SECOND EDITION

AN INTRODUCTION TO CLIMATE CHANGE ECONOMICS AND POLICY

FELIX R. FITZROY AND ELISSAIOS PAPYRAKIS

TEXTBOOKS IN ENVIRONMENTAL AND AGRICULTURAL ECONOMICS

AN INTRODUCTION TO CLIMATE CHANGE ECONOMICS AND POLICY

An Introduction to Climate Change Economics and Policy, now in its second edition, reviews important new developments and the alarming lack of progress in reducing emissions. This updated edition explains the key scientific, economic and policy issues related to climate change without assuming any prior knowledge.

FitzRoy and Papyrakis highlight how economists and policymakers often misunderstand the science of climate change. They underestimate the growing threat to future civilization and survival and exaggerate the costs of radical measures needed to stabilize the climate. Thus direct and indirect costs of fossil fuels – particularly the huge health costs of local pollution – exceed the investment needed for transition to an almost zero carbon economy in two or three decades using available technology. There is also new material on nuclear energy post-Fukushima, and how fiscal policy for investment in mitigation could help to attain full employment.

This book provides a completely up-to-date introduction for anyone interested in the economics and policy of climate change, and students at all levels in various related courses, including environmental economics, international development, geography, politics and international relations.

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Endorsements from the first edition:

'A tour de force. Brings together the current state of knowledge about global climate change in an accessible, insightful and penetrating way, convincingly demonstrates the need to act quickly and decisively, and shows the reader how that can best be done.' — *Roger Perman, Strathclyde University, UK*

'This book provides a unique introduction to the economics and policy (as well as a bit on the science) of climate change, written in a very attractive style. It addresses some surprising but relevant topics, and offers very clear statements and insights. There is no text that comes even close in contents and style, and I warmly recommend this book to everyone interested in, or worried about, climate change. Or perhaps better, it should be obligatory reading for those ignorant or not concerned about it.' — *Jeroen van den Bergh, Autonomous University of Barcelona, Spain and Free University, Amsterdam, the Netherlands*

'A welcome, clear and accessible introduction that challenges current approaches to climate change, throws the spotlight on food and farming and the urgent need to change policies to prevent catastrophic climate change, agricultural collapse, mass deaths and major conflicts.' — *Geoff Tansey, Joseph Rowntree Visionary for a Just and Peaceful World*

'This book provides a very accessible and understandable introduction to the economics and policy of climate change. As a partisan in some of the debates, I cannot be expected to agree with all of the authors' argument. But I highly recommend this book to those seeking a better understanding of what is at stake.' — *Eric Neumayer, London School of Economics and Political Science, UK*

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‘Hope you are quite prepared to die.
Looks like we’re in for nasty weather.’

‘Bad moon rising’, John Fogerty,
Creedence Clearwater Revival, 1969

Renate

Olga, Jamie,

Lucas, Andries,

Katia, Maira,

Manolis and

Kostis

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PREFACE

There is now an overwhelming scientific consensus that our planet is warming rapidly as a consequence of reckless human activity, and that human civilization will be threatened by devastating climate change unless much greater mitigation efforts are quickly implemented. Yet government targets and commitments to reduce emissions remain woefully inadequate in most countries, while policymakers (and voters) are preoccupied with current economic woes and political crises caused by the perverse and destructive policies of recent decades.

There is little awareness that major new investment in mitigation could also boost the economy, reducing both chronic unemployment and the huge health costs of local pollution from fossil fuels, as well as protecting present and future life on Earth from catastrophic climate impacts. In contrast to limited and often biased media coverage, there is a flood of available information on these issues; this, however, can easily become daunting and overwhelming for the general reader. Climate change hits on Google have nearly doubled since the crash of 2008 to around 135 million, more than for unemployment.

While there are many good and accessible introductions to climate science and to the policy debates, these usually include much more detail than the interested but non-specialist reader is willing or able to assimilate. With this book, we offer readers a short, uncluttered introduction to the *key* scientific developments on climate change, the most threatening consequences, and the most appropriate policies in response. We avoid less relevant detail and technical terminology; rather, we analyse current issues in a simple and systematic way that does not require prior knowledge of the problems. Anyone with an interest in the most vital environmental and development issues should benefit from reading the book, quickly becoming familiar with the recent evidence on global warming – and what we should do about it – without having to follow complicated jargon, numerous acronyms and a mass of statistics.

We do cover a wide range of topics, some of which have been neglected in discussions of climate change. In particular, we emphasize the role of global agriculture, already facing severe problems of erosion and water shortages, because climate change will amplify all these problems. Long before rising sea levels flood the world's coastal cities, prolonged drought in major food-producing areas could lead to starvation for the poorest populations, and large-scale loss of life.

Such catastrophes are not included in economic cost–benefit analysis that only relates future consumption of survivors to current investment in reducing emissions. In addition to the ethical obligation of the rich countries that are responsible for most past emissions, we emphasize the local and short-term benefits to all countries from conservation agriculture, reforestation, reduced pollution and energy saving – benefits that essentially pay for the extra investment needed. All mitigation policies incur political costs of persuasion and redistribution, but, in contrast to widely held views, they can generate net economic benefits as well as insurance against the incalculable human costs of truly disastrous climate change under continued growth of greenhouse gas emissions.

Some of the material here has been included in courses at various levels at the universities of St Andrews, Edinburgh, East Anglia and the VU University in Amsterdam for a number of years. This includes a first-year interdisciplinary introduction to sustainable development at St Andrews, and undergraduate and postgraduate environmental economics options at St Andrews, Edinburgh, East Anglia, and the VU in Amsterdam. We hope the book will also be particularly useful for undergraduate students in environmental sciences, economics, geography and development, who require a simple introduction to the current debate on climate change issues and policies. It should also be helpful to more advanced students and academics, as we put more emphasis on the interdisciplinary nature of the problems considered than is usual, and throughout all chapters we provide notes and references to more advanced readings on specific aspects of climate change and policy.

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Many people have played a decisive role in shaping this book. Colleagues, friends, and former students from various institutions and countries have been generous with their time reading drafts of our chapters and providing insights and feedback. They include Frank Ackerman, Natalia Alvarez, Konstantinos Angelopoulos, Jeroen van den Bergh, Joanna Blythman, Declan Conway, Tim Daw, Roger Few, Jennifer Franz, Reyer Gerlagh, Holly Jenkins, Jim Jin, Eric Neumayer, Peter Newell, Matthias Rieger, Max Steinhardt, Geoff Tansey, Pieter van Beukering, Ernst von Weizsäcker and Rehema White. We are especially grateful to Roger Perman, Strathclyde University, and Clem Tisdell, University of Queensland, who reviewed the first edition and provided detailed comments. Special thanks also to our students, who were taught parts of this material at various levels and generously provided feedback on the book's content. None of them is to blame for opinions expressed, or any remaining errors.

We were particularly privileged to work with the people at Earthscan for the first edition. They provided continuous support and detailed comments both for the content of the manuscript and for the overall presentation. We received extremely useful input from our editor Rob West, who oversaw the whole process. Claire Lamont assisted us in designing the book cover and providing help and guidance whenever called upon. At St Andrews, Nikos Terzopoulos expertly organized our manuscript into its final format. At Routledge, Laura Johnson helped and guided us through the lengthy process of rewriting much of the text for the second edition. Felicity Teague provided very careful and constructive copy-editing.

Last but not least, our deepest thanks go to our immediate family and friends, who patiently read draft chapters of the book, without having any particular expertise either in economics or in climate change issues. Their feedback was particularly important in shaping the style of the book. With their help, we produced a book that we hope is accessible to a broad audience. They contributed to every single stage of our ambitious endeavour to synthesize the rapidly expanding literature on the economics and policy of climate change, just by being there for us and responding critically to our preoccupations. This book simply would not be the same without the presence of our children, nieces and nephews, who continuously reminded us that this is a book for the benefit of future generations. We thank: Tina Caba, Ali Caba, Ozan Caba, Elif Caba, Renate FitzRoy, Jamie FitzRoy, Olga FitzRoy, Simon Knee, Andries Kamminga, Manolis Papyrakis, Kostis Papyrakis, Katia Stavroulaki and Maira Stavroulaki.

1

INTRODUCTION

Climate change and the political landscape

The first edition of this book was written during the Great Recession of 2008–2009, an event that still casts long shadows in the form of persistently high rates of un- and under-employment and slow growth of most wages in many developed economies under misguided austerity policies. Just before the financial crash, former US Vice-President and climate campaigner Al Gore had been awarded the Nobel Peace Prize, jointly with the Intergovernmental Panel on Climate Change (IPCC) for their Fourth Assessment Report in 2007. Although surface warming seemed to have slowed down since 1998, this and the Fifth Assessment Report in 2013–14 contained ever-starker warnings about the threat of climate change and the urgency of mitigation measures to reduce greenhouse gas (GHG) emissions. But as scientists criticized these very conservative reports for neglecting 'slow' feedback effects that are difficult to quantify, Arctic sea ice and snow cover were receding far more rapidly than predicted, which will accelerate warming and sea level rise. Then, 2014 turned out to be the hottest year since records began, and 2015 has been even hotter, while faster warming measured in the deeper Pacific Ocean explained most of the previous, slower surface warming.

After a long sequence of inconclusive UN climate conferences and inadequate national and EU targets for emissions reduction announced in recent years, the latest international climate summit (COP 21) in Paris finally reached a 'landmark accord', hailed by politicians and participants as a major breakthrough.[1] For the first time, virtually all countries did agree in principle on the 2°C warming limit, and even on the desirability of a 1.5°C limit. However, the agreement offered no measures to achieve these goals beyond seriously inadequate 'Intended Nationally Determined Contributions' (INDCs), with no timetables, sanctions, carbon taxes or trading, and only token funding plans for poor countries. A five-year review process and transparency requirements offer a glimmer of hope for changing aspirations into actions, but implies that effective policies will probably be dangerously delayed. Of course, the 2°C target is itself much too high – actually a 'recipe for disaster' according to leading climate scientist James Hansen, who summarized the

Paris Agreement more pessimistically than the politicians: 'It's just worthless words. There is no action, just promises.'

The sheer flood of commentary and information on the science, policy and economics of climate change has left many people unclear or confused on key questions – just how great and how urgent is the threat from climate change, and what will it cost to take appropriate action? For many years, confusion has been spread deliberately by lobbyists for the fossil fuel industries (some of whom had previously worked in a similar capacity for tobacco companies) and a few eccentrics who just ignored the real science. Confusion has been fostered by the media everywhere, including public service broadcasters such as the London BBC, which has often given more-or-less equal coverage to warnings by serious scientists and to denials by lobbyists masquerading as honest 'sceptics'. Systematic public education on these vital questions has been neglected in most countries.

Much has also been written on policy for reducing GHG emissions from various perspectives. Economists have usually ignored the possibility of large-scale loss of life under catastrophic climate change if present policies are continued with 'business as usual' (BAU). They also exaggerate the costs of mitigation by neglecting the additional health and efficiency benefits from energy saving, conservation agriculture and a greener economy, though the IMF has recently estimated just the health costs of local air pollution at 3 per cent of global gross domestic product (GDP). Yet, radical mitigation could be achieved by investing about 4 per cent of global GDP, which would of course also save expenditure on fossil fuels of about the same magnitude. However, there are always political costs of change. Increasing efficiency by shifting taxes from 'goods' such as labour to 'bads' like pollution, and switching subsidies from fossil fuels and industrial agriculture to sustainable alternatives, does generate strong opposition from the losers and their government supporters. To avoid the risk of catastrophic climate change most proved reserves of fossil fuels would have to be left in the ground, thus writing off the main assets of some of the most powerful and wealthy multinational and state-owned corporations.

Structure of the book

Any book on the economics and policy of climate change needs to be rooted in the science of climate change and what it implies for how we react or should react as a global society. Chapter 2 provides a brief, non-technical overview of consensus on the basic science of climate change. It explains the role of greenhouse gases and carbon sinks, as well as the key feedback mechanisms that are likely to accelerate the pace of climate change and risk of runaway warming, such as methane emissions from thawing permafrost, and decreased surface albedo or reflectivity as ice and snow cover recede.

Most writers on the consequences of climate change acknowledge that the world's poorest countries will bear the greatest burden of water shortages and failing food supply. However, most discussions of *policy* response to climate change pay

little or no attention to agriculture, which is of particular importance for the livelihoods of billions of poor households in the developing world (while accounting for tiny fractions of output and employment in developed countries).

Chapter 3 examines the prospects for agriculture in a changing climate, summarizing extensive evidence that modern agriculture is *already* under severe threat from the very same methods that have dramatically raised yields – as well as water and energy requirements – over the past 50 years. The predicted rising temperatures and worsening droughts in major food-producing regions that are already hot and arid, are likely to have devastating consequences for agriculture, with global impact. Each additional temperature rise of 1°C during the hot growing seasons of many important agricultural areas is predicted to reduce grain yields by at least 10 per cent. Large-scale crop failures resulting from future warming and water shortages in such areas, would cause prices of staple foods to rise dramatically, and indeed lead to mass starvation among the world's poorest peoples.

Historically, famines have always been local or regional, and there has never been a global food shortage, but the combination of declining water reserves, increasing temperatures and growing population in the developing countries means that agricultural catastrophe, probably accompanied by global conflict, becomes the most immediate threat from continued climate change. Surprisingly perhaps, simple well-tried techniques of conservation, or no-till agriculture and large-scale reforestation, could substantially reduce this threat. As well as lowering the GHG emissions from modern agriculture, these methods reverse currently accelerating carbon loss from eroding soils, and actually capture atmospheric carbon in accumulating soil organic material. Input costs are reduced, and sustainable yields increased in the long run, so abatement of GHG emissions can be combined with the co-benefits of more efficient, resilient and sustainable farming (that also produces healthier food). Further mitigation measures are, of course, urgently required, as even the most robust agriculture will ultimately be decimated if runaway warming is triggered by growing fossil fuel consumption.

Chapter 4 looks at the links between economic growth, well-being and the environment. A major theme of our approach is that the costs of climate change mitigation have been exaggerated under the influence of fossil fuel lobbying, and the prevailing ideology of ever-increasing material consumption and economic growth, whatever the real environmental costs. One reason is that many policies to reduce emissions will have substantial co-benefits, in the form of reduced pollution and better human and animal health in the short to medium term. A second point is that possibly slower economic growth due to mitigation policies is not really a 'cost' in the advanced economies. In fact, 30 years of careful survey research by social scientists shows clearly that, in rich countries, subjective well-being does not increase with average real incomes in the long run (though short-term economic fluctuation certainly influences welfare, but with negative effects of recession offsetting the gains from recovery). Other reasons are the erosion of 'social capital' and human relations that is often the price of material growth, and the importance for subjective well-being of *relative* income, particularly when basic needs have been met.

Recent surveys suggest that, even in China, where fast growth and poverty reduction have been absolute priorities, rapidly increasing inequality has been accompanied by declining happiness and life satisfaction.

It follows that, even if mitigation policies to reduce emissions also slow down the rate of material growth in rich countries, this does *not* imply a future cost in terms of reduced subjective well-being. In poor countries, which are the main focus of Chapter 5, economic growth can bring real benefits to all, though most of the benefits are usually appropriated by a wealthy minority. Sustainable development and distributional justice, without the environmental degradation and growing inequality that have hitherto always accompanied early industrialization, should thus become a major goal of international policy. The developed economies are responsible for most of the existing stock of GHGs in the atmosphere, and most discussion of policies for abatement has focused on these countries. But the largest developing countries, China and India, are now among the fastest-growing polluters (and economies), and China has overtaken the US in total emissions. We will therefore consider policies for reducing GHG emissions in both developing and developed countries, as well as the related issues of aid, trade and globalization in relation to the environment and sustainable development.

In Chapter 6 we argue that the ethical principles of justice provide an essential foundation for policies to protect unborn generations and the poorest countries from climate change, though this aspect has been neglected by many economists. Related issues arise in connection with current and persistently inadequate aid for these nations, in the face of growing threats to agriculture and water supply, and rules of international trade that mainly benefit the rich countries. Increasing aid for the world's poorest peoples can be an integral part of effective mitigation. With 20 per cent of carbon emissions from (mostly tropical) deforestation, carbon credits for forest preservation would combine aid to poorer countries with one of the most cost-effective forms of abatement. Perhaps the most cost-effective but politically fraught policy reform would be the removal of several hundred billions of dollars of direct annual subsidies from the two biggest recipients in the OECD – destructive industrial agriculture and fossil fuels. A small fraction of this would accelerate the already rapid rate of technical progress and investment in renewable energy in many areas, as well as encouraging the essential switch to conservation agriculture.

Turning to international agreements in Chapter 7, we evaluate existing and proposed mechanisms as a means to reduce global emissions. With few incentives for mitigation, and the absence of sanctions against the worst polluters such as China and the US, Kyoto has largely been a failure in the fight against climate change. Emissions trading in the EU has been equally unsuccessful in its first phase, with free distribution of carbon allowances or permits to the biggest emitters, who have used their market power to raise prices and generate huge windfall profits. Permit prices have fluctuated, but generally they have remained far too low to provide an adequate incentive for investment in alternative or decentralized energy generation. While more permits should be auctioned in future stages of the EU ETS, there is always strong industry lobbying for exceptions.

Chapter 8 reviews the economic instruments and incentives for reducing GHG emissions. Although carbon taxes have many theoretical advantages, China plans to introduce a comprehensive carbon cap-and-trade system, but with too low a carbon price initially to be effective. Applied 'upstream' to all producers and importers of fossil fuels, cap and trade could improve considerably on the European system that only covers large industrial emitters, and perhaps be politically more acceptable than new taxes. This long-overdue initiative by China may encourage other countries to follow, so that international, and ultimately global, carbon trading could result. A carbon tax or 'fee and dividend', with all revenues returned equally to all citizens of a country, could also gain majority support as most people would benefit. However, there is very little prospect at the moment of starting with one of the far-reaching 'top-down' global agreements on carbon trading or taxation that have often been proposed, before there is more experience with functioning national or regional systems.

Most economic analysis of climate change and mitigation, as we explain in Chapter 9, has seriously underestimated the risks of runaway, irreversible warming under current policies, or BAU, and resulting catastrophic effects on third-world agriculture that could lead to starvation for billions of the world's poorest people. At the same time, the costs of switching to sustainable conservation farming and alternative energy supply have been exaggerated by agribusiness and fossil fuel industries. Economic growth is simply assumed to continue unabated for the next century or two, and the worst (but assumed to be unlikely) impact of climate change is estimated by standard 'integrated assessment' models (IAMs) as a few per cent of a much larger global GDP.

As pioneering climate economist Nicholas Stern and others have pointed out, IAMs essentially *assume* their main results (including growing populations with no large-scale loss of life) and are based on fundamental misunderstanding of the latest climate and environmental science, as well as neglect of the basic ethical issues. Really catastrophic outcomes of runaway warming are not only possible, but even likely, if GHG emissions are not reduced much more rapidly than under current targets. The global conflict potential of large-scale starvation in the poorest regions, and the collapse of fragile but nuclear-armed states will threaten prosperity and security even in the most affluent countries. Prudence and concern for the welfare of our children justify major investment in mitigation, as insurance against these risks. In the developed countries we have the additional ethical responsibility for having produced most of the GHGs in the atmosphere today. The biggest developing nations are now catching up as polluters, while devastating their environments and the health of their citizens, as well as increasing the likelihood of globally catastrophic climate impact in the future. These countries are repeating all the mistakes made by the West in earlier industrialization, with little public awareness of the prime threat to their own populations. A refocusing of trade and aid policies to promote 'cleaner', sustainable development thus becomes all the more urgent.

In Chapter 10, which concludes the book, we show that the current economic crisis offers huge opportunities for 'green fiscal policy', government spending on

labour-intensive, energy-saving projects (that would also reduce unemployment, particularly in construction sectors that have been hardest hit by collapsing housing bubbles), and of course on renewable energy. These opportunities have been largely missed, with only a very small share of green projects in the stimulus packages of the major economies.

In our discussion of policy responses to climate change and environmental degradation we emphasize the ethical and distributional issues, to complement the economic, cost–benefit aspects that usually dominate the discussion. We find that substantial mitigation can be achieved with measures that actually improve health and welfare, and that most of the perceived costs of the necessary and drastic emissions reduction are political and distributional. There are also real psychological costs of changing familiar habits, even when more environmentally friendly behaviour also brings personal benefits in the long run. So we come back to the crucial issues of public education about the magnitude of the threats facing us all and, more optimistically, about the feasibility and multiple benefits of effective 'insurance' policy, issues that summarize the two main aims or themes of this book.

Note

1 Stavins, R. (2013) 'The Warsaw climate negotiations, and reason for cautious optimism', An economic view of the environment – blog, Harvard Kennedy School, 28 November, available at http://www.robertstavinsblog.org/2013/11/28/the-warsaw-climate-negotiations-and-reason-for-cautious-optimism/.

2

BASIC SCIENCE – AND SOME POLITICS – OF CLIMATE CHANGE

The IPCC's Fifth Assessment Report (AR5), published in October 2013, confirmed the overwhelming scientific consensus on the main causes of climate change – burning fossil fuels and land use change, and the urgency of major mitigation efforts. However, like the earlier reports it still suffers from the inevitable conservative bias in such a large-scale, bureaucratic and international enterprise, where numerous scientists, including many government employees, had to agree on precise wording. It does not include some of the most recent findings of climate science, particularly the role of slow feedbacks, which imply that the target threshold of a 2°C increase of global mean temperature above pre-industrial levels is dangerously high.[1] And even this weak limit is certain to be breached without a drastic and imminent reversal of current 'business as usual' (BAU) to curtail still-growing carbon emissions.

The prolonged economic slowdown after the financial crash of 2008 has diverted public attention from the long-term threat of climate change to more immediate economic problems, although predictions from climate science have become steadily more pessimistic in recent years. These economic problems, including high and persistent un- and under-employment, particularly among young people, and in the southern periphery of the EU, have been greatly exacerbated by misguided austerity policies, which we discuss in detail in Chapter 10.

Also influencing public opinion, the apparent global *surface* 'warming pause' or hiatus from 1998 to 2013 has been widely misinterpreted by the media and climate science deniers as evidence for a slowdown of *total* warming. Though generally neglected in media reporting, in fact over 90 per cent of the total energy imbalance or warming is accounted for by *ocean* warming, and the overall rate of ocean warming has *not slowed down*. However, the temperature of the sub-tropical Pacific Ocean surface layer, which is closely coupled with atmospheric temperature, has been rising more slowly, while *deep ocean warming has actually accelerated*.[2] The reason for these changes is a concentration of cooler *La Niña* weather patterns in the sub-tropical Pacific in recent years, stronger trade winds, and cooling currents that transport warmer surface water into the deeper ocean. In contrasting *El Niño* years, such as 2015, warmer surface water releases additional heat to the atmosphere.

The exact timing of these events of the ENSO, or El Niño Southern Oscillation, appears to be random, part of the unexplained 'natural variability' of the climate.

Ironically too, the widely reported 'warming pause' was actually partly the result of measurement bias. It is well known that the Arctic region is warming much faster than the rest of the globe; however (and unsurprisingly), weather stations there are less frequent than in more hospitable areas. Calculated *mean global* surface temperatures in the widely used Hadley Centre's HadCRUT4 series thus suffer from too few of the warmest Arctic observations. This downward bias can, however, be corrected by combining and interpolating surface measurements with satellite observations. The latest, most comprehensive correction for the last 15 years shows over twice the rate of warming reported in uncorrected series, namely 0.12°C per decade, which is only slightly less than the average of 0.16°C per decade since 1980.[3] The difference is easily explained by the weather patterns described above. Of course, short intervals are always inherently unreliable indicators of the long run, depending on the choice of start- and end point and natural variations, and the recent 'pause' offers no statistically significant evidence of any change in the long-run trend. In any case, the 'pause' finally ended abruptly as 2014 turned out to be the warmest year on record (and 2015 has been even hotter, helped by return of a strong, warming El Niño event).

