green finance index. The results show that the introduction of green finance and renewable energy help in environmental sustainability by reducing CO_2 emissions. But the results for carbon finance do not show any significant results which opens a new dimension for future research if this behavior of carbon finance could be associated with “Cobra effect”.

Second, the moderating role of environmental regulations on environmental sustainability and green finance is examined.The findings of moderating analysis show significant results and indicate that NDC policies are a vital factor that can support the contribution of green finance towards a sustainable environment. Moreover, the negative sign of the coefficient indicates that the introduction of these policies positively affects environmental sustainability in the form of reduced CO_2 emissions.

Third, this study examines the impact of green finance in the EKC fitting also checks the validity of EKC curve for the full sample. The results of EKC testing indicate the validity of U-shaped curve in the panel dataset. Furthermore, the results also depict a significant effect of green finance in EKC fitting, which has not been well studied in prior studies. These findings provide significant practical implications to use the path of environmentally friendly financing options such as green finance as a path towards economic development.

Owing to these findings, this study recommends that investors must focus on various sources of green finance for diversification as it provides a sustainable and environment-friendly alternative to the standard investment options.Moreover, renewable energy can replace traditional fossil fuel energy sources to reduce pollution and improve environmental sustainability.

The shift from standard finance to green finance and from fossil fuel energy to clean fuel would not only prove to be beneficial for the financial entities, investors, and industries but will also help mitigate the severe climatic change effects that the world is facing (WHO, 2022). Furthermore, the policies such as NDCs act as an efficient mechanism that facilitates the pathway towards sustainability by mobilizing the countries towards environment-friendly financing and energy consumption alternatives on micro and macro level.

On the basis of these results, it is also suggested that countries must focus on implementing policies such as NDCs to achieve SDGs.NDCs provide a very strong framework for the countries to transform their energy consumption patterns and improve the environment.To combat the issue of climatic change,countries must apply the NDC policies in all the domains of their economies. From switiching to green finance and renewable energy options in sectors like industry and agricultre to individual investment options, NDC policies will not only help in reducing harmful emissions but also in improving the economic health of countries in an environment friendly manner.

Moreover, the presence of U-shape EKC has been confirmed in the presence of green finance, which implies that all the countries must follow the path of green finance for economic growth by focusing on eco-friendly investments and projects to play their part in achieving environmental sustainability. The role of governments is very important in monitoring the implementation of environmental policies and providing awareness regarding importance of environment friendly financing option.The environmental policy implications in every domain of society seems to be a difficult journey but not unreachable.This study and its findings pave the way for practical implications of green finance in order to attain environmental sustainability.

5.2 Green Finance as an Investment Option

In the second phase, this study examines the role of Green Finance as an investment option. This study aims to examine the spillover among green finance, sustainable investments, Islamic investments and gold as traditional safe haven. It calculates average dynamic connectedness, net connectedness, net pairwise connectedness among all the asset classes. The analysis have been done in three phases i.e Pre-COVID, COVID and full sample to extensively analyze the effect of all variables in time-varying dynamics.

This study uses time varying TVP-VAR parameter combined with connectedness approach which is based on generalized forecast error variance decomposition (GEVD) for analysis and results are as follows:

First, the study estimates return and spillover for full sample and the results show that the spillovers among assets are time varying with an increase in connectedness during COVID-19 pandemic and a trough in the connectedness during 2015-2016 oil crises. Overall, green bonds, clean energy stocks and Shariah' compliant investments are the net recipient of shocks whereas, gold , Islamic stocks and sustainability stocks are net transmitter of shocks to the system.

The difference in behavior of these assets signify that they have less connectedness throughout the time-varying pattern. Whereas, Gold remains a safe haven and provides hedge benefits against all asset classes (Adekoya et al., 2021). These findings indicate that all these asset classes have can provide diversification benefits and hedging strategies for investors and corporations as the time-varying connectedness is very low (49%).

Moreover, the results from net pairwise analysis suggest some interesting inversely symmetric relationships among different asset pairs. These inversely symmetric profiles such as green bonds -sustainability pair, green bond- clean energy stocks pair, green bond- Islamic bond pair, green bond- gold pair could be used to formulate net pairwise hedging strategies. To our knowledge such net pairwise strategies have not been proposed for green investments in the literature yet. Naeem et al. (2023) examine the net pairwise connectedness between Islamic stocks and sustainable investments to report similar implications.

Second, this study examines the average dynamic connectedness among all the asset classes for the pre-COVID time period. The results indicate that the interdependence among all the returns have not been significantly high in the pre-COVID period. The total dynamic connectedness is same for pre-Covid as for the whole sample.

The total dynamic connectedness is fluctuating in 2015 due to oil crises, but for the rest of the time periods all the asset classes show time-varying increase in connectedness implying that investors must constantly revise their portfolios. A significantly high level of connectedness could be seen among all assets at beginning of 2020. This spike could be explained by COVID-19 outbreak where all the assets responded similarly to this global pandemic.

Third, this study examines the spillover among all the asset classes for the COVID-19 sample period. The total dynamic connectedness index depicts that connectedness has increased in the pandemic situation noticeably. A significantly high level of connectedness could be seen among all assets. But, a decrease in connectedness can be noticed during the early 2022 as the pandemic was almost diminishing, but with rise of COVID cases in China during the later part of 2022, the perception of pandemic was sensed again resulting as a spike in connectedness.