Another aspect of 'natural' variability, but one that is also strongly influenced by human activity, is represented by the increasing frequency and extent of extreme weather events – 'superstorms' such as Hurricane Sandy in 2012 or Typhoon Haiyan in 2013, record recent heatwaves in the US, prolonged drought in California, and an even more devastating heatwave and drought in Russia in 2010. The increasing likelihood of such events is predicted by all models of global warming. Hansen and others show that extreme heatwaves affected only 0.1–0.2 per cent of the globe in the base period between 1981 and 1990, while they now cover on average about 10 per cent of the Earth's land area, an increase of two orders of magnitude.[4] A recent study by Hajat and others (2014) predicts that, even in the UK, heat-related deaths are expected to rise by more than 250 per cent by 2050 as a result of climate change (and population ageing).[5] Of course these effects are fairly minor compared to just the May 2015 heatwave in India, blamed for 2,500 deaths, in turn a grim portent of future climate devastation in already hot regions.

In spite of all this evidence, a series of inconclusive international UN conferences on climate change only finally in Copenhagen in 2009 agreed on the goal of preventing global mean temperature from rising more than 2°C above the pre-industrial level, but with no commitments to the necessary policy measures. Meanwhile, increasing numbers of scientists see the 2°C limit as too high, a 'prescription for disaster' that would accelerate slow feedbacks and eventually push global temperatures up by 4°C or more, with catastrophic effects. Global carbon emissions are still rising, driven by coal in the big developing countries, though EU and US emissions have declined somewhat, due to recession, energy saving, and the replacement of coal by natural gas. The 2013 climate conference

in Warsaw managed to agree to meet in Lima in 2014 to prepare the ground for finally reaching a climate agreement in Paris in 2015, to be implemented in 2020, 'when the second commitment period of the Kyoto Protocol comes to an end. If that was the key objective, then the Warsaw meetings must be judged to be at least a modest success – the baton was not dropped, rather it was passed successfully in this long relay race of negotiations'.[6]

Climate science deniers (lavishly funded by fossil fuel interests such as Exxon and Koch Industries through a host of conservative 'think tanks', which do their best to conceal their funding sources) have managed to persuade a growing share of the public, particularly in the US and UK, that climate change is just 'natural variability', and in any case is not a problem. The 'climate science denial machine' has been aided by complicit or ignorant media reporting, such as Fox News' extensive coverage of notorious deniers in the US Republican Party with well-known links to the fossil fuel industry, and expertise only in deception and obfuscation. Similarly, the BBC's 'impartiality' policy often gives prominent deniers as much air time as qualified scientists to comment on climate issues. Overall, climate change is still far from receiving the attention it deserves in the media – a recent study of 37 newspapers revealed that only 0.62 per cent of all newspaper articles were climate-change relevant.[7]

While journalists who participate in the denial campaign may be ill informed or obtuse, and most are certainly scientifically illiterate, the basic facts are well known and easily accessible. The denial arguments have all been systematically refuted,[8] and those who continue confusing and misleading public opinion share a grave moral responsibility for obstructing global justice and life-saving policies. Thus, even well-informed and honest politicians have to contend with voters and colleagues whose understanding of the issues lags far behind the current science, in part because of the efforts of the deniers. The title of a recent review of these issues by climate ethics experts Robert Nadeau and Donald Brown was: 'Crimes against humanity: The genocidal campaign of the climate change contrarians.'[9]

Recent investigations by *InsideClimate News* have revealed how Exxon scientists actually did pioneering work on the dangers of climate change in the late 1970s, and brought these dangers to the attention of top management. The latter thus subsequently launched their notorious misinformation campaign in full knowledge of what it was – a fraudulent attempt to protect their profits along the same lines as what had occurred in the tobacco industry.[10]

An important motivation for denial often seems to be neoliberal 'market fundamentalism', a strong (and irrational) ideological belief that government should be minimized and intervention or regulation of the economy is generally unnecessary or harmful. Facts seem to have little influence on deniers, who prefer to rely on 'the mother of all conspiracy theories' – that thousands of scientists worldwide cooperate to manipulate data and falsify climate records in order to obtain research grants, destroy free enterprise and establish a communist atheist dictatorship! Climate

change has been termed the ultimate market failure, due to the neglected 'external' or social cost of emissions from fossil fuels. Their prices do not reflect these social costs, so major corrective measures including a carbon tax need to be imposed by government, and this is anathema to the market fundamentalists.

These fundamentalists are predominantly white male conservatives, who often also reject both the science of evolution and basic (Keynesian) macroeconomics, and have helped to turn the US Republican Party (the GOP) into a 'party that is aggressively anti-science, indeed anti-knowledge', according to Nobel Prize-winning economist and *New York Times* columnist Paul Krugman.[11] The right wing of the British Conservative Party shares a similar ideology that largely associates climate policies with unwarranted intervention by the state and EU institutions.[12] The instincts of market fundamentalists are also reinforced by the very small group of corrupt scientists who are funded by fossil fuel interests to cast doubt on climate science. The abysmal quality of their 'research' seldom survives peer review, but this may not be apparent to scientifically untrained readers grasping for straws in support of their quasi-religious ideological predilections.

US President Barack Obama's 2015 Clean Power Plan will require power stations to reduce their emissions by 32 per cent compared to 2005 levels by 2030, and has been heralded as an important signal, bitterly opposed by Republicans. Yet the ongoing shift from coal to cheap natural gas in the wake of the fracking boom is likely to achieve a similar reduction without any legislation (or Republican opposition), and so the Plan will probably have little effect on total US emissions. Even a more favourable political climate in Europe has failed to protect the EU Emissions Trading System (ETS) from industry lobbying for free permits for the dirtiest producers – known as 'grandfathering'. And the 'cap' has been consistently set at far too high a level to generate a meaningful price for carbon and incentive for investment in renewable energy. Meanwhile, the EU's economic leader with the largest renewable investment to date, Germany, continues to build new coal power stations to replace its ageing nuclear power, which is being phased out for populist political – rather than technical – reasons following the Fukushima disaster; many recent studies have shown a drastic change in public perceptions and acceptability of nuclear energy in the aftermath of Fukushima.[13]

On a more optimistic note, constant criticism and scepticism, going far beyond the normal scientific debate at the frontiers of any field, even one with such momentous social and political ramifications, has forced climate scientists to take extraordinary care in the constant scrutiny of their own and each others' results. This should ultimately increase public confidence in their robustness, and help to generate the political support needed for far-reaching mitigation measures.

In this chapter we continue with a brief summary of key facts from the geological history of the Earth's climate – *paleoclimate* – that are particularly relevant for predicting how our climate is likely to react to various future scenarios of human activity. We then turn to the evidence on current climate change, and the actual predictions of the complex computer models of the global climate system that have reached close agreement on many important issues.

A very short history of long-run climate changes

For as far back as temperatures can be reconstructed from the geological evidence, the Earth's climate has undergone major fluctuations. These have ranged from the extremes of 'snowball earth' around 600 million years ago, when most of the planet was probably covered with ice, to more frequent and extended 'hothouse' periods of global tropical climate with no polar ice. The most detailed records come from 'ice cores' drilled out of the ice caps that cover Greenland and Antarctica. The annual snowfall that has built up the ice sheets to a thickness of several kilometres also traps microscopic air bubbles from the atmosphere as the snow falls, and these can be analysed for their content of carbon dioxide, methane and other greenhouse gases. These gases (and also water vapour) absorb infrared or long-wave heat radiation from the Earth's surface better than other components of the atmosphere such as oxygen and nitrogen, and thus warm the atmosphere as their name implies. The ratio of oxygen isotopes in the ice cores also provides a precise record of the prevailing temperature when the snow fell.

The ice core records now go back for 800,000 years, and they reveal a remarkable pattern of cold periods that lasted about 100,000 years, with warmer spells of variable length in between. Other evidence shows extensive coverage of northern regions by ice sheets up to 4km thick during the cold periods, which are commonly referred to as 'ice ages'. Our current warm 'interglacial' spell – called the *Holocene* – has lasted about 11,000 years, and enabled the development of human culture in benign climates.

Ice ages were probably triggered by small changes in the Earth's axis of rotation, and orbit around the sun, that alter the distribution and intensity of solar radiation, particularly in the polar regions. A slight initial cooling then began to remove CO_2 from the atmosphere, probably through biological activity in the oceans, which amplified the cooling effect. At the same time, expanding ice and snow cover reflected more of the incoming radiation back into space – a process known as the ice-albedo effect. These positive 'feedbacks' were ultimately the main reason for much lower temperatures to persist throughout the ice ages, with the albedo effect responsible for two thirds of the cooling. Just what started the warming process that ended the ice ages is less clear, but the same feedbacks operated in reverse to increase greenhouse gases and reduce albedo as the ice cover receded and temperatures rose. While sea levels were about 120m lower than at present during the greatest extent of ice, melting then accelerated to a dramatic pace, raising the sea level by about a metre every 20 years for four centuries around 14,000 years ago. This is an ominous portent for our medium-term future, with particularly rapid Arctic warming and accelerating loss of Greenland and Antarctic ice observed in the last few years. Climate models have generally underestimated the pace of Arctic warming and loss of ice, not to mention unstable West Antarctica, where some glacial melting is already considered to be irreversible.

During the last ice age the quantity of carbon dioxide in the atmosphere was about 190 parts per million by volume (ppm). This increased over a few millennia to about 280ppm in the current interglacial, an amount that remained stable until industrialization but has now increased by more than a third to about 400ppm. Global mean temperature has increased by 1°C over the past 150 years, mainly in the last 40 years, and been accompanied by a remarkable acceleration of deep Pacific Ocean warming, 15 times faster than any time in the last 10,000 years.[14] This suggests faster surface warming in the future. Records from the ice cores also reveal rapid, short-term temperature oscillations of several degrees between the two polar regions throughout the ice ages.

A likely candidate for explaining this instability is the ocean current that transports warm, salty surface water from the South Atlantic to the North Atlantic between Iceland and Greenland, where it cools and sinks, returning south as a deep, cold ocean current. This Atlantic circulation (also known as the thermohaline circulation, and popularly called the Gulf Stream) is responsible for Northwestern Europe's relatively mild climate. The circulation probably stopped abruptly at the end of the last ice age, about 12,800 years ago, as a giant freshwater lake left by the receding ice sheet over North America suddenly flooded into the North Atlantic, and diluted the salty surface current sufficiently to prevent it sinking. The break lasted for 1,200 years, and plunged Europe into a local ice age called the Younger Dryas, though with probably little effect in much of the Southern Hemisphere. Interruption or slowing of the circulation at regular intervals before this may well have caused the observed swings of temperature between the poles, though the precise reasons remain unclear. A major slowdown or interruption of the Atlantic circulation was thought to be unlikely in the medium term, but recent research now shows an unprecedented slowdown, with potentially serious consequences on both sides of the Atlantic.[15]

There was another similar, though less severe 'mini ice age' starting about 8,200 years ago but only lasting a few centuries – subsequently the climate settled into the current stable, warm period known as the Holocene, with only minor fluctuations. The last of these was the 'little ice age', a cool spell that was illustrated by the great Flemish and other artists of the seventeenth and early eighteenth centuries in their paintings of skaters and revellers on frozen rivers, scenes that became increasingly rare with subsequent warming. Prior to that, the Medieval Warm Period (MWP) in North Atlantic regions has attracted some attention, when Viking settlers could grow crops in Southern Greenland, as their descendents have recently started to do again. However, the consensus is that current global mean temperatures are definitely higher than during the MWP, though some regions may have had similar temperatures. The Holocene is the period in which human settlement, agriculture and (urban) civilization developed.

An interesting question is: what caused these fluctuations when atmospheric greenhouse gases were quite stable? In recent decades solar indicators, which are sometimes blamed, have been *declining*, so that recent warming would have been even *greater* without solar effects!

The latest climate models also show that the effect of solar activity was fairly small over the last 100 years, with most of the warming explained by rising concentrations of greenhouse gases. The slight cooling observed in the 1950s and 1960s is also explained by the same models as a result of sulphates and dust or 'aerosols' in the atmosphere, which reflect more radiation than they absorb, and thus have a cooling effect (this continues to play a role, but is now dominated by the greenhouse effect of much-increased GHG emissions).

There is an erroneous popular view that evidence for climate sensitivity to natural 'forcing', such as orbital or solar variation, in some way undermines the importance of current anthropogenic greenhouse gas emissions for future climate change. This quite illogical conclusion is close to the opposite of the truth. Greater sensitivity of the complex climate system to one kind of forcing influence and associated feedbacks is actually more likely to imply greater sensitivity to other influences. All the evidence we have suggests that the climate has a tendency to switch quite rapidly from one relatively stable 'equilibrium' state to another (such as ice ages to interglacials). These switches have been driven by very small changes in the distribution or intensity of solar radiation, which are then amplified by various and involved feedback processes. One of these – the carbon cycle feedback – is also directly affected by modern agriculture, while thawing Arctic permafrost and Siberian peat bogs represent major additional sources of greenhouse gases that have not yet been quantified and incorporated into standard climate models.

To obtain more direct lessons for our future, we have to go further back into the past. Before the last ice age, during the *Eemian* interglacial period around 125,000 years ago, global mean temperatures were about 2°C warmer than today, with higher temperatures close to the poles and little polar ice cover, so that sea levels were about 5–10m higher than now. CO_2 levels were much *lower* than today, so albedo and solar orbital effects were probably responsible for the higher temperatures. Since nearly another degree of additional warming is now expected as the oceans catch up with the atmosphere, even with no further rise in atmospheric greenhouse gases, this suggests a long-run threat of sea level rise much greater than predicted by the IPCC for the present century, as we discuss in detail below.

The threat appears even greater if we go back much further to the *Pliocene* era, 3 million years ago, just before the start of the sequence of ice ages and interglacials that has continued ever since. Although atmospheric CO_2 levels were similar to today's, the global mean temperature was then around 3 degrees warmer than at present, and much higher in the Arctic summer. There seem to have been no glaciers in the Northern Hemisphere, and less ice in the Antarctic, while sea levels were 20–25m higher than today. Thus, dramatic rises in sea level are likely with quite modest increases in global temperature and greenhouse gas concentrations. As we explain below, there is strong, recent evidence that this process has already begun.

The likely fate of the Earth, if continued warming under BAU were to trigger large-scale carbon and methane feedbacks, is illustrated by one of the hottest periods in our distant past – called the *Paleocene–Eocene* Thermal Maximum (or PETM) – 55 million years ago. Possibly caused by a gigantic release of methane from undersea

deposits similar to those that exist today, after the impact of a large comet, temperatures rose 5–10°C above current levels, with atmospheric carbon dioxide more than doubling to 1,000ppm or more in as little as a year.[16] While most extreme warming episodes from our geological history probably took thousands of years to reach maximum temperatures, we are currently warming much faster than ever before (except in such rare catastrophic episodes). Total recoverable reserves of coal contain many times the amount of carbon released in the PETM, though this event alone left most of the Earth too hot for human habitation.

Climate change today

Signs of warming have become increasingly evident even to casual observation in recent years. Winters are shorter and milder; snow, ice cover and glaciers are everywhere receding; and, as in previous episodes, warming is much faster in the Arctic. Sea ice in summer has been receding recently much more rapidly than predicted by climate models, probably due to changing winds and ocean currents, while the remaining ice has become much thinner and hence more fragile. Summer sea ice *volume* has thus been declining at an astonishing rate, with a loss of about three quarters from 1979 to 2011. There was a surprisingly strong recovery in 2013, but the declining trend continued in 2014–15. The IPCC AR5 predicted an ice-free Arctic in late summer before mid-century, though some forecasts are down to a few years. This trend, together with reduced and shorter snow cover on land, means less solar radiation is reflected and warming is accelerated over most of the northern permafrost region and Arctic.

It also used to be thought that a warmer climate would cause the ice caps of Greenland and Antarctica to melt slowly, from the top down, and take millennia to complete. However, the dramatic rate of increase in sea levels at the end of the last ice age described above casts doubt on this view, and recent observations also suggest a much more alarming development. Both the Greenland and West Antarctica ice caps appear to be quite fragile, with large glaciers breaking off the edges, in a process that is difficult to model quantitatively but may further accelerate in the future.

The West Antarctic ice sheet is most vulnerable, as it rests on submerged islands rather than mainland. Although temperatures there have so far risen much less than in the Arctic, ice loss has also accelerated, and several large glaciers are now considered to be irreversibly melting from below due to contact with sea water. They will ultimately raise global sea levels by 1–3 metres. While no one knows how rapidly current ice loss will accelerate, further warming can only increase the likelihood of collapsing ice sheets and a repeat of the rapid sea level rise that occurred around 14,000 years ago. At the same time, it is not only polar ice that is receding – glaciers (and winter snow cover) all over the world are also shrinking rapidly, including those in the Himalayas that maintain water supply for about a billion people in the densely populated surrounding regions.

An alarming new discovery is that the large Totten Glacier in East Antarctica has the fastest thinning rate in this region, hitherto considered to be quite stable. However, warmer ocean water from below the cold surface layer seems to be entering a cavity under the Glacier to cause melting, a process that may well already be irreversible, and expose other glaciers to warmer water. Complete collapse of Totten would raise sea levels by 3.5m, and may take centuries, but this seems to be an early discovery of a feedback effect that could turn out to be unstoppable even if drastic mitigation measures slowed or reversed overall warming.[17] Most worryingly, these processes are all quite consistent with the evidence from paleoclimate that has led prominent climate scientists such as James Hansen and a team of experts recently to predict much higher sea level rises even for the present century than the IPCC's very conservative predictions of only 0.5–1m. While not all scientists are convinced, Hansen's prediction record going back to 1981 has usually been right on the mark, so this latest contribution deserves to be taken seriously.[18]

The total stock of atmospheric carbon dioxide, currently about 400ppm, has been rising by about 2–3ppm per year. In terms of carbon content, human activity is emitting about 12 billion metric tonnes (gigatonnes, or GtC) of carbon annually, of which about half is absorbed by the natural environment of the oceans, biosphere, etc., and the rest remains in the atmosphere. Due to energy saving, recession and switching from coal to shale gas, EU and US emissions have actually declined in recent years. China has finally begun to decouple growth in the economy and emissions with world-leading investment in renewable and hydroelectric power, so its emissions grew by only 3 per cent in 2012, with 8 per cent GDP growth. Thanks to these developments, global carbon emissions in 2012 grew by less than half of the average 3 per cent rate of increase in the last decade, but accelerated to over 2 per cent in 2013–14. Coal consumption is still rising in China and several other large developing countries. To avert dangerous thresholds for irreversible change, emissions need to start declining rapidly and very soon – this, however, seems politically improbable to say the least!

The capacity of many natural 'sinks' to absorb carbon is also likely to decline with further warming, a tendency that will be exacerbated as the oceans, which are the largest sink, catch up with higher atmospheric temperatures after a substantial time lag, or thermal inertia. The increasing concentration of carbon dioxide in the atmosphere is causing the oceans to become more acidic, which in turn inhibits the growth of micro-organisms (phytoplankton) that remove carbon from the air, as well as destroying coral reefs and other biodiversity. Wetlands can also contribute both to climate change mitigation (through their ability to act as a carbon sink) as well as adaptation (through water storage and flood control), although all over the world they have been severely degraded and often drained for agriculture.

Soil organic matter (humus) contains more carbon than atmosphere and biosphere combined, and under favourable conditions such as low-till cultivation and cover cropping (discussed in Chapter 3) it can accumulate or sequester large amounts of carbon. However, modern industrial agriculture and overgrazing are causing widespread soil erosion in many parts of the world, which leads to loss of

humus and further carbon dioxide emissions. The oxidization of organic matter is also accelerated by higher temperatures. The only opposing natural influences are the fertilizing effect of more CO_2 in the atmosphere, and longer growing seasons in northern latitudes, which should increase plant and particularly forest growth, and sequester more carbon. Unfortunately, these benefits are likely to be very small compared to the devastating effects of water shortages and higher temperatures in the already hot and arid regions where most of the world's poorest people live, if emissions are not radically reduced in the near future.

Deforestation and land use change contributes roughly 20 per cent of current anthropogenic carbon emissions, mostly by burning tropical rainforest, which of course also destroys irreplaceable biodiversity. In addition to carbon dioxide, burning any kind of biomass produces clouds of smoke, particles of soot and sulphates, or aerosols, that have created a persistent smog or haze over much of South and East Asia, and parts of the Amazon basin. As well as rural cooking with biomass, growing use of dirty, high-sulphur coal is also a major contributor to haze and smog in rapidly industrializing China and India. This aerosol haze obstructs solar radiation and thus has a cooling effect opposed to the greenhouse effect of carbon dioxide, as well as reducing plant photosynthesis and thus slowing growth – a phenomenon often referred to as global dimming. However, the black carbon or soot component of haze absorbs radiation and thus has a strong warming effect in the lower atmosphere, as well as reducing the reflectivity – and thus accelerating melting – of ice and snow where it is deposited, particularly in the Himalayan region. Globally, aerosols still have a very substantial overall cooling influence on surface temperatures, equivalent to perhaps 50–80ppm CO_2, but, in contrast to greenhouse gases, soot and other aerosols are quickly washed out of the air by rainfall, and therefore must be constantly replenished to maintain their effects.

Biomass burning is a major contributor to anthropogenic carbon emissions, though some of this is absorbed by fresh growth.[19] It includes the burning of forest and savannah, as well as the use of biomass for cooking by 3 billion people in much of the developing world. 'Indoor' air pollution from the latter (and other solid fuels such as coal) has been identified by the World Health Organization as a greater overall health hazard than 'outdoor' urban air pollution, though both together are responsible for over 7 million premature annual deaths, and much ill-health particularly in the developing countries. However, the elimination of aerosol pollution would have a *warming* effect as well, simply because of the removal of the net cooling or dimming caused by aerosols currently.

Future prospects

The warming effects of atmospheric water vapour, carbon dioxide, methane and other 'greenhouse' gases have been well known since the nineteenth century. In a remarkable study in 1896, the Swedish scientist Svante Arrhenius calculated the effects of a doubling of atmospheric carbon dioxide, using fundamentally the same

approach as modern climate models (though with less computing power!), and reaching a similar conclusion: a 4–6°C global temperature rise was to be expected. Since the oceans take much longer to warm up than the atmosphere, we know that warming will continue for many years, even if there were no further increase in the stock of greenhouse gases in the atmosphere. Snow and ice will continue to recede, reducing albedo and also enhancing warming, until a new equilibrium is reached with smaller ice sheets and higher sea levels.

The albedo effect is just one of the many positive 'feedbacks' that amplify the primary influence of anthropogenic GHG emissions. An important feedback that is attracting increasing attention, but which has not yet been incorporated into most climate models, is the carbon feedback. Increasing emissions from eroding soils have already been mentioned, but another potentially major source is the permanently frozen Arctic tundra regions of Siberia, Canada and Alaska. As the ground continues to thaw under the rapidly warming northern climate, organic matter such as peat begins to decompose, releasing carbon dioxide or the much more powerful GHG methane from anaerobic decomposition in water-logged, marshy areas. The tundra is believed to contain perhaps twice as much carbon as the atmosphere, and emissions of methane have been accelerating at various locations. There is also a high subsidence risk for roads and buildings as a result of thawing permafrost in many northern settlements. Furthermore, thawing permafrost can increase the risk of landslides in mountainous settings.

In low latitudes, tropical rainforest is currently an important carbon sink, but rising temperatures are likely to transform these crucial areas into carbon emitters. Worldwide, the rainforest contains nearly as much carbon as the atmosphere, and will become increasingly vulnerable to drought and natural fires. There is thus a real threat of large-scale feedbacks from the tropics as well as from the tundra.

As with uncertainty about the future rate of collapse of the polar ice sheets, there are no firm estimates of how rapidly permafrost will thaw, and how future carbon emissions from the tundra and land use changes will develop. These feedbacks are thus excluded from quantitative climate models, and are not considered by the IPCC in their predictions based on numerical models of 'well understood' climate processes. Nevertheless, it is clear that the risk of a major carbon/methane feedback can only increase with further warming. There are also huge deposits of frozen methane hydrates – perhaps trillions of tonnes containing several times as much carbon as the atmosphere – under marine sediment on the sea-beds of many continental shelves, which could be released by sufficient warming of the oceans.

What climate models tell us

In order to provide some quantitative indications of how much future warming is likely to be generated by various scenarios of growing or declining emissions over time, scientists use complex computerized simulations of the global climate system, interacting with alternative policies, such as 'business as usual', or cutting

emissions by, say, 5 per cent annually. Where long-run consequences of warming, such as slow carbon feedbacks or the collapse of the ice sheets, are not well enough understood to be quantified, they are usually omitted from models. Uncertainties about many parameter values mean that climate models typically generate a range of probabilities for outcomes, where the extreme values are relatively unlikely, and the outcomes close to the mean, in the middle of the range, are considered the most probable.

This approach yields interesting and alarming insights that do go beyond simply listing possible outcomes in qualitative or descriptive terms. One of the key predictions, on which a wide consensus has been reached, is that 'most' of the proved reserves of fossil fuels must remain unburned in the ground to avoid irreversible and catastrophic warming. The IPCC's AR5 suggested that (then) current emissions for another 30 years, or about 300 billion carbon tonnes (gigatonnes or GtC) of additional carbon emissions (only a small fraction of current reserves, however defined), is the maximum, cumulative 'carbon budget' that would provide a 50 per cent chance of remaining below the 2°C threshold by 2100. With an equal chance of probably disastrous further warming, this is an extraordinarily high-risk carbon budget (and of course emissions could never decline instantaneously from current levels to zero). In fact, the IPCC's neglect of slow feedbacks probably means that a relatively 'safe' carbon budget is likely to be less than half their estimate. Many scientists now believe that these effects from declining albedo and thawing permafrost, plus delayed ocean warming, mean that global temperature is likely to exceed the (already dangerous) 2°C threshold *even if* all emissions were stopped immediately.

As already mentioned, paleoclimate evidence from the Pliocene era suggests that even current CO_2 levels of 400ppm and the UN Convention target of at most 2°C above pre-industrial levels are both dangerously high. Both are almost certain to be breached under current policies, causing sea levels to rise ultimately by 20m or more, inundating the world's coastal cities and much of the most fertile agricultural land. With this background, leading climate scientists such as James Hansen et al. (2008) and prominent environmentalist Bill McKibben and associates (350.org) have been campaigning for a CO_2 target of 350ppm, as the maximum level to ensure the survival of our civilization.[20] Such a target is *directly* achievable, albeit only with radical mitigation policies, whereas global temperatures are the *result* of chosen policies and their interaction with natural systems, and subject to much uncertainty about the precise response. Thus, the target of 1.5°C above pre-industrial temperature, while obviously more prudent than 2°C and now supported by more than 100 nations, is less helpful for policy than the CO_2 target of 350ppm.

Thus, our moral responsibility to the poorest and most vulnerable inhabitants of this and future generations requires *reversal* of current emissions growth in the very near future. According to James Hansen et al. (2013), and many other prominent scientists and environmentalists, emissions need to *decline* rapidly, complemented by large-scale reforestation and conservation agriculture to sequester 100 billion tonnes of carbon, in order to attain the safe level of atmospheric carbon, 350ppm,

by 2100.[21] The total additional carbon budget, or cumulative emissions until the end of the century, would then be about 130GtC, yielding cumulative emissions since industrialization of about 500GtC. This policy could stabilize global temperature at about 1°C above pre-industrial levels by 2100, with only slight overshooting by mid-century. An essentially zero-carbon global economy should be achieved by 2035–45, as we discuss in detail in Chapter 9.

To summarize briefly here, such radical mitigation (far faster than in any historical examples except the collapse of the Soviet Union and its heavy industry after 1990) will be impossible without large-scale, global mobilization for mitigation. Just as only mobilization for World War 2 ended the Great Depression, so could a similar effort today to build a low-carbon economy with a 'green fiscal policy' or New Deal end the misery of high and persistent unemployment left by the Great Recession, as a 'climate policy bonus'. We show that just using existing technology, supplying most of the world's energy from wind, water and solar (WWS) would be feasible in 20–25 years with an annual investment of about 4 per cent of global GDP. This is similar to the IMF's estimate of the *direct* health costs of local pollution, without considering climate change, which is probably an underestimate, and about the same as the International Energy Agency's estimate of the global *fossil fuel* investment needed over the next 20 years under BAU plus the direct cost savings from phasing out the use of fossil fuels.

This is, of course, much more ambitious than current EU and other targets of just an 80 per cent emissions reduction by 2050, and the IPCC temperature threshold of 2°C, but, as we discuss in Chapter 9, it is technologically and economically achievable, and could actually provide more co-benefits in the form of major improvements in well-being, including full employment. It would require behavioural changes, and doubtless face bitter opposition from market fundamentalists and all who stand to lose from the demise of fossil fuels.[22]

To protect the health of their urban populations, developing countries will sooner or later have to take steps to reduce current dramatic levels of local air pollution from coal burning and motor vehicles, particularly in the biggest cities (this kind of clean-up, which Western countries partially accomplished decades ago, is much easier than reducing carbon dioxide emissions). Aerosols are quickly washed out of the atmosphere by rainfall, in contrast to very long-lasting carbon dioxide, so these measures would promptly eliminate much of the aerosol cooling, and hence have a substantial *warming* effect, only partially offset by drastically reducing black carbon (soot) emissions.

Ocean currents are another major area of uncertainty. As noted above, recent evidence suggests that the Atlantic circulation is slowing down, probably due to an influx of fresh water from melting Greenland and Arctic ice. If this sufficiently diluted the salty surface flow, it would no longer sink as it cooled. Though a complete interruption of the circulation may be unlikely in the medium term, such a repeat of the many apparent past interruptions of the circulation indicated by ice core data could become a serious additional destabilizing factor, though with effects that are unlikely to resemble the scenario in science fiction film

The Day After Tomorrow. However, a weakening of the circulation could still have serious effects on the global weather system, in particular disruption of the Asian monsoon. This, in turn, would endanger the food supply for around 2 billion inhabitants of the region.

While much climate modelling is concerned with predicting mean global temperature under various assumptions, models can already explain some of the considerable regional variations in warming that have been observed in recent years. Thus, parts of the Arctic have seen temperature increases of 3°C over the last three decades, with much less warming in the tropics. Most climate modellers agree that hot and dry continental interiors are likely to become hotter and drier, with more frequent droughts, posing a serious threat to water supplies and agriculture in many developing countries, and also the whole Mediterranean region.

Total rainfall is expected to increase, with more water vapour in a warmer atmosphere. However, much of the increased precipitation is expected to be in the form of heavy rainstorms that increase the risk of flooding and erosion, while rapid runoff means that intense rainfall is less effective in replenishing ground water and reservoirs. Extreme events of all kinds such as storms, floods, heatwaves and droughts are already becoming more frequent and severe, and this trend will almost certainly continue. If the concentration of greenhouse gases does not soon begin to decline rapidly, the world described by climate modellers at mid- or end of century will be parched and scorched throughout much of its once most populous areas.

Canada and Siberia may have milder winters, but extremely hot and dry summers, and just how many of the future world's refugees these northern regions with their poor soils will be able to feed remains doubtful. The threat to world food supply is already severe for a number of reasons, even before climate change impacts kick in, as we discuss in detail in Chapter 3. With continued warming on present trends, climate models 'suggest severe drought conditions by the late half of this century over many densely populated areas such as Europe, the eastern USA, southeast Asia and Brazil'.[23] This is all the more serious because sources of water for the irrigation of modern high-yielding crop varieties, such as ground water and 'fossil water' aquifers, are being rapidly depleted by overuse, as we discuss in subsequent chapters.

Conclusions

One of the most alarming trends in current climate change is the dramatically increasing loss of late-summer Arctic sea ice, and the resulting albedo effect of reduced reflectivity. This will accelerate warming in the whole permafrost region, as tundra and ocean without snow and ice cover absorb most of the sun's incoming radiation. This, in turn, will boost carbon feedback as methane is released from thawing peat bogs, and could soon put global warming on an essentially irreversible path to overshoot the 2°C threshold. Many of the IPCC's predictions

are now seriously outdated, though they are still regularly cited by policymakers in support of their ambitious-sounding, but actually far-too-late targets, such as the 80 per cent reduction of emissions by only 2050. Unless rapid mitigation starts much sooner than under official targets, the feedback effects are likely to overwhelm later efforts and become irreversible, rendering subsequent stabilization of the climate enormously costly if not unattainable.

As we show in Chapter 3, water shortages and soil erosion are already threatening food production in many areas. These problems will be exacerbated by climate change and growing populations, and represent the most serious medium-term threat to the poorest and most populous countries. Over a longer time horizon, sea level rise could be much faster than current model predictions, if loss of ice from Greenland (and perhaps also Antarctica) continues to accelerate, and the ice cap begins to collapse. In subsequent chapters, we show how climate policy has been largely constrained by fossil fuel and other industrial interests, as well as widespread lack of knowledge about the most cost-effective alternatives, and the probable consequences of our current inaction.

Notes

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3

SUSTAINABLE AGRICULTURE

Sequestering carbon for food security

Introduction

'Make agriculture truly sustainable now for food security in a changing climate' is the core message (and sub-title) of the United Nations Conference on Trade and Development or UNCTAD's (2013) path-breaking Trade and Development Review, *Wake up before it is too late*.[1] In this seminal review, experts from around the world summarize the compelling case for radical and urgent reform of the whole global food system, based on extensive peer-reviewed research and field trials in many countries.

The vulnerability of industrial agriculture to resistant pests, extreme weather events and chronic water shortages is becoming ever more apparent, and numerous practical examples show how related systems of regenerative, organic or eco-agriculture, low/no tillage instead of ploughing, agro-forestry, pasture cropping and cover crops all contribute to greater resilience in the face of extreme weather conditions. A major component of this necessary adaptation to the unavoidable climate change, which is already 'in the pipeline', is to build up the soil organic matter or humus that has been severely depleted by modern agriculture and erosion. This soil organic matter (SOM) greatly improves water retention, soil and plant health, and reduces runoff and erosion.

Much farmland has lost half or more of its original SOM and carbon content in the last century. Together with deforestation and biomass burning, this has contributed probably nearly as much extra carbon to the atmosphere as fossil fuel burning. Sustainable agriculture and *reforestation* have the potential to reverse this process and sequester around 4GtC or 30 per cent of current annual carbon emissions in soils and biomass – a really major contribution to mitigation, as well as all the other benefits we discuss below. In particular and in stark contrast, industrial agriculture and land use change are *adding* about 3GtC to anthropogenic emissions, and most of this could be avoided by switching to sustainable agriculture, reducing meat consumption and halting deforestation.

Now recall from the previous chapter that, out of total annual emissions (close to 12GtC in 2015), about half now remain in the atmosphere on average, raising CO_2 concentrations by about 3ppm annually. The rest is sequestered in oceans and

land sinks (with considerable annual variation in the latter). Thus, sustainable agriculture and reforestation instead of industrial agriculture and deforestation could actually *stabilize* atmospheric carbon. Of course, energy saving in other sectors and switching from growing use of fossil fuels to renewables remain essential policies to *reduce* the current, dangerous level of atmospheric carbon to the more prudent, long-term target of 350ppm CO_2. If all this sounds too good to be true after decades of lobbying and misinformation by agribusiness, UNCTAD has now provided a major public service by summarizing the extensive body of peer-reviewed scientific research, which clearly demonstrates both the feasibility and the urgency of sustainable agriculture.

Over the past half-century, rapid economic and population growth have culminated in a global food system dominated by industrial agriculture and giant multinational corporations, and based on cheap oil and water. Substantial costs of increasing oil- and gas-based inputs (energy, chemical fertilizers and pesticides) for industrial agriculture mean that organic farming can be equally or even more profitable with comparable scale and other conditions. New skills and more labour are generally required, but chemical (and energy) inputs per unit of output are much lower. Recurrent food scares and scandals have generated rapidly growing demand, as well as premium prices for organic certification. This provides assurance to consumers that organic produce is very unlikely to contain toxic pesticide residues, which are widespread in most conventional grown products (of course, organic certification is no guarantee for various other, important dimensions of quality).

However, in the transition period needed to rebuild degraded soil fertility after a history of industrial agriculture, and attain organic certification, yields and revenues may fall substantially, and new skills have to be acquired. These skills differ from conventional practice and teaching in a system dominated at every level by agribusiness, so there are substantial barriers to attaining the long-run economic advantages of sustainable farming. The public health, environmental and climate benefits of the transition, described in detail below, provide a strong argument for government support. Effective policies have resulted in about 20 per cent of Austrian farmland being certified organic, and 12 per cent in Switzerland, but with much lower levels in other developed countries offering less support for the transition.

Agriculture uses 70 per cent of the world's freshwater withdrawals for irrigation, much of which comes from 'water mining', or rapidly depleting ground water and aquifers. Dramatically increasing application of toxic chemicals in conventional agriculture now poses a major threat to human and animal health,[2] while around 70 per cent of antibiotics made are used in 'factory farming' (CAFOs or 'confined animal feeding operations'), often prophylactically or to stimulate growth. This, together with widespread over-prescription in medical use, has helped to generate a growing global incidence of antibiotic-resistant infections, which now threatens to destroy the basis of modern health care.[3]

Furthermore, industrial monocultures in SOM-depleted soils are increasingly vulnerable to soil erosion under the ever more frequent extreme weather events

(which are consequences of climate change). Biodiversity has also declined dramatically, with a few varieties of the staple cereals directly or indirectly (through animal feed) supplying most of the world's rapidly rising demand for calories – especially and most wastefully in the form of animal products. The hidden price for higher yields has been declining nutritional density, and rising susceptibility to pests and infections, which in turn require increasing herbicide and antibiotic inputs on a never-ending 'chemical treadmill'.

In spite of the much-touted 'miracle' of the green revolution in tripling grain output in the last half century, the nominal FAO food price index in 2014 remains about twice as high as its long-term level prior to the crash of 2007, imposing major hardship on the world's poor who spend most of their income on food, and often benefit least from overall GDP growth. Nearly a billion people are still seriously undernourished in poor regions, while twice as many rich individuals are overfed and overweight. Globally some 30–40 per cent of all food produced is wasted, of course for very different reasons in rich and poor countries.

Much less is known about the chronic *malnourishment* of an estimated nearly 5 billion people, in deprived, low-income households everywhere. There are probably many more in rich countries (often also overweight), who consume mainly processed food, containing excessive sugar, salt, refined carbohydrates and trans fats, and who suffer rapidly increasing incidence of the (non-infectious) 'diseases of civilization', which we discuss further below. As just one of many striking examples, the number of 'pre-diabetics' (at high risk of developing type-2 diabetes) increased from about 12 per cent of the adult population in England in 2003 to 35 per cent in 2012.[4]

Renowned American chef, organic farmer and food writer Dan Barber has eloquently summarized the issues, not only for the US, but for other developed – and increasingly developing – countries as well:

> Eroding soils, falling water tables for irrigation, collapsing fisheries, shrinking forests, and deteriorating grasslands represent only a handful of the environmental problems wrought by our food system – problems that will continue to multiply with rising temperatures. . . . Our health has suffered, too. Rising rates of food-borne illnesses, malnutrition, and diet-related diseases such as obesity and diabetes are traced, at least in part, to our mass production of food. The warnings are clear: because we eat in a way that undermines health and abuses natural resources (to say nothing of the economic and social implications), the conventional food system cannot be sustained.[5]

In the rest of this chapter, we consider in more detail how population and economic growth push rising demand for food and, in particular, animal products for the growing middle classes in developing countries, who are persuaded to imitate Western lifestyles by unrelenting and unregulated advertising. This growing demand and the industrial food system are interacting with climate change to threaten not only human and animal health but future global food security, and

indeed the survival of future generations. In contrast, we show how sustainable agriculture could provide healthy food for a growing population and also reduce net carbon emissions by nearly half.[6]

Growing global food demand

Projections of current trends typically lead to predictions by food agencies, such as the FAO, and politicians that we will need to grow 70 per cent or more food by 2050. Since population is only projected to grow from 7 billion today to about 9 billion by mid-century, with most of this growth among the poorest peoples, who have below-average demand, it certainly cannot be population growth that is the main driver of such predictions (though it does remain a major problem in many poor countries).

Instead, rapidly growing middle classes of the big developing countries, such as China, India, Brazil and others, are switching from traditional, mainly vegetarian diets to newly affordable, Western-style diets, with increasing demand for meat and dairy. Because intensively reared animals in particular are such inefficient producers of calories, '36% of the calories produced by the world's crops are being used for animal feed, and only 12% of those feed calories ultimately contribute to the human diet (as meat and other animal products)'.[7] Thus *total demand* for food crops, primarily for animal feed, rises dramatically with the proportion of meat and dairy in human consumption, and hence with the number of people who can afford this more expensive diet.

To illustrate this, in the US, where per capita meat consumption is one of the highest in the world, total annual grain consumption per person is around 700kg, mostly indirect in the form of animal products. In India, where the prosperous middle class is still quite small and much of the population remains vegetarian, average annual grain consumption is about 190kg, mostly direct. Globally, only about 55 per cent of total calories from crop production are used to directly feed humans, while the rest is diverted to animal feed and biofuels. In China, more than three decades of double digit economic growth since 1980 have *quadrupled* both average per capita real GDP (according to official statistics, which may, however, be exaggerated) *and* the consumption of meat, now over twice the US total, and China has become a major importer of grains and soy. Per capita meat consumption in China is now about half the US level.

Demand for animal products is also boosted by the failure to tax and price animal products in accordance with the massive environmental costs incurred in their 'industrial' production. Price-cutting competition between the giant retail chains maintains artificially low prices, which encourage unsustainable and excessive consumption (in rich economies), and growing demand by the emerging middle classes (in the LDCs). The retail chains also use their monopsony buying power to ruthlessly squeeze farmers' margins, and enforce unsustainable 'productivity' gains at the cost of product quality, the environment and health risks to all involved, as we develop in detail later in this chapter.

Growing production of biofuels from food crops adds to demand and contributed to the doubling of grain prices before the crash of 2008, encouraged by extensive government subsidies based on lobbying by agribusiness, and the mistaken belief that biofuels reduce GHG emissions cost effectively. In the US, nearly 40 per cent of the maize harvest is used to produce bioethanol. In fact, when emissions from the whole industrial agricultural cycle of growing grains for biofuel are taken into account, any small net reduction in emissions comes at high but unaccounted costs, including deteriorating soil quality and chemical pollution of local water supplies.

Diverting crops to biofuel adds pressure to cultivate forest or grassland, and such 'indirect land use change' (ILUC) often releases huge amounts of carbon, a 'carbon debt' that can be much greater than the benefits of lower fossil fuel consumption. Heavily subsidized demand for biodiesel in the EU has also led to large-scale destruction of tropical rainforest in Malaysia and Indonesia, to make way for palm oil plantations to supply one of the main ingredients of biodiesel, also with disastrous effects on the carbon balance, and biodiversity. EU incentives to encourage the sensible use of bio-waste to produce biogas by anaerobic digestion were so badly designed that now 55 per cent of all the feedstock for biogas production comes from food crops, mainly a growing area of maize monoculture. This intensive maize cultivation is causing serious soil structural degradation, erosion and flooding in South-West England and elsewhere, yet UK farm lobbies have blocked EU initiatives to monitor damage and protect soil.[8]

Ethanol production from perennial sugar cane in sub-tropical Brazil, the world's leading producer, is more efficient than producing ethanol, biodiesel or biogas from food crops or palm oil in the US or EU, but the carbon debt from ILUC remains a major problem. While deforestation in the Amazon rainforest has declined by about 75 per cent since it peaked in 2004, it jumped substantially to nearly 6 million hectares in 2013 as protective legislation was relaxed under intense lobbying by the agribusiness sector. Various degrees of degradation through selective logging, fire and climate change continue to affect nearly as large an area.[9] The lesser-known, unique *Cerrado* or wooded savannah, second only to the Amazon region in biodiversity, is now even more threatened, and has lost more than half its original area to (mostly industrial) agriculture (e.g. for growing soy for export as feed to the factory farms of the EU and elsewhere).

The scale and depth of the problems already caused by growing demand for meat, and industrial agriculture, are eloquently reviewed by the CEO of Compassion in World Farming, Philip Lymbery, in his aptly titled new book, *Farmageddon*: 'Some 70 billion farm animals are produced worldwide every year, two-thirds of them are now factory farmed . . . they consume a third of the world's cereal harvest, 90 per cent of its soya meal, and up to 30 per cent of the global fish catch'.[10] Clearly, reducing demand for meat and animal products by the rich could have major environmental benefits, reversing the rapidly growing demand for food grains and resulting ILUC. Much less recognized are the already devastating effects of industrial agriculture on animal health and welfare, and especially the consequences for human health, which we discuss later in this chapter.

The green revolution and industrial agriculture: Malthus reloaded?

Population growth was regarded as the principal threat to food security until the 1960s, a view famously first expounded by English clergyman–economist Robert Malthus, in his 1798 book, *An Essay on the Principle of Population*. His pessimistic predictions that only starvation could limit population growth were repeated by 'neo-Malthusian' environmentalists after WW2, as death rates in developing countries declined and population growth accelerated. However, global population increased two and a half times in the second half of the twentieth century, mainly in developing countries, and with no major famines. This was only made possible by the 'green revolution', which yielded a threefold expansion of world grain output, but also required a similar extension of irrigated area, a tenfold increase in the use of chemical fertilizers, and an astronomical rise in pesticide use. The triumph of agribusiness in the age of cheap oil seemed to sound the death knell of neo-Malthusianism.

The green revolution was first introduced in Mexico, followed by India in the 1960s, where it raised yields, at least for richer farmers who could afford the more expensive inputs, and was based on selective breeding of short-straw or 'dwarf' varieties. This essentially transferred the savings from shorter stalks into more grain, but with much shorter root systems than older varieties, while high yields also required high inputs of water and chemical fertilizer. Energy and chemical inputs based on oil or gas were cheap, irrigation was usually subsidized, so high-yielding monocultures and labour-saving machinery were the most profitable choice for large farmers in many countries. However, nutritional density and quality have declined substantially, and since these modern varieties have come close to physiological limits to useful output, there have been no further productivity gains in the highest-yielding areas in Western Europe and elsewhere in recent years, while toxic pesticide use has soared as pests develop resistance.

In a scathing critique of the green revolution, historian Nick Cullather concludes that supposed success stories, such as Mexico, India and Pakistan, are now 'among the most undernourished nations', with serious problems of malnutrition for their large poor populations.[11] By contrast, the poorest farmers in much of Africa and parts of Asia were never able to afford the high-input, modern methods, but lack the knowledge to develop more productive, sustainable farming. As well as being among the most vulnerable to climate change and soil erosion, these regions also still have some of the world's highest rates of population growth, and remain the least developed, both economically and politically.