The pandemic sample shows a spike in spillover from all the assets to the system depicting that they show similar behavior in the global pandemic situation. The general trend shows that gold is not a receiver of spillovers and acts differently than the rest of the assets but in the covid situation it also receiving shocks from the system.

The results of net directional connectedness show that gold acts as a net transmitter of shock in the early pandemic period whereas shifts its behavior as a recipient in the late 2022.These results are in contrast to those shown by full sample and pre-COVID sample showing that COVID has affected the behavior of gold as a safe haven during the pandemic. Finally, net pairwise connectedness confirms the aforementioned results.

These results could be helpful to investors in their portfolio reallocation strategies and for individual investments as well. These results present practical implications regarding green finance, Islamic finance and sustainable investments in the time-varying pattern specially in the crises period. Investors could use the insights provided in the results for optimal risk management and portfolio diversification using green investment option.

A diversified and environment friendly portfolio could be constructed by using optimal weights and strategies using these assets in their portfolios. The results from net directional connectedness of all the asset classes provide practical information regarding optimal diversification options. The overall results of connectedness among asset classes in all three datasets could be very helpful for policy makers with respect to stabilize economies, especially during crises situations.

In conclusion, the overall results of both phases of analysis prove that green finance could be a transformational variable both for environmental sustainability and in financial sector as a diversifier. By directing finances towards green finance, in the form of sustainable investments, green bonds, green credits, clean energy investments, investors could not only get better returns on their investments but would also help in mitigating environmental degradation.

By converging towards green finance practices, a more resilient and sustainable ecosystem could be built meanwhile generating economic growth and better financial returns on investments.

5.3 Recommendations and Policy Implications

Our study provides policy implications and future research directions in the following domains.

The results could be useful to the businesses as they could shift towards green finance and clean energy practices in their operations These practices would not only help in increased return for the businesses but also help maintain a sustainable ecosystem by improving environmental sustainability. Similarly, the results depicting the positive impact of environmental regulations towards environmental sustainability could provide practical and efficient implications for the government. Governments must formulate regulations specifically for environmental sustainability, also, agreement to policies like Kyoto protocols and NDCs could help ensure smooth transition towards a sustainable environment. Governments must also promote green finance as an investment and financing option to help decrease the pollution. The policies and their efficient implementation at country level by respective governments could be the first step that can bring change towards the global cause of environmental degradation.

As Pakistan is one of the countries who adapts NDC policies on order to mitigate climatic change, the findings of this study are beneficial for Pakistan.Policy makers can use the results to carefully implement the policies effectively to achieve the goal of combating environmental degradation.

The findings are also helpful for future investors as they provide evidence of obtaining portfolio diversification benefits using green and sustainable investments rather than conventional investments. By investing in these socially responsible and environmentally friendly investment options, investors could not only manage a diversified portfolio with optimal risk-return tradeoff but also help in mitigating the risk of environmental degradation. The results also provide future implications to the industries to converge their operations towards environmentally friendly options.

Finally, the results provide valuable insights to general public by increasing their awareness regarding the serious issue of environmental degradation and its harmful impact on society. The discussions and analysis provide some valuable suggestions and implications which could be implemented to take a step towards a sustainable environment. Apart from application of green finance in investments decisions and manufacturing decisions, the general public must also convert their everyday practices towards green and sustainable options. This could be done by using their finances for purchasing products of companies that ensure green and sustainable practices. Also, environmental degradation could be reduced by adapting renewable and reusable resources. Green finance could be used as an effective tool to mitigate the climatic risk without compromising the positive returns of the investors.While this study gives a new orientation to the prior research on environmental sustainability, several questions have remained unanswered which could be focused in the proceeding studies. Such as:

The presence of carbon finance fails to decrease CO_2 emissions providing a new orientation to future research. Hence, future studies must be conducted with different datasets and measures for carbon finance to confirm the results and to check if the results support the presence of Cobra effect in carbon credit markets. This study has taken 70 countries based on NDC policy regulations; future studies could be conducted by investigating all the countries that agreed upon these policies.

This study entirely focused on NDCs as a determinant of environmental regulations; we suggest to extend the analysis in future studies using other determinants of environmental regulations, such as COP27 as a proxy for international policies and country-specific indicators such as pollutants prevention indicators, clean-air indicators etc. This study uses daily data of assets classes for spillover analysis. It is suggested that industry wise data is used to extensively examine the diversification benefits of green finance from another perspective. This study focuses on examining the spillover and connectedness of assets under study. Future research can calculate hedge ratios of these investments and determine the hedge portfolio returns to further extend the dimensions of portfolio and hedging strategies.

5.4 Limitations of Study

While this study gives a new orientation to the prior research on environmental sustainability, several questions have remained unanswered which could be focused in the proceeding studies. Such as:

More proxies for carbon finance could be used to confirm the results.

Dataset is limited to 70 countries, it could be increased to all the countries abiding by NDC policies in future research.

Dynamic connectedness could be measured using more sustainablr and Islamic indexes to confiirm the results.

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