Though often neglected in modern emphasis on growing demand for animal products by the better-off, remaining population growth is thus still putting severe strains on some of the most vulnerable environments as competition for resources increases, with about 80 million extra mouths to feed every year. In particular, deforestation and overgrazing to supply fuel and subsistence for poor rural populations (or to provide meat for the urban middle classes) are important causes of soil

erosion and desertification all over the developing world. The poorest populations suffer from almost universal female illiteracy and high infant mortality, and they have multiple 'incentives' for large families. These include the insurance motive to provide for old age, the need for family labour in subsistence agriculture, lack of access to contraception, and the lack of education, cultural status and job-market opportunities for women.

It is true that, if less food were fed to animals, diverted to biofuels or wasted, *current* global crop yields could easily provide enough calories for the 9 billion people expected by mid-century (though nutritional quality of much of this output is already inadequate in many respects). But even under these assumptions, the modern food system would be unsustainable in several dimensions. Indeed, industrial agriculture itself is a major cause of climate change, soil erosion and progressive water shortages even in developed countries, and growing, diverse health threats to crops, animals and human consumers everywhere. Malthusian warnings are being resurrected, not only about continuing population growth in poor countries, but for questioning the very foundations of future global food security and international order.[12]

Climate models generally predict declining rainfall and more major droughts in many already hot and arid regions, as well as more frequent flooding, particularly where soils have been degraded by industrial agriculture, or overgrazing by more traditional farmers. These areas contain most of the world's poorest and most vulnerable populations and ecosystems, and already often suffer from severe water shortages. Furthermore, research in various environments has shown that higher temperatures reduce grain yields, by *at least* 10 per cent for each extra degree Celsius above 30 degrees during the growing season, unless much more resilient varieties can be developed in time.

The increasing concentration of CO_2 in the atmosphere does encourage photosynthesis in arid conditions, and there has been some increase in green foliage over warm and dry areas since 1980. However, 'total protein and nitrogen concentrations in plants generally decline under elevated CO_2 atmospheres', and uptake of vital minerals zinc and iron is also reduced, thus lessening nutrient quality. This is a particularly serious problem because an estimated 2 billion people already suffer from these and other deficiencies, causing many health problems and an annual loss of 63 million life years. This population depends mainly on C_3 grains and legumes most affected by rising CO_2.[13] Transpiration also declines, which results in less cooling from the natural evaporation of water, and hence yields additional warming. Further warming due to rising emissions, and more frequent weather extremes, are likely to far outweigh any benefits from CO_2 fertilization in the future. Northern regions of Russia, Europe and North America could benefit from longer growing seasons, but their soils are generally so poor and acidic that they are unlikely to be able to compensate for major climate-related losses in the main food-growing areas of the South.

While world grain output per head of population has been declining for 20 years, surpluses in the most developed countries have been maintained with the

help of about 300 billion US dollars in annual subsidies, or six times the world's aid budget. As Nobel Prize-winning economist Joseph Stiglitz explains, 'When farming becomes more lucrative because of the subsidies, the demand for land is increased, driving up the price. With the price of land so high, farming has to become capital-intensive. It has to make heavy use of fertilizers and herbicides, which are as bad for the environment as the increased output is for farmers in the developing world.'[14]

Most of the agricultural subsidies go to the richest and biggest farmers in the wealthy countries, while heavily subsidized exports to poor countries depress their own agricultural prices, undercut local producers, and increase poverty and displacement of the poorest rural populations. At the same time, EU and US rules prevent developing countries from exporting many of their agricultural products to the richest nations, thus further damaging the world's poorest farmers. This group is also the most vulnerable to the effects of current erosion, future warming, declining rainfall and worsening water shortages. Reform of trade and subsidy policies on its own will not be sufficient. Radical changes in agricultural practices, discussed below, are needed to reduce these threats and provide more food security. Education in the new methods, knowledge and technology transfer, and aid for the transition are all essential, but still far removed from an agenda that remains dominated by agribusiness multinationals and rich-country farming lobbies.[15]

Industrial agriculture, health and the food system

Industrial agriculture is not obviously related to human health in popular discussion. The 'diseases of civilization' are more often associated with affluence, sedentary lifestyles, and processed and junk food. This last, of course, is produced and marketed by food and retail industries, while the industrial agriculture that produces their raw materials, is rarely closely observed – and even less understood – by urban consumers. Though recurrent scandals and food scares have tarnished the image of factory farming, lack of public education in the basic issues of food and health and intensive lobbying by agribusiness have maintained the prevailing view that more industrial agriculture is the only way to feed our expanding population and appetites.

Apparently unrelated to agriculture, it is well known that decades of overprescription (and inappropriate use) of antibiotics has helped to generate widespread antibiotic resistance in many common bacterial infections. In the US, over 2 million annual cases of resistant infections are reported, leading to at least 23,000 deaths, with similar numbers in the EU. Some bacteria are already resistant to all known antibiotics, and the flow of new antibiotics from the pharmaceutical industry has virtually ceased due to increasing costs and complexity. As leading medical practitioners are warning with ever-increasing urgency, we are in imminent danger of reverting to the pre-antibiotic era, when even minor infections could be difficult to treat, and might well turn out to be fatal.

Far less known is the fact that 70–80 per cent of antibiotics used in the US are fed to animals in intensive feedlots or CAFOs, much of this to healthy animals in sub-therapeutic doses to promote growth and weight gain. Of course, the extreme overcrowding and unsanitary conditions in factory farms provide ideal conditions for all kinds of infections, and even in the EU, where the use of antibiotics as growth promoters was banned in 2006, an estimated half of all antibiotics are used in agriculture. As well as directly inducing resistance in animal pathogens (which can also transfer genetic material for resistance to other bacteria), the antibiotics consumed leave residues in animal products, and in manure, which is used as a fertilizer, so affected crops may also contain traces.

An insidious and even more pernicious threat from over-use of antibiotics has emerged in recent years.[16] There is now a huge amount of evidence that constant exposure to antibiotics, particularly in earliest childhood, or even gestation, is seriously damaging the human microbiome – the collection of microbes that live on and in our bodies. Since the ancestral microbiome is an essential part of the human immune system, this damage not only exacerbates the threat from old or new and resistant pathogens. It is also an important factor in the dramatic rise of allergies, autoimmune diseases (such as asthma, diabetes and inflammatory bowel disease), obesity and metabolic disorders in recent decades, with much more to come – in addition to all the untreatable infectious epidemics of the approaching 'antibiotic winter' – unless major reforms are rapidly instituted.

Remarkably, what may turn out to be the most dangerous and overused antibiotic, and the worst long-term environmental toxin of all, was only granted an antimicrobial patent in 2010. The herbicide glyphosate has of course never been prescribed for humans or animals, yet it is present in most food and feed consumed in the Americas, and in most of the concentrated feed used in EU factory farms, so that residues were also found in nearly half of a sample of urban Europeans who had not directly used glyphosate (in 18 countries), and in many other human and animal samples.[17] It has recently been found that low-level exposure to glyphosate can also confer antibiotic resistance to dangerous pathogens, an alarming addition to the already serious risks from overuse of standard antibiotics in view of the ubiquity of glyphosate residues in industrially produced food and feed.

Glyphosate is the active ingredient in Monsanto's Roundup® herbicide, which has enjoyed explosive growth since 1995, and is now applied to most of the maize, soy (and other crops) in North and South America, much of which is exported as feed. These crops are the genetically modified 'Roundup Ready®' varieties immune to glyphosate, which was claimed by Monsanto to kill all the weeds, reduce overall herbicide use and rapidly biodegrade, while being harmless to mammals.

The experiences of numerous affected individuals and a rapidly growing number of peer-reviewed papers are now refuting all these claims.[18] A proliferation of resistant weeds has resulted from prolonged application of Roundup®, so farmers have had to dramatically increase their dosage (and Monsanto's profits). Glyphosate turns out to be highly persistent, and like the (therapeutic) antibiotics discussed above it damages our microbiome – particularly the beneficial gut bacteria that

form a vital component of our immune system, while sparing pathogens. In the US, where glyphosate residues are found in much higher concentrations than in Europe, there is an astonishingly close correlation between rapidly rising glyphosate use and the dramatic increase in a series of modern immune-related 'epidemics', particularly autism in children, celiac disease, diabetes, obesity, and death rates from senile dementia, intestinal infection (age adjusted) and acute kidney failure.

About half the sevenfold rise in autism since 1995 seems to be due to better diagnostics, but this still leaves an alarming unexplained increase. A recent study of mothers in California showed a 60 per cent increase in autism for those who lived, during pregnancy, close to 'an agricultural pesticide application'. Deteriorating wildlife health, particularly birth defects among deer fawns, and birth defects in the human population have been found to be strongly correlated with rapidly growing glyphosate use in the US over the past two decades.[19]

Of course correlation does not necessarily prove causation, and many other toxic chemicals are accumulating in the environment, but there is now direct, laboratory and other evidence from controlled comparison trials for the toxicity of glyphosate and other pesticides to human cells, other mammals and beneficial gut bacteria. Furthermore, pesticides are generally applied with adjuvants to enhance absorption by plants, which are treated as 'trade secrets' and simply declared to be inert by manufacturers, and so are not subject to testing or controls by complacent or compliant authorities. In a recent analysis, Mesnage et al. summarize:

> Despite its relatively benign reputation, Roundup® was among the most toxic herbicides and insecticides tested. Most importantly, 8 formulations out of 9 were up to *one thousand times more toxic than their active principles*. Our results challenge the relevance of the acceptable daily intake for pesticides because this norm is calculated from the toxicity of the active principle alone. Chronic tests on pesticides may not reflect relevant environmental exposures if only one ingredient of these mixtures is tested alone.[20]

Further confirmation comes from a follow-up study of rats exposed to ultra-low concentrations of Roundup® in water for 2 years (less than half the concentration allowed in drinking water in the EU, and 14,000 times lower than the US limit!). More than 4,000 genes in livers and kidneys were affected, corresponding to increased liver and kidney pathologies observed in the treated animals.[21] Pigs have similar digestive systems to humans, and in the first such controlled comparison of animals over their commercial lifespan in normal farming conditions, pigs fed GM maize and soy (mostly Roundup Ready®, containing glyphosate residues) were compared with similar pigs on a diet of conventional, non-GM maize and soy in the same proportions. After slaughter, the GM-fed animals were found to suffer from much higher incidence of severely inflamed stomachs (four times the incidence for males, twice for females) than the non-GM pigs.[22]

Using a large sample of 168 pigs, all these results were statistically highly significant, and while holding all other relevant conditions constant, they do lend

credibility to numerous anecdotal reports from farmers about severe digestive and reproductive problems among GMO-fed animals, including birth defects. Glyphosate residues, likely to be a major cause of these problems, have been found in high concentrations in Roundup Ready® GM maize – and again in striking contrast to repeated industry claims, the nutritional composition of GM maize differs from conventional but non-GM maize, while organically grown maize has a more healthy nutritional composition (all samples commercially grown in the US state of Iowa).[23]

In a sample of Danish dairy cows all were found to excrete glyphosate in urine, ingested as residues in their (imported) GM feed, and to absorb 30 per cent of the ingested glyphosate. All had severe deficiencies of the vital trace elements manganese and cobalt, likely due to the chelating effect of glyphosate, which binds to minerals in the soil and inhibits plant uptake. Various health markers indicated multiple organ damage.[24]

Other recent, related research in peer-reviewed publications has found higher glyphosate residues in the urine of chronically ill people in Germany, and evidence that glyphosate reduces beneficial gut bacteria of poultry and cattle, while increasing harmful bacteria. Severe pathologies were only observed in rats fed with GM maize after a much longer trial than the standard 90 days used in industry studies, showing clear evidence of the toxicity of glyphosate residues in combination with adjuvants used in Roundup® that greatly enhance toxicity. Much higher rates of cancer and birth defects have been reported for years from areas in Argentina where GM crop spraying is most intensive, and in March 2015 the World Health Organization (WHO) belatedly classified glyphosate as probably carcinogenic.[25]

In spite of all this evidence, industry claims that glyphosate and other herbicides are harmless to humans and animals are still so widely accepted that there is virtually no official monitoring of residue levels in crops, animals or food products. Allowed residue limits have actually been recently *raised* by environmental regulators in the EU and US at Monsanto's request and based on industry studies, to accommodate the rising intensity of Roundup® use as ever more weeds become resistant, as well as even more toxic combinations with dicamba and 2,4-D for use on new GM crops with multiple resistance. However, in response to growing evidence of the dangers, Denmark, the Netherlands and France have banned glyphosate for private use, and Sri Lanka and Brazil are likely to follow.[26]

Most safety research (including clinical drug trials) is performed by the manufacturer, or is industry funded or influenced, so that *negative* results are rarely published, treated as confidential, and unavailable to researchers and policymakers. Recent studies of the US Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA) reveal an astonishing history of systematic corruption, as early warnings about the dangers of GM crops by the FDA's own scientists were covered up under industry pressure, and subsequent safety research and evaluation have been outsourced to the manufacturers of the very products whose safety is at issue. There is thus a major bias in the published literature on the safety of most agricultural and many other chemicals (including many pharmaceuticals) that are

freely available on the market, are claimed by official agencies to be safe or GRAS (generally recognized as safe), but have *never* undergone the rigorous and *independent* testing that is the legal precondition for these designations.[27]

Another major threat to agriculture and environment has been identified by an international research team of 29 leading experts: the Task Force on Systemic Pesticides analysed over 800 peer-reviewed studies on the most widely used insecticides – the neurotoxic 'neonics' or neonicotinoids (and also filpronil). Their report, The Worldwide Integrated Assessment of the Impact of Systemic Pesticides on Biodiversity and Ecosystems (WIA), is published in a special issue of the peer-reviewed journal *Environmental Science and Pollution Research* (August 2014), and is already being compared with Rachel Carson's (1962) landmark warning, *Silent Spring* (the similarities extend to blanket attacks on the research by industry spokespeople and industry-funded scientists).

One of the lead authors of WIA, Jean-Marc Bonmatin, is quoted in the press release: 'Far from protecting food production the use of neonics is threatening the very infrastructure which enables it, imperiling the pollinators, habitat engineers and natural pest controllers at the heart of a functioning ecosystem.' While highly toxic to all invertebrates, the most affected groups are terrestrial invertebrates, such as earthworms, rarely observed but vital for soil health and fertility. Most visible is the dramatic decline of bees, butterflies and other pollinators, on which most of the world's crops depend, which suffer both through direct effects of neonics and from increasing susceptibility to viral infections, which may also be implicated. There is now compelling evidence that neonics directly cause the colony collapse disorder that has decimated honey bee populations around the world.[28] There has been an equally dramatic decline in most of the insect population, as well as many of the insectivorous birds that feed on them, in Europe and other regions where neonics have become the most popular insecticides. While this decline started earlier, partly due to habitat loss and monocultures under industrial agriculture, it has accelerated alarmingly since the introduction of neonics in the 1990s. After the release of WIA, detailed regional studies in a leading scientific journal, *Nature*, have shown that 'decreases in bird numbers are most rapid in areas that are most heavily polluted with neonicotinoids, suggesting that the environmental damage inflicted by these insecticides may be much broader than previously thought'.[29] All this evidence continues to be strenuously denied by manufacturers Bayer and Syngenta.

Neonics are highly persistent, water soluble, systemic insecticides that can be taken up by plants at any stage, and are often applied prophylactically to seeds. They bio-accumulate throughout the environment, are extremely toxic to all invertebrates, and may also affect some vertebrates such as small birds, and aquatic species. As usual, regulatory testing is grossly inadequate, ignoring long-term cumulative effects of chronic exposure.

While much of this has been known to experts for some time, since WIA is a meta-analysis of published research, from a social sciences perspective one of the most striking conclusions about neonics is that 'recent studies . . . suggest that their use provides no net gain or even a net economic loss on some crops'.[30] Since

agribusiness dominates agricultural education, and funds most of the research and advice available to farmers in most developed and many developing countries, it is not surprising that overuse and inappropriate use of pesticides is so widespread. WIA urges priority for the 'precautionary principle' – chemicals allowed into the environment (including the many thousands that have never been tested at all) should first have their *long-term* safety established by *independent* experts, both in isolation and in their interactions with other reactive substances.

This of course would mean a dramatic reversal of the current, industry-dominated policy of revealing only *positive* test results to compliant regulators. Much of the research on – and testing of – agrichemicals (and similarly for medical drugs) is done by the corporations who produce them and profit from their sales, or is directly funded by them. Negative results are frequently claimed to be 'confidential', and remain unavailable to independent researchers.[31]

Industry-lobbying influence on politics (often by persistently casting doubt on valid science to confuse public perceptions, as well as by outright corruption) is such that restrictions on widespread, dangerous, toxic substances are only even *considered* when irrefutable evidence of serious, perhaps irreparable harm on a large scale over an extended time period has been provided by independent researchers (who often risk loss of funding and even their jobs). This institutionalized regulatory capture and corruption has delayed action by decades in classic and depressing cases, such as leaded petrol, tobacco, DDT, asbestos, industrial chemicals such as PCBs, and organophosphate pesticides, and is well documented by many authors.[32]

One success in the campaign to protect pollinators and ban neonics has been a 2-year EU moratorium in 2013 (though only on three out of seven neonics, and only for use on crops attractive to bees). The UK coalition government *opposed* the ban, and in spite of massive public protest by many environmental organizations, David Cameron's Conservative government announced a partial and temporary suspension of the ban in 2015.[33]

The looming threats to health from antibiotics in factory farming have been discussed above, but the enormous quantities of waste produced by large feedlots or CAFOs in many countries are also causing severe local pollution and health hazards. Animal manure from large CAFOs is often stored in lagoons or discharged into waterways, causing extensive pollution and eutrophication, while breeding pathogens and mosquitoes. Air pollution from ammonia, hydrogen sulphide and organic dust is a health hazard to CAFO workers and nearby residents. Regulation of CAFOs is weak and poorly enforced in the US and developing countries, and even in Europe there are growing concerns over air and water pollution. These external costs are borne by workers and neighbours, but not by the agribusiness owners of factory farms, so the prices paid by consumers are far below the real costs of production. Nevertheless, many consumers are already paying a heavy (though delayed) 'price' for the products of factory farming, in terms of the health hazards from weakened immune systems and antibiotic-resistant infections, as explained above.

Intensive chemical use in industrial agriculture has devastated natural predator populations and soil microbiota, while breeding increasingly resistant strains of

pests and weeds, which in turn generate rapidly growing use of Roundup®, neonics, and other pesticides including even more toxic 2,4-D, in a 'chemical treadmill'. Today a few modern high-yielding crops and varieties are grown worldwide, often in monocultures that are particularly vulnerable to newly evolved epidemics. The new stem rust fungus, Ug99, to which no commercial wheat varieties were resistant when it appeared in 1999, has spread to the Middle East from its origins in Uganda, and has the potential to devastate much of the world's wheat harvest, unless resistant strains can be widely cultivated in time.

A final consequence of industrial agriculture has received little publicity, but is likely to be an additional factor in the upsurge of the many 'diseases of civilization'. A dramatic decline in minerals and other nutrients in most common food products over the past 50–60 years has been documented in both the UK and US, and is probably similar in other developed countries. The effects of this trend are of course exacerbated by the parallel growth in consumption of processed 'junk' food, mainly consisting of 'empty calories' – unhealthy refined carbohydrates, sugar and trans fats.[34] In the case of wheat, the modern, high-yielding varieties have much lower content of essential minerals than older varieties, while organic cultivation of the older varieties yielded the highest nutritional content in a recent comparative trial. Rapidly growing wheat gluten intolerance in developed countries may be related to changing nutritional content of modern varieties, particularly an increase of the protein glia-alpha 9, and to the many unlabelled additives used in commercial baking, as well-weakened human microbiomes. A leading food writer, Joanna Blythman, provides a detailed account of food additives based on her undercover investigations in *Swallow This*.[35]

There are also strong ethical arguments against factory farming and the associated meat-processing industry. The first is the large-scale cruelty to animals involved, and appalling conditions for many workers, which the industry makes great efforts to conceal from the public eye. Since Schlosser's pioneering exposure of industry abuses, investigators have faced increasing barriers of secrecy and legal threats to whistle blowers. Existing weak regulations for animal (and employee) welfare are routinely ignored by both industry and regulators. And of course the systematic denial of health hazards and suppression of critical research by agribusiness is an ongoing scandal in most developed countries.[36]

The final component of the modern food system is retailing, dominated in the rich countries by giant corporate chains, which are driven by profit motives with minimal regulation 'to increase the amounts consumed, to create more eating opportunities and ever more varieties of processed, value-added – more profitable – foods, and foods that turn cheap materials into expensive ones'.[37] These of course are the least healthy foods, and the retail chains' monopsony or market-buying power allows them to enforce the 'cheapest' (and most destructive) industrial production methods on their suppliers. This in turn means inflicting external and less visible costs on the environment and consumers, such as toxic residues, emissions and addictive added sugars, supported by massive marketing campaigns of disinformation, much of which targets children. These chains are also expanding rapidly in developing countries.

A big contribution to food waste in rich countries is supermarket policy of rejecting superficially blemished and 'misshapen' fruit and vegetables, which also encourages pesticide use by growers. Nutritional density, however, is rarely monitored or reported, though actually easy and cheap to measure approximately with a refractometer as the 'Brix number'. Demonstrating the power of modern marketing, for a change in a healthy direction, France's third-largest supermarket chain *Intermarché* has been promoting (with great success) 'inglorious fruits and vegetables' with prominent displays of 'ugly' produce, offering a 30 per cent discount to help overcome any remaining customer aversion.[38] This episode is of course the exception that contrasts with the generally pernicious effects of supermarket power on both agriculture and health: demanding rock-bottom prices from factory farm suppliers instead of nutritional quality and safety, and bearing considerable responsibility for many modern 'diseases of civilization', of which overweight and obesity are only the most visible.[39]

Erosion, desertification and warming

Soil erosion and desertification are among the most significant threats to maintaining or increasing world food production, although in the early stages erosion may be nearly invisible and difficult to measure. The impact of soil erosion – a precursor to desertification – has hitherto been largely neglected, though both are exacerbated by global warming, declining rainfall and water shortages in the most vulnerable areas. As soils lose organic matter and degrade, they become more susceptible to erosion and less productive, thus reducing the availability of arable land for food production. These problems, together with declining yields as temperatures rise, and dwindling water reserves for irrigation, are likely to generate catastrophic results in the medium-term future – the collapse of agricultural production in the most populous, developing countries – unless we follow UNCTAD's advice and '*wake up before it is too late*'.

Soil erosion or the loss of the most fertile and usually thin layer of topsoil only becomes spectacularly visible in dust storms, such as those that ever more frequently envelop Beijing, and have been detected on the West Coast of the US, and Southern Australia. Most of the time, however, as geologist David Montgomery explains in his pioneering book *Dirt*, soil erosion is an insidious and invisible process resulting directly from modern agricultural methods, that leads to loss of topsoil, tens or even hundreds of times faster than natural rates of soil formation in problem areas. Worldwide about 80 billion tonnes of topsoil are lost annually, including the majority of the plant nutrients, which are most concentrated in the topsoil. Rich farmers can replace some of these nutrients with chemical fertilizers, though SOM loss renders the soil ever more prone to further erosion, but this temporary stop-gap is too expensive for poor farmers in the most vulnerable areas.[40]

Several factors interact to cause the damage. The traditional method of cultivation by ploughing, first buries organic residue, and then leaves the surface exposed

without crop cover for long periods and between rows (particularly under common monoculture). Heavy machines used in large-scale, industrial agriculture compress or 'compact' the soil even at depth, preventing water absorption and penetration by plant roots. Surface water then runs off and is lost, carrying away valuable topsoil. Reliance on chemical fertilizers depletes the organic or humus content of the soil, which then accelerates moisture loss, and allows the surface to be blown away in hot and dry conditions, or be washed away by heavy rainfall, particularly on hill slopes. Nitrate fertilizer pollution, pesticide residue and animal waste from intensive production are devastating the local water supplies under modern farming around the world.

The end result of this progressive degradation, when all the topsoil has been lost, is barren subsoil or rock that will not support vegetation – the largely irreversible process known as desertification. Worldwide, the degradation of arable soil is reducing productivity, changing local and global weather patterns, and increasing temperature extremes – while at the same time also threatening the world's food supply. The pace of desertification will only intensify with rising global temperatures and increasing populations in the most vulnerable areas – unless there is a concerted international effort to promote the large-scale adoption of conservation methods. Around the world, there are already numerous environmental disasters resulting from unsustainable water and land use – disasters that are becoming increasingly serious with more frequent droughts and erratic temperatures.

Few visible alterations to the Earth's surface reflect the consequences of unsustainable natural resource use as dramatically as the now-infamous desiccation of the Aral Sea in Central Asia. Due to inefficient irrigation and mismanagement of irrigation water for cotton production, water diverted from the Sea's main feeder rivers resulted in the loss of over two thirds of its volume in less than a generation. The methods of irrigation that drained the Sea continue to compromise food security and ultimately sustainability as industry, agriculture and humans compete for limited water resources.

The demise of the Aral Sea has affected population health across Central Asia, as well as economic welfare. The irrigation infrastructure is dilapidated and losses in transport have resulted in severe water logging, salination and soil erosion – precursors to desertification. Summers in the already arid climate are hotter and winters colder with the loss of the Sea, and desertification throughout the basin is now threatening productivity of remaining arable land. The Aral Sea disaster is considered to be one of the great environmental catastrophes of the twentieth century, but it is being followed by many others, such as the disappearing Lakes Chad in West Africa and Urmia in Iran. As the global climate continues to change, already fragile ecosystems around the world, with their growing animal and human populations, will similarly become ever more vulnerable to ecological collapse.

Another cause of erosion and desertification is overgrazing of arid grassland, driven by rapidly growing demand for animal products. When too much of the surface vegetation has been damaged or removed, the soil in between can be blown

away until remaining roots have no support left. In the most fertile regions, a thick layer of topsoil means that erosion can continue for decades with little effect on crop yields when high or rising use of chemical fertilizers is maintained.

However, much of the world's agricultural land has only a thin cover of topsoil and about 80 per cent has already suffered 'moderate to severe erosion', and is therefore particularly vulnerable to drought and overgrazing. Annual loss of topsoil is estimated at around 80 billion tonnes. Nearly 1 per cent of the world's cropland is abandoned annually due to erosion, and since 1970, about '30 per cent of the world's cropland has become unproductive, and much of that has been abandoned'. Urbanization and road building add substantially to the toll on agricultural land. At the same time, the total arable area has been increasing, largely as a result of deforestation, but also from the cultivation of vulnerable steppes and grassland.

While this expansion has been responsible for much of the rise in global food production in recent years, as yield-growth has slowed down, yields in vulnerable areas may start to decline under the influence of rising temperatures and water shortages, and reverse the trend. Furthermore, most of the newly cultivated lands are highly vulnerable to erosion and loss of productivity under industrial agriculture. There is still a large global land area (comparable to the existing arable area) that is considered potentially suitable for cultivation, which is one of the reasons for continued optimism by the United Nations Food and Agriculture Organization on future world food supply. However, while deforestation already contributes about 20 per cent of anthropogenic carbon emissions, extension of industrial agriculture to marginal and waste-land will only accelerate carbon loss and soil erosion.

In contrast to optimistic official predictions, a series of interacting factors will combine to threaten future food supply unless major changes in agriculture are implemented. First, more extreme weather, with rising temperatures and less rainfall in the already most threatened, arid areas will accelerate erosion and desertification. As explained above, hotter growing seasons in these regions will reduce grain yields by at least 10 per cent for each extra degree Celsius above 30 degrees, unless much more resilient varieties can be developed in time, and these effects will overwhelm the relatively small benefits of longer growing seasons and more atmospheric CO_2 in northern regions.[41]

Equally serious, much of the irrigation water that is a necessary input for the high-yielding varieties of the green revolution comes from rapidly depleting aquifers and ground water that are at best only replenished at much slower rates than current use. In the Great Plains of North America, practically all water for irrigation must be pumped from the Ogallala Aquifer, a rapidly declining fossil freshwater resource established over geological time scales. Additional demands from industry and development are also lowering water tables at alarming rates of 3 metres or more per year in parts of India, Northern China and elsewhere, encouraged by lavish subsidies and political pressure for cheap water. Around the world, excessive water use has led to shrinking lakes, and disappearing rivers,

such as the Colorado in the US, the Yellow River in China, and many others in developing countries.

Finally, the rapid growth of tropospheric ozone pollution produced by sunlight interacting with vehicle emissions is predicted to have increasingly damaging effects on crop yields (as well as human health) in the more prosperous developing countries where car ownership and traffic are growing faster than GDP. Densely populated and rapidly urbanizing China is particularly vulnerable to this form of pollution, in addition to all the other problems facing its agriculture that are discussed later. Air pollution is estimated by the WHO to cause over 7 million premature deaths annually, but there seem to be no estimates of the less obvious mortality and morbidity due to contamination of soils and water, again a major problem in China, where much of the agricultural land and ground water has been severely contaminated by industrial and urban effluent. In summary, we are living in a 'food-bubble economy', maintaining production by using up the natural capital of topsoil and ground water, or 'mining soil and water', as well as the fossil fuels that provide the massive energy and chemical inputs for continuing industrial agriculture, but simultaneously degrade the environment.

Most analysts simply ignore these trends and believe that expanding cultivation and biotechnology will continue to increase yields over the next half century in a continuation of the green revolution, progressing fast enough to feed a growing population in spite of accelerating erosion, declining water supplies and rising temperatures. High-yielding, and high-input, plants have already reached essential physiological limits to useful yields, though more resistant and hardier varieties will undoubtedly be developed.

Genetic biotechnology has not provided any substantial yield gains, and concentrates on more feasible objectives such as resistance to herbicides, which ensures rapidly growing sales for agribusiness as ever more weeds develop resistance, and rapidly growing dangers to human and animal populations as discussed above. Award-winning food-and-agriculture writer Geoff Tansey shows how recent research and regulation on intellectual property rights has been dominated by multinational corporations and a World Trade Organization that has been 'captured' by these and allied political interests. Policy is largely designed to secure monopoly profits for agribusiness, through patented seeds and other 'IP rights', with devastating consequences for the welfare of poorer farmers who cannot afford the expensive inputs, and for consumers everywhere.[42]

The 'official' view of the rich countries and their agencies mirrors that of their multinationals' corporate lobby – developing countries should raise productivity by purchasing their patented seeds and agrichemicals. However, water shortage, soil erosion and climate are already severe constraints in many hot regions, problems that will worsen under climate change, and be exacerbated by introduction of large-scale industrial agriculture that displaces small-scale, independent family farmers, who on average produce higher yields per hectare. Instead, as we show below, conservation- or eco-agriculture is the only feasible alternative for sustainable productivity gains, and resilience to climate change.

Food security, sustainable agriculture and climate change

As the trends of soil and water depletion demonstrate, to continue current 'worst practice' industrial agriculture would be a recipe for eventual disaster even *without* any further climate change. Perhaps surprisingly, many relatively simple and well-tried and cost-effective techniques can improve prospects for food security and simultaneously reduce future warming. Perhaps the most obvious step is to reduce depletion of water reserves, by governments in both developed and developing countries switching subsidies from wasteful water use to water conservation technologies, and introducing appropriate incentives by realistic pricing of this valuable resource. The alternative to traditional flood irrigation is modern low-flow or micro-irrigation, which requires some extra initial investment, but then uses much less water, and has proved to be extremely effective in arid areas from Israel to the Southern High Plains of Texas. Switching subsidies and introducing pricing would be a major reform that could avoid penalizing the poorest farmers, as well as protecting future supplies.

An important measure to limit soil erosion has actually been more widely adopted in North and South America than elsewhere. Instead of ploughing, conservation low-till (or no-till) methods leave crop residue on the surface (without ploughing, and little or no cultivation) to form a mulch or organic cover that retains moisture and protects the soil from erosion. Additionally, a leguminous cover crop such as clover can be grown after the main harvest to fix atmospheric nitrogen and replace expensive and polluting, artificial nitrogen fertilizer. Seed is sown in narrow slits cut through residue and surface soil.

A common disadvantage of such minimum tillage farming is the increased use of herbicides to control weeds, but this can be avoided by combinations of crop rotation, biological pest control or rolling the cover crop as described below. A major benefit is that resistance to drought and both wind and water erosion is dramatically improved, while the cost of energy-intensive ploughing and chemical inputs is avoided. In the poorest developing countries, simple hand tools can replace specialized seed planting equipment used elsewhere, so lack of knowledge among traditional farming populations remains the chief barrier to widespread adoption.

In addition to resulting erosion, the most subtle damage from the combination of monoculture cropping, ploughing and intensive chemical use is the destruction of soil micro-organisms and organic matter. Much of the loss is the direct result of erosion, but fungi (called *mycorrhiza*) and earthworms, which are vital for plant absorption of micronutrients and trace elements, and also carbon sequestration, are damaged by cultivation and many chemicals in industrial agriculture. This is revealed in the striking decline of key nutritional elements in industrially farmed produce over recent decades noted above. The progressive decline of soil organic matter means that farmland has now become a significant carbon emitter, while also losing topsoil through erosion. The second environmental gain from conservation tillage is the *reversal* of carbon loss, as organic matter accumulates and

the carbon content increases. Mycorrhizal fungi seem to slow down the decay of organic matter, and thus facilitate the accumulation of carbon in the soil.

In rich economies, the 'humble potato' has long been regarded as an inferior product, the demand for which declines as real incomes grow. However, potatoes have many advantages over staple grains. They yield 'up to four times as much complex carbohydrate per hectare as grain, better quality protein, and several vitamins . . . plus many of the trace elements poor people, and grain, lack' (since most of the nutrients are just below the skin, the usual practice of potato peeling loses these benefits). Furthermore, 'potatoes are . . . faster growing, need less land and water, and can thrive in worse growing conditions than any other major crop'.[43] It is thus not surprising that potato production is increasing faster than other crop growing in the developing countries.

The traditional risk from 'late blight', the fungus infection that devastated potato harvests in Ireland and elsewhere in the mid-nineteenth century, when it was a staple food, has hopefully been banned with development of several blight-resistant varieties. As traditional grains and grain-fed animal products become increasingly expensive under the influence of climate change, soil erosion and water shortages, while the environmental and health costs of factory farming become increasingly apparent, more resilient and cheaper potatoes would become attractive substitutes. Ancient grains such as quinoa and amaranth are also more nutritious than modern varieties, and better adapted to harsh environments (of course, adaptive crops alone can only provide a brief respite from a worsening climate in the long run, and only marginally reduce the urgency of mitigation, in contrast to claims by climate science deniers that 'adaptation' will solve any problems if climate does change).

All these simple measures are highly cost effective, and yield substantial returns in the long run. However, the full potential of low-till and cover crops is only realized when enhanced herbicide use is replaced by mechanical or integrated weed control. Combining low till with organic farming as described below yields major benefits to soil and food quality, further reduces energy and chemical inputs, and enhances carbon sequestration. Nevertheless, education in the new methods is essential, and has been seriously neglected under the influence of agribusiness lobbies – an obvious policy failure that would be extraordinarily cost effective to amend.

Eco-agriculture and regenerative organic farming

There is a fundamental contradiction between the objectives of low till and the intensified use of herbicides to control weeds instead of ploughing, and continued use of chemical fertilizers. Weeds and other pests become resistant, so higher doses or more toxic chemicals have to be used. Chemical fertilizers and herbicides counter some of the benefits of low till, damaging micro-flora and -fauna to inhibit the formation of stable soil structure and organic matter, as well as the uptake of micronutrients. Health hazards to farm workers, consumers and the aquatic environment

are well documented, though still strenuously denied by the agribusiness lobby and its dependent academics and funding recipients.

In addition, the 'cocktail effect' of many thousands of chemicals, including agrichemicals, to which we are constantly exposed, has been little studied. The industry has strenuously opposed and watered down new EU legislation on the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), though only about 3,000 of over 100,000 chemical substances in the environment have ever been tested. Abject failure to test the safety of GM crops and associated herbicides was discussed in detail above. Biological and integrated pest control, crop rotation, mechanical weed control and cover crops all offer alternatives to farmers with requisite skills, though agribusiness has so far managed to steer research funding, farming education and policy away from such 'threats'.

Ploughing for weed control is still widespread in organic farming. However, with extensive use of cover crops and rotation, better soil structure, and higher humus content, organic ploughed land absorbs more water and is thus less susceptible to wind and water erosion than under conventional farming. Nevertheless, the combination of reduced ploughing or low-till methods with organic cultivation is a major new advance in agriculture – described as the long-outstanding 'holy grail' of organic farming. This combination has been pioneered by the Rodale Institute in Pennsylvania, USA, and further reduces energy inputs, to less than a third of the requirement under conventional ploughing and chemical use.

The most successful system is simple and economical – an appropriate cover crop, such as a legume to suppress weeds and fix nitrogen in the soil, is flattened by a roller at the appropriate time in the growing season when breaking the stems stops further growth, and also kills most weeds, followed by the seed drill for planting (all in one pass), with no further cultivation before harvest.[44] In developing countries in particular, and depending on local conditions, complementary *agro-forestry* combines the planting of trees or bushes in close proximity with conventional crops to yield additional, related benefits, including windbreaks, biofuel and other harvests, and carbon sequestration.

Since 1981, research with comparative trials of different methods at the Rodale Institute and elsewhere has established that well-managed 'regenerative organic farming' can match conventional yields in some crops and conditions, and so be competitive even without premium market prices for certified organic products. This advantage can only increase if energy and chemical-input prices rise. Yields under drought conditions have been much greater, due to the superior water retention ability of enhanced soil organic matter. Most importantly for climate policy, organic no-till methods in these trials could sequester *twice as much carbon* in soil as standard no-till (as well as avoiding the substantial carbon emissions from conventional agriculture). Extrapolated to worldwide adoption and currently often degraded grasslands, these results suggest a potential for carbon capture and storage in the soil of up to a third of total anthropogenic carbon emissions.

Though only beginning to attract interest in developing countries, there is growing evidence that organic and low-till agriculture offers particular promise for

both higher yields and more sustainable rural development. Substituting relatively cheap *local* labour, crop varieties and other resources for expensive imported chemicals, hybrid seeds and machinery is important in poor regions, where cover crops and no-till can also increase resistance to the drought and erosion that are often greater threats in these areas than in temperate zones. Many successful field trials have shown that these methods can reduce irrigation water demands, contribute to food security and help to reverse the flight of displaced rural poor. However, an essential precondition for any improvement remains the halting of heavily subsidized food exports from rich countries that undercut local suppliers.

Grasslands or permanent pasture form a neglected component in the potential for sustainable agriculture, although they comprise about three quarters of total agricultural land, or 3.5 million ha. Much of these grasslands are severely overgrazed and degraded, particularly in arid regions, and thus subject to increasing erosion. Under carefully managed grazing, with sufficient intervals so that grasses and other plants have time to recuperate, they can develop much deeper root systems and become major carbon sinks, comparable to arable land under organic low-till methods. The resulting dense, permanent grass cover protects the soil against erosion and provides high-quality nutrition for ruminants, which is reflected in a more healthy nutritional profile for resulting meat and dairy products. Claims that extensively reared animals generate more GHG emissions than factory farming have been shown to be baseless.

Cuba remains a pioneering example of nationwide conversion from high-input agriculture to near-organic farming that has been largely ignored by the rest of the world. This transition was essentially enforced by the collapse of the Soviet Union (Cuba's main aid and trade partner), the continuing US embargo, and the resulting food crisis as fertilizer and energy imports were drastically curtailed. Large industrial state farms were divided into small cooperatives using local resources, and farmers' markets have flourished. Calories consumed fell by about a third, diets changed, physical activity increased – and the result was an average weight loss of 8 kilos per person.

Most interestingly for Western observers, major declines in cardiovascular, diabetes and stroke mortality led to a 20 per cent drop in the total mortality rate. Many shortages persist, not least because Cuba remains the second poorest county in the Americas, due to persistently inefficient central planning and political repression, but belated establishment of diplomatic relations with the US in 2015 offers new hope. Education levels are very high, infant mortality is lower than in the US, and the food crisis has been largely overcome with a remarkable system of low-input, sustainable rural and urban agriculture. Further liberalization and decentralization of the economy, following the end of the US embargo, might help to generate much more interest in this example among other developing countries.[45]

A number of studies find that organic yields for single crops, particularly in the high-yield EU countries, are lower than conventional. Since it may take many years to restore the fertility of soils degraded by a long history of industrial agriculture, yields during this process are certainly likely to be depressed, and comparative

studies do not generally consider the history of the land. Furthermore, most organic farmers still plough, not having adopted the more productive no-till and cover crop combination pioneered by the Rodale Institute (in northern regions with long winters, cover crops between harvest and spring planting may not grow, though crop residues can still protect the soil and low till is feasible in most soils).

Another important factor is that organic farms are usually mixed, where animals can scavenge, graze and fertilize, and represent a joint product at low additional cost and with considerable environmental benefits, all in striking contrast to factory farming and CAFOs. Furthermore, grass-fed animal products have numerous nutritional advantages over grain-fed meat, eggs and dairy from industrial farming, including otherwise scarce vitamin K2 (menaquinone), which long-term studies have shown to dramatically reduce both osteoporosis and heart disease (absence of glyphosate residues from GM grain feed is also important).[46] Multiple or intercropping, with complementary varieties growing alongside each other, are also common, and similarly provide multiple products, so that single-crop comparisons miss key features of best-practice organic production, not to mention the long-term environmental and health benefits.

Also misleading are the claims by defenders of industrial agriculture that organic produce is not 'significantly' more nutritious, where 'significance' is often subjective, and conflicts of interest, such as funding from agribusiness companies, is hardly ever mentioned. Again, the date of conversion to organic is also generally ignored, as are pesticide residues, such as glyphosate in conventional products, and the sometimes more rapid deterioration of organic fruit and vegetables after harvest, since no chemical preservatives may be used. However, the most recent and careful meta-analysis to date, in the prestigious *British Journal of Nutrition*, does find higher levels of many antioxidants in organic produce, and much lower levels of pesticide residues (and cadmium) than in conventional, factory farm products.[47] Some residues may drift onto organic crops from spraying on adjacent fields, but these are minimal compared to levels found in treated crops.

These residues are rarely monitored by health and safety or environmental agencies, and results receive little publicity, while claims for their safety are usually based on limited and short-term testing of single chemical substances by the manufacturers themselves, or on industry-funded studies with little regard for conflicts of interest, as discussed above in the case of glyphosate. None of these studies considers potential 'cocktail effects' of interaction between any of the numerous (often toxic) chemical residues, found in the highly reactive environment of the human body. While animal products have been much less researched, we provided some evidence above for the widespread presence of glyphosate residues in animals and humans in the EU, probably from imported, Roundup Ready® GM feed, though in much lower concentrations than in the US.

Another controversial issue is the effect of organically grown food on human health, which has proved difficult to test rigorously in view of numerous potential confounding factors, the long human lifespan and rather long-term effects of pesticide residues found in animals. These problems affect most attempts to study

environmental or dietary influences on human health, and a common solution is to use shorter-lived organisms under controlled conditions. The fruit-fly *Drosophila melanogaster*, with a lifespan of less than two months, is widely used to model human reactions, but has only recently been used to provide the first-ever direct evidence of health benefits from organic food. In this remarkable study (published in a prestigious, peer-reviewed journal), organic diets increased both longevity and fertility of *Drosophila* compared with conventional diets, in samples with initially uniform heath properties, and greater activity and stress resistance were also observed for some organic components.[48]

Conclusions

In spite of official complacency, the 'food bubble' generated by industrial agriculture and soil and water 'mining' is unsustainable. Deforestation to expand the cultivated area is a major driver of global warming, which in turn will exacerbate existing problems of declining water resources and progressive erosion, though the precise path of change cannot be predicted exactly. Even the best conservation methods will not protect all areas against the worst extremes of future weather if global warming progresses unabated, but they do offer more robustly sustainable food supply, with impressive cost savings compared with high-input agriculture. In addition to securing future food supply, reducing emissions and sequestering atmospheric carbon with conservation and no-till agriculture could provide a major contribution to mitigation efforts. This could be matched by agro-forestry and large-scale afforestation or reforestation to stabilize total atmospheric carbon during the switch to renewable energy. Essential complementary measures are realistic pricing of water (and pollution) to protect declining reserves – and taxation of animal products to reduce the devastating environmental impact of unsustainable intensive rearing. The main obstacles remain lack of public education and government capture by agribusiness lobbies.

Notes

1 United Nations Conference on Trade and Development (UNCTAD) (2013) *Wake up before it is too late: Make agriculture truly sustainable now for food security in a changing climate*, Report, United Nations, Washington DC.

2 A uniquely qualified author to survey these issues is Arden Andersen, who is a soil scientist, international consultant on sustainable agriculture, and medical doctor with additional qualifications in public health. He received the 2012 Eco-agriculture Lifetime Achievement Award; his *Food Plague: Could our Daily Bread be our Most Life Threatening Exposure?*, Kindle edition, 2013, summarizes numerous peer-reviewed scientific papers as well as his own experience of health, agriculture and nutrition.

3 Authoritative reviews of this threat are provided by the chief medical officer of England in Davies, S., Grant, J. and Blaser, M. (2013) *The Drugs Don't Work: A Global Threat*, Penguin, London, UK, and by Martin Blaser, director of the Human Microbiome Project at New York University, and a pioneer in the field, who summarizes decades of

relevant research in his 2014 book *Missing Microbes*, Henry Holt, New York, NY. See also Spector, T. (2015) *The Diet Myth*, Weidenfeld & Nicolson, London, UK.

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15 There are many useful surveys of aspects of the world food system in addition to the references in Note 3 above, including Weis, T. (2007) *The Global Food System*, Zed Books, New York, NY; Rajotte, T. and Tansey, G. (eds) (2008) *The Future Control of Food*, Earthscan, London, UK; Patel, R. (2007) *Stuffed and Starved*, Portobello Books, London, UK; Nestle, M. (2007) *Food Politics: How the Food Industry Influences Nutrition and Health*, University of California Press, Berkeley, CA.

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26 See extensive documentation published by the Institute for Science in Society (2014) 'Scandal of glyphosate re-assessment in Europe', ISIS Report 09/07/14, London, UK, available at http://www.i-sis.org.uk/Scandal_of_Glyphosate_Reassessment_in_Europe.php.

27 See Druker, S. M. (2015) *Altered Genes, Twisted Truth*, Clear River Press, New York, NY, and Vallianatos, E. and Jenkins, M. (2014) *Poison Spring: The Secret History of Pollution and the EPA*, Bloomsbury, London, UK. Druker, a distinguished public interest attorney, reveals how the FDA's own files had 'exposed how the Agency had covered up the warnings . . . , lied about the facts, and then ushered these (GM) foods onto the market in violation of federal law'. Vallianatos is a former EPA scientist, who documents a similar history of corruption and fraud, with the complete outsourcing of science due to repeated budget cuts, leading to unquestioning acceptance of industry data, so that most pesticide registrations are not based on valid test results.

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31 This resembles 'bad pharma', an industry that similarly runs or funds the trials of its own products, and 'when these trials produce unflattering results, the data is simply buried. All of this is perfectly legal.' The industry spends three times as much on marketing as on R&D, and 'new' drugs are often just slight modifications of existing versions to gain patent protection for exorbitant monopoly pricing, with no clinical advantages. Ben Goldacre, a leading British science writer and doctor, exposes the sordid details: Goldacre, B. (2013) *Bad Pharma: How Medicine Is Broken and How We Can Fix it*, Fourth Estate, London, UK.

32 See Grandjean, P. (2013) *Only One Chance*, Oxford University Press, Oxford, UK; Oreskes, M. and Conway, E. M. (2012) *Merchants of Doubt*, Bloomsbury, London, UK; Markowitz, D. and Rosner, D. (2002) *Deceit and Denial: The Deadly Politics of Industrial Pollution*, University of California Press, Berkeley, CA.

33 *The Guardian*, 24 July 2015.

34 Pollan, M. (2008) *In Defense of Food*, Penguin, London, UK, and Pollan, M. (2007) *The Omnivore's Dilemma: A History of Four Meals*, Penguin, London, UK, provide detailed references and review the extensive literature on the devastating health effects of modern industrial agriculture and processed food production. See also Davies, D. R. (2009) 'Declining fruit and vegetable nutrient composition: What is the evidence?', *HortScience*, vol 44, no 1, 15–19; Thomas, D. (2007) 'The mineral depletion of foods available to us a nation (1940–2002)', *Nutrition and Health*, vol 19, 21–55.

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36 See Schlosser, E. (2001) *Fast Food Nation: The Dark Side of the All-American Meal*, First Mariner Books, New York, NY; Pollan (2008); and Lymbery (2014).

37 Tansey, G. (2014) 'Food justice is about more than food security and nutrition', *Devex*, 23 July, available at https://www.devex.com/news/food-justice-is-about-more-than-food-security-and-nutrition-83925, is a good short summary. Geoff Tansey has been a Joseph Rowntree Visionary for a Just and Peaceful World, and received the Derek Cooper Award for best food campaigner/educator in 2008.
38 *Ecowatch*, 22 July 2014.
39 Food writer Joanna Blythman provides devastating detail for the UK in her path-breaking 2004 book, *Shopped: The Shocking Power of British Supermarkets*, 4th Estate, London, UK, following Schlosser's (2001) revelations for the US, and an equally alarming account of the food industry based in part on her undercover investigations in *Swallow This* (2015). In the meantime the health situation in the US, Britain and elsewhere has continued to deteriorate, illustrated by the dramatic increase in pre-diabetic symptoms noted above (Note 4), numerous immune-related diseases and allergies, and accompanied by persistent failure of the regulatory authorities to face up to the market and lobbying power of agribusiness and retailing.
40 See Montgomery, D. (2007) *Dirt: The Erosion of Civilizations*, University of California Press, Berkeley, CA, for a detailed history and prescient review of the neglected menace of soil erosion.
41 See Montgomery (2007), and Brown, L. (2008) *Plan B3.0*, Norton, London, UK. Roberts, M. and Schlenker, W. (2008) 'Estimating the impact of climate change on crop yields: The importance of non-linear temperature effects', National Bureau of Economic Research, Working Paper No 13799, Cambridge, MA, predict up to a 79 per cent fall in average yields in the US by the end of the century under rapid warming. By contrast, smaller estimates of future climate impact on agriculture by Cline, W. (2007) *Global Warming and Agriculture*, Center for Global Development, London, UK, are based on predictions of climate change under business as usual, which are completely unrealistic in the light of recent science (Chapter 2).
42 These issues are discussed in detail by Rajotte and Tansey (2008).
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44 Moyer, J. (2011) *Organic No-till Farming*, 40 Acres Press, Austin, TX.
45 Wright, J. (2008) *Sustainable Agriculture and Food Security in an Era of Oil Scarcity*, Earthscan, London, UK. The decline in mortality and obesity in Cuba, following the drastic reduction in calories consumed after the collapse of Soviet aid, is documented in Franco, M., Ordunez, P., Cabillaro, B., Tapia Granados, J. A., Lazo, M., Bernal, J. L., Guallar, E. and Cooper, R. S. (2007) 'Impact of energy intake, physical activity, and population-wide weight loss on cardiovascular disease and diabetes mortality in Cuba, 1980–2005', *American Journal of Epidemiology*, vol 166, no 12, 1374–1380.
46 See Gunnars, K. (2013) 'Why grass fed butter is good for you', Authority Nutrition, November, available at http://authoritynutrition.com/grass-fed-butter-superfood-for-the-heart/, with many references to peer-reviewed research papers.
47 Barański, M., Srednicka-Tober, D., Volakakis, N., Seal, C., Sanderson, R., Stewart, G. B., Benbrook, C., Biavati, B., Markellou, E., Giotis, C., Gromadzka-Ostrowska, J., Rembiałkowska, E., Skwarło-Sońta, K., Tahvonen, R., Janovská, D., Niggli, U., Nicot, P. and Leifert, C. (2014) 'Higher antioxidant concentrations and less cadmium and pesticide residues in organically-grown crops: A systematic literature review and meta-analyses', *British Journal of Nutrition*, vol 112, no 5, 794–811.
48 Chhabra, R., Kolli, S. and Bauer, J. H. (2013) 'Organically grown food provides health benefits to drosophila melanogaster', *PLoS ONE*, vol 8, no 1, 1–8.

4

ECONOMIC GROWTH, WELL-BEING AND SUSTAINABILITY

Economic growth: falling behind or moving forward

Comparing life in a village in Roman England with mediaeval life 1,000 years later, no major changes would be noticeable. The villagers would cultivate small plots of land and keep some livestock close to their home, have a life expectancy of less than 35 years (due mainly to very high child mortality) and live in hovels, cold in winter and dark at night. Living standards, real income or consumption, were more or less stagnant. We often forget that economic growth as we know it is a phenomenon of the last 250 years, propelled by the industrial revolution in Western Europe and a continuous stream of technological advancements.[1] This unprecedented and almost uninterrupted rise in real income or GDP per capita since the mid-eighteenth century was soon perceived to be an end rather than the means to something else, and economic growth became a synonym for progress in general.

Yet the distribution of this progress has been extraordinarily unequal, and is becoming ever more skewed to benefit the super-rich. The income share of the top 1 per cent has been growing rapidly in most major economies under neoliberal globalization since about 1980 (more than doubling to over 20 per cent in the US, one of the most unequal Western societies, while the share of the top 0.1 per cent *quadrupled*). At the same time nearly half of the world's population still subsists on less than two dollars per day, or the equivalent in terms of subsistence production. Over the same period, real hourly wages for the median male worker have not increased in the US, and the bottom 20–40 per cent of earners have also seen stagnating or declining real wages since the turn of the century in Germany, the UK and other major economies.

In 2014 the richest 1 per cent of the world's population owned nearly half of global wealth. The growth in the share of the wealthiest billionaires in the world has recently been most dramatic. In 2010, the top 388 billionaires held as much wealth as the bottom 90 per cent of the world's population, compared to just the top 92 billionaires in 2014. Furthermore, the Tax Justice Network has recently shown that inequality has usually been substantially underestimated, since the super-rich have been concealing a growing share of their assets in off-shore tax havens.[2]

A few hours' flight from New York or London is enough to reach villages in developing countries where life has hardly changed for centuries. Political economists, as early as Adam Smith with his theory of the division of labour, sought explanations for the divergence in growth patterns between the fortunate rich and the ill-fated poor nations. Many Nobel Prizes have been awarded for work on economic growth. It seems that investment in physical capital and infrastructure, human capital or education, restraining population growth, openness to trade (but protection of infant industries in the early stages of development, as demonstrated by post-war South Korea and Japan, and much earlier by Britain and the US), technological progress and good institutions or social capital, all contribute to increased rates of economic growth. In recent years, most developing countries have been able to reduce the income gap with their Western frontrunners (a phenomenon called *convergence*), although for many of the poorest economies it would still require several decades for this to be fully eliminated (and even this assumes that the faster growth of poorer economies is sustained in the longer term).[3]

There is certainly a wide range of interlinked factors that affect economic growth and performance (including climate). While most developing nations experienced modest but positive economic growth over the last three decades, the economies of many sub-Saharan countries stagnated as a result of conflict, poor infrastructure and adverse climatic conditions. This pattern contrasts with the experience of a few successful growth 'miracles', such as Thailand, Malaysia, Taiwan, South Korea and India, and mainland China more recently. The rapid industrialization of most populous China in particular (with its dependence on dirty coal) has drastically increased consumption of non-renewable resources and carbon emissions, with China now exceeding the USA as the world's worst polluter. Most of the world's poorest people have benefited little from economic growth, with the partial exception of China, where several hundred million of the poorest have seen a modest improvement. However, inequality is also increasing rapidly in China, as in most other countries, as the highest incomes have grown fastest, and the destruction of traditional family and social structures and relationships has led to *declining* average life satisfaction.

As we discuss in detail in Chapter 5, less developed countries (LDCs) are most vulnerable to climate change and environmental degradation in general. They lack basic infrastructure and resources to protect themselves from droughts, floods and disease, and more frequent extreme weather conditions will fall disproportionately on the poor living in their territories. Countries located in tropical and semi-tropical regions with extensive coastlines will be particularly hit, as is already the case for the 43 low-lying small coastal countries belonging to the Alliance of Small Island States (AOSIS).[4] Certainly, poverty also contributes to environmental stress, as the destitute often destroy their immediate environment to survive by using accessible trees and bushes for fuel, without replanting. At the micro level farmers overgraze pasture and destroy forest with 'slash-and-burn' agriculture, while businesses discharge their waste into local waterways and the atmosphere without penalty. At the macro level, governments fail to enforce even minimal environmental standards and penalties or taxes on polluters, while neglecting green technologies such

as solar and wind power that would offer major economic as well as environmental benefits. At the same time, international corporate interests lobby intensively for high-input, labour-saving Western technology in both industry and agriculture, with consequent damage to environment and traditional employment.

In the poorest countries, environmental degradation and resource depletion get worse as economic development accelerates. However, higher incomes, which encourage growing demand for a cleaner environment, a structural change towards services and the imposition of environmental regulation, often reverse the pattern. This relationship (often called the 'Environmental Kuznets Curve') holds for several air pollutants, such as sulphur dioxide and nitrogen oxides that result in local acid rain and respiratory problems, but not for carbon dioxide, the primary greenhouse gas.[5] As we discuss in Chapter 7, to address such global public 'bads' as global warming, what is needed is coordinated collective action among nations, that restrains free-riding problems in environmental policymaking, rather than sole reliance on technology and markets where polluters do not pay.

A sustainable development path (from Malthus to Kyoto)

After centuries of economic growth (at least in the developed world) and popular faith that the rest will eventually catch up, it is easy to forget that there may be limits to how much longer our planet can support ever increasing consumption. In this context, 'sustainability' has become one of the most popular terms in environmental discourse over the last three decades, reflecting both concerns over the health of our environment and about (so-far) robust economic growth.[6] The term 'sustainable' has become widely used as a substitute for 'environmentally friendly' to characterize any kind of economic and social activity (one often reads about sustainable architecture, sustainable agriculture, sustainable cities, sustainable tourism and business sustainability, among others). More recently, several economists have suggested that economic analysis that focuses on sustainability issues can form a separate distinctive subfield called *sustainability economics*.[7]

Ultimately, sustainable development addresses concerns about the feasibility of continuous economic development and growing material consumption on a planet of limited resources and fragile ecosystems. The industrial revolution and the Enlightenment movement in the eighteenth and nineteenth centuries were based on unquestioning faith in the ability of science and technology to harness nature and support ever-increasing material welfare. Though Britain had been largely deforested by the end of the eighteenth century for the production of charcoal as fuel, coal subsequently provided the foundation for industrial expansion and the belief that nature supported (rather than constrained) continuous economic progress. Thomas Malthus with his 'Essay on Population' in 1798 was one of the first intellectuals to criticize the cornucopian optimism of the time and to stress that an ever-expanding population was unsustainable with limited land and food

production.[8] IPCC reports and environmentalists now echo Malthusian pessimism by emphasizing that growing population and consumption both directly impact on the entire planetary environment.

In the nineteenth century, John Stuart Mill had already related well-being (or utility in the terminology of economics, as we discuss later in Chapter 6) to the pleasure derived from a healthy natural environment. But only in the second half of the twentieth century did critical thinkers begin to realize that our lifestyle and consumption patterns were not viable in the long term due to environmental constraints and pollution, and the environmental movement hence gained momentum. Prophetic writings such as the 'Economics of Spaceship Earth' by Kenneth Boulding in 1966, and Rachel Carson's *Silent Spring* in 1962, were long derided or ignored, but now they seem more relevant than ever before as climate catastrophe and mass extinction become the likely predictions of the most sophisticated scientific models with continued growth of GHG emissions under 'business as usual'.[9]

In 1983 the World Commission on the Environment and Development was set up by the United Nations to address growing concerns 'about the accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development'. In its 1987 report 'Our Common Future' (also known as the Brundtland Report after its Chair) the notion of 'sustainable development' emerged.[10] From its almost 400 pages, the definition of 'sustainable development' as 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs' stood out. While this stresses the need for intergenerational equity in terms of welfare, the Brundtland Report also emphasizes the importance of equity within generations, 'in particular the essential needs of the world's poor, to which overriding priority should be given'.

What the Brundtland Report tried to achieve was coordinated global action on environmental problems combined with economic development. It accepted that there are environmental limits to growth but also that poverty and environmental degradation are interlinked and need to be addressed jointly: environmental degradation affects mostly the poor and it is the poor who cannot afford to deal with it in the first place! The report claimed that growth was also essential in the rich countries, which are expected to provide aid more generously for the poor without compromising environmental protection and the welfare of future generations.

What followed the Brundtland Report was the UN Conference on Environment and Development in Rio in 1992, with an unprecedented representation of countries and heads of state (172 countries, 110 heads of state). The sustainable development rhetoric was already becoming popular and many countries participated without fear of having to make uncomfortable concessions. The Framework Convention on Climate Change as part of the Summit acknowledged for the first time (at a political forum) that carbon dioxide emissions were contributing to global warming and that the industrialized countries had to take action (initially stabilize emissions at 1990 levels by 2000).[11] The Convention included preparations for a binding agreement to tackle the issue – and in 1997, the Kyoto Protocol on climate change was finalized.

Based on the same rhetoric of sustainable development as in the Brundtland Report, it was agreed that global GHG emissions should be reduced by only 5.2 per cent compared to 1990 levels by 2008–2012 (the so-called 'first commitment' period of the Kyoto Protocol) and that this relatively small burden would fall on the industrialized nations (Annex-I countries). Poorer nations would thus be unconstrained in their development, and richer nations could maintain economic growth. Modest as this goal was, the first step was taken to acknowledge the threat of global warming for the welfare of future generations, although this welfare was still perceived purely in terms of material consumption. A second 8-year commitment period (2013–2020) had more ambitious targets (a reduction of GHG emissions by at least 18 per cent below 1990 levels), which still, however, falls short of what is necessary to stabilize our climate (and so far developing countries are still not required to undertake any reductions).

IPAT: impacts, population, affluence and technology

The scale of our current environmental impact is unprecedented in the history of humanity. As we discussed in Chapter 2, the concentration of CO_2 in the atmosphere has been continuously increasing from its pre-industrial level of 280ppm to around 400ppm today, and we have already experienced global warming of approximately 1°C since the early nineteenth century. Even worse, our environmental impact has intensified in recent years, and, as earlier chapters have shown, unless serious mitigation efforts are quickly implemented, albedo and carbon feedback effects are likely to become irreversible, leading to global agricultural catastrophe in a few decades. Global warming is of course only one of the many environmental challenges humanity faces as a result of expanding economic activity since the industrial revolution. Natural habitats have been continuously degraded by our overharvesting and excessive pollution, resulting in widespread deforestation, species extinction and water scarcity. Global warming will simply reinforce environmental challenges humanity has been facing for many decades as a result of expanding consumption and population pressure.

Economists often decompose such environmental impacts (I) into three parts: (1) the level of human population (P); (2) our affluence measured by income per capita (A); and (3) the environmental friendliness of technology in use (T). The IPAT equation, a simplistic but rather intuitive relationship attributed to Paul Ehrlich and John Holdren in the 1970s, relates our global environmental impact to the product of human population, income per capita and technology (i.e. $I = P \times A \times T$).[12] In order to embark on a sustainable path and reduce GHG emissions and other human impacts on the environment, some contribution has to come from the right-hand side of the equation: namely, stabilizing population, constraining material growth and/or adopting environmentally friendly technologies.

So, how do our prospects for a sustainable future look so far? Almost every dimension of environmental health has deteriorated over the last few decades (from carbon emissions to water scarcity and deforestation – only sulphate aerosols have declined in North America and Western Europe as coal has been replaced by oil and gas), so we are undoubtedly heading towards an environmental catastrophe. Without urgent and decisive policy measures targeting population levels, unsustainable consumerism and dirty technologies, there is no scope for optimism.

For global warming, the time bomb is ticking even faster. If we are serious in tackling climate change and avoiding the (often cited but actually too high) tipping point of a 2°C temperature rise, we need to adopt more aggressive strategies for carbon mitigation. Which of the right-hand parts of the IPAT equation, though, offers a glimpse of hope? As we will discuss in Chapter 5, there does not seem to be much hope from the population factor (at least in the short- or medium term). Current trends predict that the global population will increase by at least 2 billion people by 2050 in an already overcrowded planet, with developing nations like India leading the way – China's recent decision to relax the one-child policy is certainly likely to exacerbate the problem.[13] While fertility rates are declining over time, it is unlikely that the global population will stabilize before mid-century. The location of population also plays a role, and several studies include geographical factors in the IPAT equation to show that higher urbanization increases carbon emissions (other things equal), while population density has the opposite effect.[14]

The average output per person around the world is also rising fast. Even a modest annual growth rate in GDP per capita of 3 per cent (much below the until recently double-digit growth performance of China) would result in about a fourfold expansion of production by 2050. Attempts to constrain GDP growth would be highly unpopular, especially (but not only!) in developing countries, where the environment has low priority. With global population and average income on the rise, there is little hope that carbon mitigation (or sustainability more broadly) will come from the *P* or *A* side of the *IPAT* identity, at least in the immediate future, unless production and population adjust (by necessity) as a direct result of a global warming catastrophe. Much more hope in mitigating our environmental impact is linked to the technological parameter *T*. Generous technology and knowledge transfers and investment in renewable and energy-saving technologies, which we analyse in detail in Chapter 9, will need to more than compensate for the environmental pressure from population and economic growth, for a global climate catastrophe to be averted.[15]

Economic growth, welfare and life satisfaction

In both popular media and academic discussion, the 'welfare' of a country, or individual, is generally identified with their 'standard of living' – real disposable income or consumption per capita. Economic growth that raises average real

income (after allowing for inflation) is automatically assumed to increase average welfare in the common-sense usage of making (some) people feel better off. As we discuss in Chapter 6, social welfare is traditionally regarded as a 'sum' of individual welfare levels, mainly dependent on the objective income measure. Of course, average income may increase simply because rich people are getting richer, while the poor remain poor or more people descend into poverty. This has been happening under austerity since 2010 in many countries, and more generally under neoliberal policies since the late 1970s – initially in the US and UK, but then followed by most other countries.

These issues of income (or welfare) distribution receive increasing attention because of their obvious political significance, at least in democracies. However, most advanced economies (apart from the Nordic countries) following the neoliberal programme have repeatedly cut taxes for the rich and reduced regulation of booming financial sectors, while often reducing the real value of minimum wages and other welfare measures for the poor, thus directly contributing to increasing inequality since around 1980. The rising income inequality under neoliberal policies soon translates into increased inequality in other social dimensions (such as inequality in access to health), as discussed in the 2010 Strategic Review of Health Inequalities in England (widely known as the Marmot Review).[16] This creates a vicious circle of persistent poverty and inequality, where underprivileged households can only afford inferior health and educational standards for their children (and hence poor prospects for a better life and higher income levels in the future). Social mobility between generations and the pipe dream of 'equality of opportunity' so often paraded by politicians have thus been steadily declining, particularly in the US and UK, in parallel with the growth of inequality.

Rather than simply *assuming* that individual well-being depends on income, social scientists for many decades have actually been asking people to evaluate their own well-being, usually in terms of questions about 'satisfaction with life' (LS) or simply 'happiness', as indicators of 'subjective well-being' (SWB), and relating their answers to objective data on the person's income, family situation, health, work and many other factors. While economists were initially sceptical about subjective data, the responses to repeated surveys of this kind have displayed remarkable consistency across countries and over time, and with objective indicators of welfare, so that the key results are now well established and widely disseminated. Thus, since 2011, the OECD publishes a bi-annual review, *How's Life?*, reporting many indicators of well-being, including life-satisfaction survey results from all 36 member countries. It is all the more astonishing that the majority of macroeconomists and policymakers continue to ignore subjective well-being and most of the other indicators, and, like most textbooks, focus mainly on per capita GDP or real income (growth) as the main welfare indicator and policy goal (though unemployment, which rises when growth slows down, does also receive attention from Keynesian economists in particular).

In most advanced economies of Western Europe, Japan and North America (and in many developing countries), average life satisfaction has remained flat, with

no upward trend, over nearly four decades of economic growth that has doubled real GDP per head. This contrasts starkly with the traditional belief that income growth always raises welfare, and is known as the 'Easterlin Paradox'.[17] Of course, inequality has also been growing quite rapidly in many economies in the decades of neoliberal policies since about 1980, so that most of the gains from growth have gone to a rich minority, mainly the top 1 per cent. This makes it perhaps less surprising that *average* LS has failed to rise. Many other factors also help to explain the paradox, including environmental degradation in emerging economies, and loss aversion and social capital, as explained below.

Thus, in spite of very rapid economic growth, which has taken large numbers out of extreme poverty, and quadrupled real per capita GDP from 1990 to 2010, average SWB in China did not increase over these two decades, though there has been a small rise since then. Life satisfaction and self-reported health of the poor have declined, while both have increased for the wealthy, which is a remarkable illustration of the social and environmental costs of excessive material growth with deregulated markets, rapidly rising inequality, loss of social capital, and severe environmental degradation. Estimates of the morbidity costs of $PM_{2.5}$ (small-particle air pollution) alone in China range from 10 to 13 per cent of GDP. Recent studies point to a substantial variation in LS across Chinese cities, where those living in urban centres with the highest levels of atmospheric pollution and traffic congestion report significantly lower levels of welfare. Indeed, pollution has become such a serious cause of popular discontent that China now invests more than any other country in renewable energy, and, in a major policy shift, agreed with the US in 2014 on climate goals and peak coal consumption by 2020.[18] In the US, the developed country with the fastest-growing inequality, average happiness has declined from 1973 to 2015, and the poor have suffered the most.

Recent, path-breaking work by Jan-Emmanuel De Neve and co-authors has shown how recurring 'negative growth' of GDP, which means essentially episodes of recession, has strong negative effects on life satisfaction in a large sample of more than 150 countries, both developed and developing.[19] Episodes of positive growth, in contrast, have only weak or insignificant positive effects. This 'loss aversion', which is also well known in microeconomic experiments, can help to explain the absence of any long-term or trend growth of average life satisfaction in many countries, providing strong confirmation – and a new explanation – of Easterlin's results. The sharp decline in SWB caused by rising unemployment, often declining real incomes for many, and job insecurity in periodic recessions basically offsets whatever gains accrue during longer periods of positive growth (which have mainly benefited high earners since about 1980), resulting in a generally flat trend (some economists have claimed that economic growth is generally correlated with increasing SWB by confusing these short-term cyclical fluctuations with long-run trends).

The neoliberal or 'market fundamentalist' policies that have been ever more widely adopted in a growing number of countries since the late 1970s, are based

on the idea that smaller government, lower taxes for the rich and more market 'freedom', particularly for powerful corporations, are always better, generating faster economic growth that, in the long run at least, will 'trickle down' to benefit everyone. In other words, intervention in the economy through regulation and taxation, particularly of high earners, reduces incentives and the efficiency of 'free' markets (although this efficiency really only emerges under the very strong, and far from realistic, assumptions of economics textbooks, and even then does not necessarily guarantee any fair distribution of rewards).

In practice, neoliberal policies have usually included major tax cuts for the rich, extensive privatization and deregulation, leading to growing corporate and financial power, greater inequality and insecurity for many, and poverty for the least fortunate. The pressures of globalization and outsourcing, and systematic policies opposing unionization, have reinforced neoliberal tendencies, and further weakened the bargaining power of less-skilled workers in increasingly insecure and often stressful jobs. Lower wages have stagnated in many countries, and most of the benefits of growth have accrued to the highest earners, and capital owners. The US and UK are among the most extreme examples of these developments, but numerous other countries, both developed and developing, including China and India, have been affected in various degrees.

The prominent critical journalist and best-selling author Owen Jones shows in his latest book, *The Establishment*, how neoliberal ideology is the 'glue' that unifies a diverse ruling elite in politics, business and the media in the UK, both a major victim of neoliberalism and victory for the establishment, but also typical for tendencies elsewhere, and aptly summarizes:

> Britain's political life remains under a suffocating ideological grip. Slashing taxes on the wealthy; selling off public assets; rolling back the state; cutting back social security; weakening trade unions: all this is relentlessly passed off as the mainstream, the 'centre-ground' from which only the unelectable and the extreme deviate.[20]

The concept of 'social capital' summarizes a variety of activities and attitudes, including individual social interactions through family and friendship, participation in community activity, and trust in neighbours and institutions, that have been ignored by traditional economics and policy. However, there is extensive evidence on the importance of social capital for individual SWB, and how neoliberal policies and resulting inequality have seriously eroded social capital in many countries. All this in turn helps to explain the weak effects of intermittent periods of even high rates of GDP growth on average SWB, in countries as different as the US and China. In very poor countries, where many lack basic necessities, average SWB is indeed generally much lower than in rich countries, though there are very large variations between countries with similar income levels. However, middle-income Costa Rica has greater average life satisfaction than the much richer US and UK. Again, social capital and inequality are important explanatory factors.

Rich countries that have maintained high levels of social capital in flourishing but tightly regulated market economies with large public sectors, are the Nordic social democracies, Denmark, Finland, Sweden, Norway and Iceland. They regularly top international league tables of life satisfaction and good governance (with the Netherlands and Switzerland, which share some of their characteristics). Echoing an unusually broad consensus, *The Economist* (2 February 2013) called its review of the Nordic economies 'The next supermodel', still a surprising endorsement from an otherwise consistently neoliberal publication.

As a result of highly progressive taxes, larger public sectors and stronger welfare states, income distributions in the Nordic social democracies have remained much more egalitarian than in the rest of the EU, while high levels of social trust have been maintained, and environmental protection is a top priority. Nordic employment-to-population ratios and female participation rates are among the world's highest, as are expenditures on education, real incomes and most measures of social welfare, both subjective and objective.

However, inequality has been increasing in Sweden, albeit from a very low base, and Finland and Denmark have been hard hit by recession. Real GDP per capita *declined* by more than 7 per cent in Finland, and by about 6 per cent in Denmark, from 2007 to 2014, as these countries' membership of – and association with – the Eurozone forced costly internal devaluation upon them as their export markets suffered. Iceland's economy was devastated by the collapse of its inflated banking sector (though mainly due to a huge currency devaluation it recovered much faster, and with lower unemployment, than most countries in the Euro area, which did not have the option of devaluation).

It is thus remarkable that life-satisfaction levels have remained among the highest in the world in these nations (well above Germany, whose real per capita GDP *grew* by about 7 per cent in this period, one of the highest rates in the EU). The main reason seems to be that social capital and associated comprehensive welfare states with generous safety nets for the least fortunate have all remained intact through the recession. This record stands in marked contrast to Southern European countries, where the economic crisis was not only more severe, but where the effects were exacerbated by large-scale collapse of initially much weaker welfare support, and of social capital.

In detailed comparisons across OECD countries from 1980 to 2007, American political scientist Benjamin Radcliff shows that life satisfaction is strongly associated with the *opposite* of every element of the neoliberal agenda – namely with higher taxes, bigger government, more generous welfare states (and resulting lower inequality), better regulated markets and more union membership. These remarkable results hold after controlling for the most important individual influences on life satisfaction, including an index of social capital, health, employment and marriage, the last two of which turn out to have 'smaller' effects in the appropriate metric than the size of government or generosity of the welfare state. As Radcliffe summarizes, 'Seen in this light, it seems difficult to overestimate the significance of the welfare state as an agent for human happiness.'[21]

In stark contrast to the Nordic model of social democratic, egalitarian society, the 'godmother' of neoliberal policy, Margaret Thatcher, famously claimed that there was no such thing as society, only individuals (and families). This component of neoliberal ideology has encouraged the growing tendency of conservative media and politicians to blame the poor for their plight, as 'lazy' or 'scroungers', thus justifying both welfare cuts and tax reductions for the 'deserving' rich. At the same time, mass media, most of which represent neoliberal business interests, have convinced a majority of the population in most advanced economies that inequality is much less – and welfare payments to the poor are much greater – than the true figures.

As Cambridge economist Ha-Joon Chang summarizes: 'Once poor people are persuaded that their poverty is their own fault, that whoever has made a lot of money must deserve it and that they too could become rich if they tried hard enough, life becomes easier for the rich.' And LSE economist John Hills demonstrates that a growing proportion of the rest of the population has also been persuaded by the relentless neoliberal media onslaught that the poor have only themselves to blame, and deserve welfare cuts to end their 'culture of dependency'.[22] Yet according to the UK Department of Work and Pensions (DWP), 'Children in families where at least one adult was in work made up around 64 per cent of all children on low income', suggesting that low wages rather than feckless parents were the main cause of child poverty. Economist Chris Dillow provides details and more evidence for this in his excellent blog.[23]

When individual material success is increasingly promoted as the ultimate virtue, and social capital declines, individuals tend to seek fulfilment in conspicuous consumption and rivalry rather than cooperation, compensating for loss of social interaction and support through individual status-seeking and overwork to overtake rivals, or even just to hold down a succession of insecure jobs. Among the adverse consequences have been a dramatic rise in clinical mental illness, stress, 'burnout' and youth suicide, all of which are correlated with inequality under the rise of neoliberalism. Austerity policies since 2010 have also reinforced the neoliberal agenda of cutting welfare for the poorest, with the new excuse of 'deficit reduction' and the most disastrous consequences in the southern periphery of the Eurozone, as we discuss in detail in Chapter 10.

Competition between individuals is of course a fundamental instinct, but the evolution of language and 'tribal morality' helped to restrain in-group competition and facilitate the cooperation that was essential for survival of early, hunter–gatherer human societies in harsh environments. Altruistic behaviour, which has been observed even in infants, also evolved to support cooperation at a much more sophisticated level in these societies, and their still-surviving remnants as 'primitive tribes', than among any other social animals.

Already in Victorian capitalism, varying individual abilities (in addition to accidents of birth) were used to justify extreme inequality of outcomes as the result of impartial, market-based rewards for 'merit' or success, and penalties for failure, summarized by crude analogies with then new evolutionary biology such as

'social Darwinism' and 'survival of the fittest'. Perhaps in reaction to the devastation inflicted by WW2 and the prior decade of the Great Depression, starkly contrasting ideals of social justice and democracy then led to the development of modern welfare states in the advanced economies, with substantial public sectors, social safety nets and high marginal taxes for the rich, while collective bargaining and high employment supported by various policies kept most wages rising in line with steady economic growth.

This period, known as the 'Golden Age' of capitalism, now appears to have been a historically brief and exceptional interlude of *declining* inequality and steady growth of real incomes for most citizens. But this happy interlude was rudely interrupted by the OPEC oil price shocks and subsequent 'stagflation' or recession combined with inflation in the 1970s, which set the stage for the rise of neoliberalism. Instead of blaming OPEC or, more fundamentally, overdependence on hitherto cheap fossil fuels and other policy errors, conservative economists led by Friedrich von Hayek and Milton Friedman, and supported by a growing number of 'think tanks' funded by business interests, argued that the basic problem with advanced economies was simply too much government involvement, regulation and taxation, and too little reliance on 'free' markets.

This conservative or neoliberal agenda was then enshrined in Anglo-American policies by Margaret Thatcher, elected in 1979, and Ronald Reagan a year later, and has since become the conventional 'wisdom' in the global economy. The consensus is maintained by media and politicians dominated by the business and financial interests of the very rich who have gained most from just these neoliberal policies. Climate science denial and opposition to carbon taxes or other restrictions on fossil fuel use (and profitability), especially in the US, Australia and Canada, and to a lesser extent in the UK, have also become an integral part of the neoliberal and conservative think-tank agenda. The inverted 'logic' behind these beliefs is that, because climate policy would require *more* government, which is always harmful, 'therefore' climate change cannot be a problem needing intervention![24]

The actual record of neoliberal policies has been quite different from their promise. Economic growth in the advanced economies was slower and more volatile after 1980 than in the Golden Age, interrupted by crises and recessions even before the Great Recession of 2008/9. Privatization of quasi-public goods such as water supplies or railways has been disastrous for consumers everywhere, though often yielding lavish profits to new owners. As already explained, most of the real income growth accrued to the highest earners, particularly the top 1 per cent, who have also come to dominate politics and policies in most countries, with no evidence of a 'trickle down', but rather the contrary. Under neoliberal policies, the combined forces of globalization, outsourcing, digital technology and more recently robotics, have been given free rein to displace traditional manufacturing and employment and restrain real wage growth for the less skilled, as well as to progressively undermine much 'white-collar' or middle-class job content, security and pay, and generate warnings of a new age of 'secular stagnation' by prominent economists. At the same time, an increasing number of highly skilled workers in

particular, and some of the low skilled as well, have been required to work excessively long hours (over 50 per week), in most advanced economies except the Nordic, with disruptive and damaging effects on family life and health. Average hours per worker in all the Nordic countries have also declined much further than in the US since 1970, while productivity *per hour worked* rose *faster* than in the US in all the Nordic economies.[25]

One of the most insidious effects of the growing concentration of income and wealth in advanced economies is the political economy effect, or the parallel growth in political and policy influence exerted by the wealthiest individuals. While most extreme in the US, this is also quite evident in Europe, as leading economist Paul Krugman explained in his keynote speech for the 2015 European Dialogue: policy has everywhere shifted to the right on the classical left–right axis, in support of the conservative, neoliberal agenda of lower taxes for the rich, more privatization of public services and less welfare for the poor. This has been particularly striking since 2010, when most left-of-centre parties such as Labour in the UK and the Social Democratic Party (SPD) in Germany have embraced the conservative–populist arguments for deficit reduction and austerity of the mainstream media, or 'mediamacro', which are rejected by almost all academic macroeconomists (at least in the UK and US, though not in Germany). With very detailed statistical evidence for the US, political scientists Martin Gilens and Benjamin Page have shown the following: 'economic elites and organized groups representing business interests have substantial independent impacts on U.S. government policy, while average citizens and mass-based interest groups have little or no independent influence'.[26]

Clearly consistent with these findings, although deregulation of rapidly expanding financial sectors in the US and UK led directly to the Great Recession, none of the fundamental reforms recommended by experts has been enacted, and austerity policies since 2010 have only impeded recovery for the majority, while quantitative easing has mainly generated asset price booms that benefited a wealthy minority. In view of all these obvious failures of neoliberal economic policies, as well as the resulting (though much less discussed) erosion of social and environmental capital, it is not surprising that average life satisfaction has remained flat in most of the advanced – and many developing – economies. Yet in spite of all the evidence to the contrary, most economic policy is still based on the idea that only further growth of GDP, even in rich countries, *without* substantial redistribution and more progressive taxes, can raise general welfare and eliminate poverty.

A further problem with the dominant growth paradigm is that, once basic needs for food and shelter have been satisfied, well-being is strongly influenced by social comparison. People compare their own consumption with that of reference – or peer – groups, such as neighbours or colleagues with similar or higher incomes, and form aspirations or ambitions to match or exceed their consumption. A major cause of unhappiness turns out to be the gap between aspiration and achievement, a gap that is enhanced by relentless media and TV advertising and obsession with celebrity lifestyles. Economic growth does not remove the gap, and if the highest incomes increase most rapidly, as in many economies in

recent decades, the relative deprivation of the poor also grows, and the gap widens for a majority. At the same time, the income people say they need to get by with comfortably remains higher than their current income, even for the very rich, and in spite of the economic growth from which they have profited most, so again the gap remains or even grows. This process is known as adaptation and is familiar to everyone from personal experience – yesterday's luxuries become today's 'necessities'.[27]

However, a rise in *relative* income, say through promotion to a better-paid job, does bring real or apparent benefits in terms of status, consumption and comparison with reference groups. But reference groups also change as people move to more attractive and more expensive neighbourhoods, and compete with new rivals at a higher level of their organization. The aspiration gap may shrink but not disappear. People with the most materialist aspirations are generally the least happy, and competition for career advancement becomes a 'rat-race' just to 'keep up with the Joneses', let alone to overtake them. Individuals regularly overestimate the benefits of effort to earn higher income and status by not realizing that their aspirations will also ratchet upwards with their own material 'progress'.[28] Even when the benefits of effort in terms of gains in relative income and status are correctly perceived, people will generally work more than is socially optimal, because each individual's effort or advancement *reduces* the relative position of neighbours or rivals, thus imposing an external cost on society.

The simplistic, traditional model of isolated economic actors, whose well-being depends only on their own consumption, thus ignores all the social interaction including rivalry and aspirations, and encourages the perverse policies that drive excessive growth, overwork in the rat-race of individual competition, and environmental destruction. With a more realistic, psychologically based view of human behaviour, it follows that income taxation can raise true welfare by discouraging excessive effort and competition, rather than inevitably distorting 'optimal' activity. In contrast to conspicuous material consumption, the enjoyment of family and personal relationships is not normally compared to others' enjoyment, and is not eroded to the same extent by adaptation and rising aspirations. Thus, for most people above poverty levels in rich countries, working and earning less, and spending more time with friends and family, would probably make them happier in the long run, but the problem is that this would only work if everyone 'downsized' together. Thus collective action would be needed to realize these benefits for a majority without anyone losing out in relative terms; otherwise only exceptionally idealistic individuals manage to opt out of the rat-race.[29]

A popular argument against major investment to mitigate GHG emissions and global warming is that economic growth would slow down, and reduce welfare in the future. Of course, this argument completely ignores the disastrous long-term effects of *failing* to tackle climate change (but neoliberal market fundamentalists usually deny basic climate science as well as any government intervention that might reduce the profits of fossil energy corporations that fund their think tanks and political representatives). It also misrepresents major investment in mitigation as very costly,

ignoring that there are also substantial immediate benefits for employment. Some economists have described the scale of investment required to stabilize our climate as a new *energy-industrial revolution*, comparable to other waves of major technological change in history (e.g. those related to the initial expansions of railway and electricity networks). The design of new cleaner cities and radical changes in how we produce energy can support an alternative low-carbon, more inclusive, lower unemployment growth path.[30] And furthermore, as we have seen, the evidence is overwhelming that economic growth in rich – and in many developing – countries is *not* related to life satisfaction. However, commitment to full employment, urgent climate change mitigation, more redistributive taxation (which does not necessarily lead to slower growth) and other egalitarian policies, as in the Nordic economies, could *raise* life satisfaction for most of the 99 per cent who have lost out under neoliberal policy, with its frequent recessions, increasing inequality and growing job insecurity for most employees.

Relative deprivation refers to the growing gap between the lower half or so of the income distribution who have lost out in the decades of neoliberal growth, and the highest earners, particularly the top 1 per cent, who have enjoyed rapidly increasing shares since the late 1970s. Relative deprivation means not only low pay, insecure jobs and more frequent unemployment, but also generally poor education and worsening health problems such as obesity and type-2 diabetes, as well as mental illness, debilitating conditions that are often transmitted to the next generation unless there is effective remedial intervention at an early, and especially pre-school, age.

For those who are above the *relative poverty* line in any country (usually defined as 50 per cent of the median income), it is important to remember that income has only a small effect on happiness or well-being. Unemployment and divorce are major causes of unhappiness, while family, health (particularly mental health), social relationships and job satisfaction, together with personality traits that are largely inherited or that develop in the first three years of childhood, are the most important factors influencing happiness in adult life. In comparisons across advanced countries, social capital indicators can explain not only most of the differences in average reported happiness, but also much of the variation in the opposite extreme – rates of suicide. At the same time, recent studies point to a positive relationship between generosity and happiness (this confirms the 'hedonistic paradox', that people who most explicitly pursue their own happiness may be less likely to enjoy it than altruists who help others).

The ecological footprint

A very simple indicator of the unsustainability of current consumption levels is the crude but suggestive *ecological footprint*.[31] The main idea is that there is only about 1.7 'global hectares' (gha) of ecologically productive surface area per inhabitant of the Earth.[32] In the early 1960s, the corresponding measure was close to 3.2gha and declined steadily as a result of environmental and population pressures. However,

humanity's demand on the biosphere (in terms of productive surface) constitutes our global ecological footprint, and is about 2.6gha. This includes the area required to absorb *all* waste, including GHG emissions, in natural sinks. Thus, our global ecological footprint already exceeds the total sustainable capacity of the biosphere, which constitutes our 'ecological deficit'. Clearly this deficit cannot be sustained indefinitely, and the growing pressure we impose on ecosystems will sooner or later translate into food shortages, biodiversity loss and accelerated climate change.

Perhaps not surprisingly, the average ecological footprint per inhabitant of the USA is close to 7gha, about four times the average available area of 1.7gha per person. Such large differences in environmental impacts are also typical across households in developed economies, with carbon footprints across richer households often exceeding the ones of poorer families by a magnitude of 10.[33] This of course depends on current technology and consumption habits, and could be reduced by greener technology and consumption. However, if developing countries' material living standards and greenhouse gas emissions per head were to approach the European or US average over time without a radical switch to renewable energy and cleaner technologies, the ecological deficit implied by our global footprint would expand dramatically. Carbon sinks will deteriorate, and as temperature rises and ecosystems collapse, humanity will be forced by necessity to drastically reduce its ecological footprint.

The illusionary comfort of sustainability (strong vs weak sustainability)

In order to produce the unprecedented levels of consumption currently enjoyed by wealthy countries, we need to complement our human labour with large amounts of other factors of production. Economists classify these productive inputs into four categories: manufactured, human, natural and social capital. Manufactured capital consists of the stock of machinery, buildings and infrastructure that is used in any productive activity. Human capital consists of those skills, abilities and knowledge embodied in labour. But all kinds of capital (except non-renewable resources) can increase as a result of investment (which is the alternative to current consumption), provided the investment is more than the amount of capital that has been 'used up' or become obsolete in the period of production.

Natural 'capital' is more difficult to define precisely, but we can think of it as all those environmental services and resources or 'raw materials' provided by nature. These include (potable) water, breathable air, fisheries, forests, land, non-renewable resources (such as fossil fuels), as well as the overall services that nature provides for recreation (amenity value), waste assimilation and life support. Intrinsic or existence value of the natural world is also important to many, in addition to all the above 'use' values. Social capital is much more abstract, and depends on the institutional framework within which economic activities take place (such as the extent of property rights and the role of bureaucracy and corruption). Just as importantly, as we

discussed earlier, social capital includes the whole network of informal personal relationships – such as trust in neighbours, friends and authorities – on which both everyday life and all economic transactions ultimately depend, and which are so important for life satisfaction or happiness.

Natural capital depreciates through exhaustion of fossil fuels, aquifers and other non-renewables, as well as the destruction of fertile soil or forests. Pollution of air and water threaten future health and agriculture. Neoclassical economists assert that this does not necessarily imply the end of a sustainable world, as long as there is sufficient investment in other kinds of capital. If the 'total stock' of capital in some appropriate sense is maintained (whatever its composition), then sufficient substitutability between man-made (i.e. physical, human and social) and natural capital should enable future generations to enjoy at least the same level of welfare as today. The assumption of a non-declining stock of 'total capital' in the economy is known as *weak sustainability*. While there are obviously always *some* possibilities for substitution between different kinds of capital, relying on weak sustainability as an excuse for large-scale destruction of natural capital requires a high level of corruption or a naïve faith in future technology that owes more to science fiction than to any relevant discipline.

Ecological economists, environmentalists and ecologists believe that natural and man-made capital are often complements rather than substitutes. The natural environment has intrinsic value, in addition to its direct effects on human welfare. True or *strong* sustainability emphasizes conservation of natural capital and stabilizing population, rather than maintaining the material productivity and consumption growth that is actually eroding natural and social capital in the advanced economies. The combination of a growing world population and consumption with unavoidable further warming does mean that numerous species (and human lives) risk extinction by mid-century. Strong sustainability remains an ideal rather than a precise guide for policy, and is thus often rejected as irrelevant – but without wide acceptance of this ideal instead of continuing current growth patterns, our chances of averting climate catastrophe and agricultural collapse will be slim.[34]

Genuine savings and investment

A famous weak-sustainability rule of thumb, known as the Hartwick rule, suggests that all revenues from exhaustible resources (after deducting extraction costs) need to be saved and invested in other forms of capital (human, physical or natural).[35] This of course only applies to those kinds of resources for which markets and realistic prices exist. To verify weak sustainability more generally, economists compare total investment in new capital with the estimated monetary value of all the kinds of capital used up or worn out (depreciated). This difference between new investment and all capital 'consumed' or worn out in a particular year is called 'genuine' savings or investment, which obviously has to be positive for weak sustainability to hold. The new capital added to the economy can also be in the form of natural capital, such as investment in

abatement, planting trees or searching for new resource deposits. Whatever the limitations of the concept, it can provide a useful early warning signal: negative genuine savings strongly suggest that the economy is on an unsustainable development path of imminent environmental collapse and deteriorating welfare. Recent studies reveal that this is the dismal reality for many parts of the world.[36]

The genuine savings measure is far from ideal. It assumes that man-made capital can always replace degraded natural resources to sustain human living standards and happiness. It ignores the fact that natural resources may be useful in the future in ways unknown to current consumers, and with no available substitute (loss of plant species, for instance, may hinder future medical progress). It also ignores the intrinsic value many people attach to nature, which is an important component of happiness, starting in early childhood.

Furthermore, in order to measure substitution and genuine investment, we need to attach monetary values to natural resources and their services, which are often not traded in real markets. As we discuss in Chapters 6 and 9, such estimated values (or 'shadow prices') may underestimate the true, long-run benefits of natural wealth, in particular to future generations who are not represented in current decision making. Last, a country may also preserve its own resource base by importing, say, tropical timber, minerals or goods manufactured with intensive energy use and pollution from other nations with lax environmental regulations (and thus contribute to negative genuine savings abroad). A third or more of China's emissions are thus caused by manufacturing for export to the rich countries.

GDP (Gross Domestic Problem)[37]

Even the most casual attention to media reporting on economic policy confirms a near obsession with one measure of economic performance – gross domestic product or GDP, and its growth from year to year. GDP is just the market value of all final traded goods and services, or the sum of consumption and investment. As noted above, average consumption (and GDP) per capita at a point in time has little relationship to subjective well-being in comparisons among the richer countries, and growth of life satisfaction is unrelated to economic growth in this group, as well as among many developing countries. Not only has this fundamental flaw in our key economic indicator been basically known (though largely ignored) for 40 years, but the most obvious and well-known economic inconsistencies in the concept of GDP are also neglected. Thus non-market activities, such as housework or childcare in the family, and the value of additional leisure when working time is reduced, are omitted when GDP growth rates or levels are compared.

As emphasized already, capital of any kind depreciates in various ways, and to maintain a given capital stock there must be sufficient investment every year to replace the annual loss or depreciation. Business accounts report a surplus only after subtracting an allowance for the depreciation of their manufactured capital (as well as other costs of current output) from total revenue. Net National Product (NNP)

is defined by subtracting depreciation of man-made capital from GDP, but this measure is seldom used because accounting and tax conventions affect the value of depreciation, so NNP is considered to be unreliable and subject to arbitrary errors.

Astonishingly, however, neither business nor national accounts even attempt to allow for the natural resources that have been used up, damaged or destroyed. One reason is that it is usually very difficult to put a money value on damage to the environment, caused by GHG and other emissions and our unsustainable consumerism. However, many natural resources are sold on world markets, so it would actually be easy to incorporate their depletion into accounting rules, but even such reforms are strongly resisted by business lobbies. Nobel Prize-winning economist Joseph Stiglitz describes one such episode from his term as Chair of former US President Bill Clinton's Council of Economic Advisors, when he campaigned in vain for improved national accounts.[38]

Most economists also forgot the original purpose of the GDP measure, which was developed in the early 1930s by Simon Kuznets to assess the state of health of a slowly recovering American economy. While such an imperfect proxy would have been useful to grasp the pace of recovery during the Great Depression, Kuznets himself warned of its limitations as a proxy for the welfare of a whole nation. There was undoubtedly a value in creating a new measure in the 1930s when government officials often had little (or no) idea of what was happening to the economy, but since then GDP has been misused (by politicians and economists alike) and misrepresented as the ultimate (and often sole) measurement of human welfare.

Robert F. Kennedy in a 1968 speech at the University of Kansas (on 18 March 1968, a few months before his assassination) launched a fierce critique of GDP as a measure of progress – in a rather prophetic way, the speech touches upon almost all major limitations of GDP that several decades later environmental economists discussed. One can only imagine that, if the speech had been written at a more recent time, it would have almost certainly focused on climate change:

> We will find neither national purpose nor personal satisfaction in a mere continuation of economic progress, in an endless amassing of worldly goods. We cannot measure national spirit by the Dow Jones Average, nor national achievement by the Gross National Product. For the Gross National Product includes air pollution, and ambulances to clear our highways from carnage. It counts special locks for our doors and jails for the people who break them. The Gross National Product includes the destruction of the redwoods and the death of Lake Superior . . . . It includes . . . the broadcasting of television programs which glorify violence to sell goods to our children . . . . And if the Gross National Product includes all this, there is much that it does not comprehend. It does not allow for the health of our families, the quality of their education, or the joy of their play. It is indifferent to the decency of our factories and the safety of our streets alike. It does not include the beauty of our poetry, or the strength of our marriages, the intelligence

> of our public debate or the integrity of our public officials . . . the Gross National Product measures neither our wit nor our courage, neither our wisdom nor our learning, neither our compassion nor our devotion to our country . . . .[39]

Greening the GDP

There have in fact been various attempts to provide more comprehensive or 'greener' versions of GDP, adjusting for negative environmental (and other) externalities of economic growth. In the 1990s the United Nations Statistics Division created the System of Integrated Environmental–Economic Accounting (SEEA) to provide some guidelines on how to construct an environment-adjusted measure of GDP. The new measure subtracts from GDP all capital depreciation (both in physical and natural capital through resource depletion), as well as estimated costs of environmental degradation. This attempt to create a measure of sustainable income has not been widely used, although it improves on the UN's earlier Human Development Index (HDI), which, as we discuss in Chapter 6, only adds education and life expectancy and ignores sustainability, but is frequently cited.

A much broader-based Index of Sustainable Economic Welfare (ISEW) has been constructed for several countries by Friends of the Earth and the New Economics Foundation, and has been declining or has remained stationary in recent decades. The similar Genuine Progress Indicator (GPI), originally developed by Daly and Cobb, has been estimated for many countries. Average global GPI per capita followed GDP per capita from 1950 until peaking in 1978 and declining ever since, while GDP per capita doubled in the following decades.[40] These indices are constructed using GDP data after adjusting for non-market output, income inequality and depreciation of both man-made and natural capital, as well as externality and clean-up costs. They thus subtract from GDP the estimated monetary value of a broad range of externalities, which are generated by our unsustainable consumption patterns. While no substitute for direct survey evidence on happiness, and subject to unavoidable uncertainty in attempting to quantify environmental damage, the GPI index does include important aspects of sustainability and welfare that are totally ignored in the conventional GDP measure of market activity.

Rather than trying to modify GDP to obtain a more meaningful index of welfare, an interesting new approach by the New Economics Foundation (NEF) in London measures the ecological efficiency with which nations attain subjective well-being or happiness, the Happy Planet Index (HPI). This is defined as the product of life satisfaction with life expectancy (happy life years), divided by the ecological footprint, or 'the average years of happy life produced by a society . . . , per unit of planetary resources consumed'.[41]

As examples of how the HPI works, resource-rich Sweden has a large ecological footprint to attain a high level of happiness, and thus scores lower than countries such as Austria or Iceland that achieve similar 'happy life years' with much smaller

footprints or lower resource use. The UK, with relatively low life satisfaction and a moderate footprint among advanced economies (though still close to three times the available 1.7gha per person), has an HPI just above Sweden, though far below the leaders. Some relatively poor countries such as Cuba and Costa Rica manage to achieve surprisingly high levels of life expectancy and satisfaction with very modest resource use, thus coming close to the top of the HPI ranking, indicating much greater ecological efficiency than even the best performing advanced economies. There are surely interesting lessons for development and sustainability to be drawn from further study of this promising new approach.

Degrowth

Some ecological economists suggest that staying within our ecological boundaries requires a *downscaling* of economic activity – this is commonly referred to as the *degrowth* debate. The degrowth movement is sceptical about the ability of technological innovation to prevent climate change (although it might slow it down!) and instead advocates a deliberate reduction in consumption – at least for the global rich. Negative growth has often been coupled with reduced carbon emissions (e.g. in Eastern Europe after the collapse of Communism and more recently in many Western economies that suffered from the current global financial crisis). Nevertheless, even the degrowth proponents themselves acknowledge that any radical downscaling of consumption is likely to be unpopular (with politicians and their electorates alike). In order to be socially acceptable, degrowth would need to be accompanied by policies that alleviate the negative effects of sustained economic contraction on employment, low-income earners and social stability.

The degrowth proponents give some suggestions as to how this can be done (many of which could be useful policy recommendations irrespective of whether one is in favour of degrowth or positive growth). Reduced working hours, for example, can allow for more people to be employed, and hence sustain a low rate of unemployment even during prolonged recessions. A strengthened social security system can provide an additional safety net against increased unemployment; in parallel, a guarantee for providing some basic income level for everyone in the economy can ensure that (absolute) poverty will not rise. Governments would need to raise taxes on the rich to finance a more drastic redistribution of income (although taxes on low incomes should be reduced, to create genuine progression instead of the current plethora of legal tax breaks for the rich).

Of course, in the same way that the quality of economic growth matters (some paths of economic expansion are more environmentally friendly than others), economic degrowth can take place in many different ways. The different types of downsizing can correspond to varying degrees of success (in reducing carbon emissions) depending on the sectors that contract. So far, it seems unlikely that the degrowth debate will extend beyond the academic realm and receive sufficient

social and political support that would enable concrete and sustained degrowth government policies to materialize.[42]

Ecologists vs economists

Ecologists are concerned with the integrity and stability of whole ecosystems, and thus have a keen interest in the adverse impacts of human actions on their functioning. For this reason, they interpret sustainability quite differently from most economists. Their central concern is the survival of the entire biosphere, not just a given level of human prosperity, or the wasteful consumption of the richest nations. Of course, as we have argued at length, there is abundant evidence that the current pattern of Western material consumption is already unsustainable, let alone its imitation by the LDCs as the world warms up. Reflecting on ecology raises profound questions about the valuation of non-human life, which, as we discuss in Chapter 6, receives much more attention in the ethics of eastern religions, especially Buddhism. However, more pragmatic and widely shared concerns about the survival of our own children, as well as those in the most threatened, poorest parts of the world, are in themselves quite sufficient to justify urgent and drastic action to reduce the environmental cost of conventional economic growth.

Ecologists and environmentalists tend to be sceptical about substitution possibilities and the scope for new technologies to replace natural resources, which are often irreversibly destroyed by traditional economic growth. This is particularly relevant for what is often defined as 'critical natural capital', which provides our life-support ecological services, but the 'criticality' of natural capital and the inherent value attached to it are closely linked to social perceptions, rather than to any strict biophysical limits and threshold effects determined by natural scientists. From this position, the basic ideas of strong sustainability form the only meaningful and morally acceptable guide to future development. Clearly, past economic growth has diverged very far from this ideal, and global warming already threatens numerous ecosystems (with much tropical rainforest and biodiversity likely to be destroyed by temperature increase and drought by mid-century).

The ultimate threat from water shortage, soil erosion and further warming is not just to ecosystems, but to the lives of perhaps billions of the world's poorest people in hot and arid regions, who face the risk of large-scale famine if present trends continue. Sustainability indicators for the wealthy northern countries alone, which may even benefit from climate change, are both ethically and strategically bankrupt in a nuclear-armed world order and global economy that is threatened with partial collapse.

Ecological economists try to combine insights from various disciplines and arrive at a more inclusive and holistic evaluation of costs and benefits of policies than the narrow monetary estimates usually used by economists and governments. These in turn are often dominated by industry lobbies that influence public opinion and actively promote deception and distortion of scientific evidence to conceal environmental and health costs. This is particularly easy to do when the costs are

difficult to quantify, and affect poorer countries or future generations. Decades of false claims by the tobacco industry and more recently by the fossil fuel lobby and its allied – and well-funded – politicians and think tanks[43] are facilitated by an environment where media and politics are generally subservient to business interests, with public legitimacy based on the false ideology that economic growth makes everyone happier.

Conclusions

Economic development has been at the expense of our global environmental health. A truly sustainable future, however, requires economic development that does not compromise the health of ecosystems, climate stability or the well-being of the future poor. But how do economists perceive such a 'sustainable future'? As highlighted above, sustainability is often an ambiguous concept, with some emphasizing the role of continuous material growth, and others putting more emphasis on environmental protection. Whatever the definition, unmitigated climate change is certainly inconsistent with sustainable development. Generous investment in renewable technologies and knowledge transfers will be necessary to decouple economic growth from GHG emissions and environmental degradation more generally, particularly as China and India's current economic ascent imposes enormous environmental harm. National accounts, which are used to calculate our most common estimate of welfare – GDP – currently do not correct for the loss of environmental assets and pollution. Even when green accounting tries to incorporate such damages into a more comprehensive measure of well-being, money values cannot be accurately provided for all non-marketed environmental services, nor can material consumption and environmental quality ever be complete substitutes.

Even more importantly, there is increasing evidence that long-term growth rates of average income and life satisfaction are unrelated in many countries, both rich and poor. Our unsustainable, materialist consumerism not only fails to raise average well-being but also comes at the expense of social and environmental capital. This suggests that sacrificing consumption in richer countries for investment in public goods and aid transfers, is likely to achieve a convergence in happiness globally, though at no cost – and even ultimate gain – for those already rich. Rivalry and aspirations for higher relative income result in continuous competition, excessive growth and an ever-expanding list of consumer needs and habits. While our ecological footprint suggests we already live beyond our means, we mistakenly prioritize relative consumption over more fundamental determinants of happiness, namely social relationships and environmental quality.

Notes

1 From 1500 to 1820, per capita GDP grew by only 0.14 per cent per year in Western Europe, but this accelerated subsequently to peak at 4.1 per cent during the Golden Age from 1950 to 1973. Growth in the advanced economies averaged only 1.8 per cent

per year during the subsequent neoliberal era from 1980 to 2010, inequality increased rapidly and average unemployment was much higher. More discussion of these episodes is provided by Chang, H.-J. (2014) *Economics: The User's Guide*, Pelican, London, UK.

2 Shaxson, N., Christensen, J. and Mathiason, N. (2012) 'Inequality: You don't know the half of it', Tax Justice Network, Chesham, Bucks, UK, 19 July, available at www.taxjustice.net/cms/upload/pdf/Inequality_120722_You_dont_know_the_half_of_it.pdf; Hardoon, D. (2015) 'Wealth: Having it all and wanting more', *Oxfam Issues Briefing*, London, UK, available at http://policy-practice.oxfam.org.uk/publications/wealth-having-it-all-and-wanting-more-338125; Saez, E. and Zucman, G. (2014) 'Wealth inequality in the United States since 1913', Working Paper No 20625, National Bureau of Economic Research, Cambridge, MA.

3 Leimbach, M., Kriegler, E., Roming, N. and Schwanitz, J. (2015) 'Future growth patterns of world regions – A GDP scenario approach', *Global Environmental Change*, In Press; Di Vaio, G. and Enflo, K. (2011) 'Did globalization drive convergence? Identifying cross-country growth regimes in the long run', *European Economic Review*, vol 55, no 6, 832–844.

4 In the AOSIS Barbados Declaration in 1994 and subsequent 5-year programmes of action, climate change and sea level rise appeared first in the list of sustainability concerns. Of course the AOSIS states focus primarily on monitoring sea level rise, mapping vulnerable areas and assessing damages rather than taking any proactive measures. The declaration can be downloaded from the website of the Alliance: www.sidsnet.org/aosis/index.htm.

5 The Environmental Kuznets Curve (EKC) is likely to hold, though, when considering national carbon dioxide emissions per unit of GDP rather than per capita, reflecting efficiency improvements but not a decrease in pollution. See Roberts, J. T. and Grimes, P. E. (1997) 'Carbon intensity and economic development 1962–91: A brief exploration of the Environmental Kuznets Curve', *World Development*, vol 25, no 2, 191–198. See also Iwata, H., Okada, K. and Samreth, S. (2011) 'A note on the environmental Kuznets curve for CO_2: A pooled mean group approach', *Applied Energy*, vol 88, 1986–1996.

6 John Pezzey suggested that the plethora of definitions of sustainability necessarily contributes to confusion. See Pezzey, J. C. V. (1997) 'Sustainability constraints versus optimality versus intertemporal concern, and axioms versus data', *Land Economics*, vol 73, no 2, 448–466. For a more recent discussion, see Kuhlman, T. and Farrington, J. (2011) 'What is sustainability?', *Sustainability*, vol 2, no 11, 3436–3448.

7 See Baumgärtner, S. and Quaas, M. (2010) 'What is sustainability economics?', *Ecological Economics*, vol 69, no 2, 445–450, as well as Van den Bergh, J. C. J. M. (2010) 'Externality or sustainability economics?', *Ecological Economics*, vol 69, no 4, 2047–2052.

8 See Malthus, T. (1798) *An Essay on the Principle of Population*, Oxford University Press, Reprint 1993, Oxford, UK.

9 See Boulding, K. (1966) 'The economics of the coming spaceship Earth', in H. Jarrett (ed.) *Environmental Quality in a Growing Economy*, Johns Hopkins Press, Baltimore, MD, and Carson, R. (1962) *Silent Spring*, Houghton Mifflin, New York, NY. Since Carson's classic appeared, there has been a dramatic increase in the use of new (and old) chemical entities, and their dispersion in the environment, most of which have not been tested for toxicity and long-term effects even in isolation, let alone in the numerous combinations found in human samples. Yet about a third of North American chemical output in 2006 was rated by the United Nations Environment Programme (UNEP) as 'persistent, bio-accumulative and toxic to humans and animals', Cribb, J. (2014) *Poisoned Planet*, Allen Press, Lawrence, KS, 7. Science writer Julian Cribb's book has been called a 'Silent Spring' for the twenty-first century, and describes how 'man-made chemicals are creating a silent epidemic'.

10 World Commission on Environment and Development (1987) *Our Common Future*, Oxford University Press, Oxford, UK.

11 A convention on biological diversity and a statement on forest principles also emerged out of the negotiations at the Earth Summit.
12 See Ehrlich, P. and Holdren, J. (1972) 'One-dimensional ecology', *Bulletin of the Atomic Scientists*, vol 28, no 5, 16–27. For an overview on how the IPAT identity has evolved and been used over the last 30 to 40 years, see Chertow, M. R. (2008) 'The IPAT equation and its variants', *Journal of Industrial Ecology*, vol 4, no 4, 13–29, as well as Rosa, E. A., Rudel, T. K., York, R., Jorgenson, A. K. and Dietz, T. (2015) 'The (human) anthropogenic driving forces of global climate change', in R. E. Dunlap and R. J. Brulle (eds) *Climate Change and Society: Sociological Perspectives*, Oxford University Press, Oxford, UK.
13 For global population trends, see the latest report on 'World Population Prospects' of the United Nations Population Division: www.un.org/en/development/desa/population.
14 Liddle, B. (2014) 'Demographic dynamics and per capita environmental impact: Using panel regressions and household decompositions to examine population and transport', *Population and Environment*, vol 26, no 1, 23–39.
15 The same point has been emphasized by Jeffrey Sachs. See Sachs, J. D. (2008) *Common Wealth: Economics for a Crowded Planet*, Penguin Books, London, UK; Sachs, J. D. (2011) *The Price of Civilization*, Bodley Head, London, UK.
16 Marmot Review (2010) 'Fair society, healthy lives, strategic review of health inequalities in England post-2010', UCL Institute of Health Equity, London, available at www.marmotreview.org/AssetLibrary/pdfs/Reports/FairSocietyHealthyLivesExecSummary.pdf.
17 The Easterlin Paradox is due to the pioneering work of American economist Richard Easterlin: Easterlin, R. (1974) 'Does economic growth improve the human lot?', in P. A. David and M. W. Reder (eds) *Nations and Households in Economic Growth: Essays in Honour of Moses Abramowitz*, Academic Press, New York, NY. A summary of his most recent work is: Easterlin, R. A. (2013) 'Happiness and economic growth: The evidence', Discussion Paper No 7187, IZA, Bonn, Germany.
18 See Smyth, R., Mishra, V. and Qian, X. (2008) 'The environment and well-being in urban China', *Ecological Economics*, vol 68, no 1–2, 547–555; Brockmann, H., Delhey, J., Welzel, C. and Yuan, H. (2008) 'The China puzzle: Falling happiness in a rising economy', *Journal of Happiness Studies*, vol 10, no 4, 387–405; Easterlin (2013).
19 A major development and confirmation of Easterlin's findings is by De Neve, J.-E., Ward, G. W., De Keulenaer, F., Van Landeghem, B., Kavetsos, G. and Norton, M. I. (2015) 'Individual experience of positive and negative growth is asymmetric: Evidence from subjective well-being data', *IZA*, Discussion Paper No 8914, Bonn, Germany. Opposing claims made by David Sacks et al. (2012) are based on confusion between short-term correlations and long-term trends, and inclusion of obvious outliers, as explained by Easterlin (2013). Sacks et al. (2012) also ignore the microeconomic evidence that income has only a very small effect on well-being above the poverty line when other variables are controlled for. See Sacks, D. W., Stevenson, B. and Wolfer, J. (2012) 'Subjective well-being, income, economic development, and growth', in J. Yifu Lin and B. Pleskovic (eds) *Development Challenges in a Post-crisis World*, World Bank, Washington DC.
20 Jones, O. (2014) *The Establishment: And How They Get Away with it*, Penguin, London, UK, 84.
21 Radcliff, B. (2013) *The Political Economy of Happiness*, Cambridge University Press, Cambridge, UK, 129. Research on social capital is discussed by Bartolini, S. (2014) 'Building sustainability through greater happiness', *The Economic and Labour Relations Review*, Symposium on Development, Equity and the Environment, vol 25, no 4, 587–602; Bartolini, S. and Sarracino, F. (2011) 'Happy for how long? How social capital and GDP relate to happiness over time', *Ecological Economics*, vol 108, 242–256; Helliwell, J. F. (2006) 'Well-being, social capital and public policy: What's new?', *The Economic Journal*, vol 116, no 510, 34–46. See also, Konow, J. and Earley, J. (2008) 'The hedonistic paradox: Is homo economicus happier?', *Journal of Public Economics*, vol 92,

no 1–2, 1–33. A comprehensive review of many of these and related issues is provided by a series of 'world happiness' reports, the latest of which is: Helliwell, J. F., Layard, R. and Sachs, J. (eds) (2015) 'World Happiness Report 2015', Earth Institute, Columbia University, New York, NY, and also Radcliff (2013).

22 Ha-Joon, C. (2014) *Economics: The User's Guide*, Pelican, London, UK, 196. Widespread misperceptions about welfare payments and inequality are documented by Hills, J. (2015) *Them and Us*, Policy Press, London, UK.

23 Dillow, C. (2015) 'Poverty & ideology', Stumbling and Mumbling, Blog, 2 July, available at http://stumblingandmumbling.typepad.com/stumbling_and_mumbling/2015/07/poverty-ideology.html.

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5

DEVELOPMENT IN A CHANGING CLIMATE

Millennium goals for development and environment

We live in a world of collapsing ecosystems and environments, from fisheries and rainforests to clean air and water, as well as persistent, extreme poverty in most developing countries, where climate change is only one of many serious challenges. The eight Millennium Development Goals (MDGs), agreed at the UN Millennium Summit in 2000 (by 189 countries), attempt to create a road map for improvement in the main problem areas. The plan reflects high aspirations in many development dimensions, but little progress can be expected without major policy changes, as not only Africa's disappointing performance, in particular, so far suggests.[1] Generous aid, technology and knowledge transfers need to be complemented with radical policy changes in environmental protection, gender equality, international trade and poverty alleviation.

The MDGs for 2015, in brief, are to eradicate extreme poverty, achieve universal primary education, promote gender equality, reduce child mortality, improve maternal health, combat diseases (HIV/AIDS, malaria, typhus, etc.), ensure environmental sustainability and develop a global partnership for development.[2] Under the environmental sustainability objective alone, there is a formidable list of more detailed targets, including halting biodiversity loss, improving access to safe drinking water and sanitation, reversing deforestation, and mitigating climate change.

It is obviously counterproductive to target global warming in isolation. Developing nations, and the poorest countries in particular, have special needs and characteristics that all merit urgent attention. Many of them are far behind schedule for achievement of all MDGs, and are still further handicapped by rapidly growing populations, poor infrastructure, increasing income inequality and worsening environmental degradation. Developing nations generally, and most outside observers, see economic growth as one of the essential elements needed to achieve their MDGs. Economic growth will in principle allow governments and individuals to increase their spending on education, health, the environment and general infrastructure, though, as we discuss below, these 'public goods' are frequently neglected, with the richest classes capturing most of the benefits of growth for

themselves. The crucial question here is whether growth will continue to come at the expense of even higher greenhouse gas emissions, more deforestation, environmental degradation and inequality.

In September 2015, the UN agreed on new Sustainable Development Goals (SDGs) for 2030 to build on the Millennium Development Goals, including SDG 13 – 'Take urgent action to combat climate change and its impacts.' However, simply stating new admirable goals such as the SDGs, without outlining the radical policy changes required, increases the likelihood that they will prove as ineffective as the previous round of MDGs. Again, SDGs are only targets or goals that *depend on* 'urgent action', particularly on climate change, and, as we have emphasized in other chapters, there is little prospect of this, either at the 2015 UN climate summit in Paris or anywhere else, as long as the world remains in the grip of neoliberal ideology.

This chapter focuses on the challenges faced by developing nations, especially those with large populations, suffering widespread and extreme poverty. In a world of 7.3 billion people, about a billion live on the estimated 'equivalent' of less than a dollar per day, though many are subsistence farmers who scarcely interact with the market economy. The majority of the poorest live in sub-Saharan Africa and South Asia, with East Asia achieving the greatest improvements in reducing poverty since the 1960s (mainly driven by China's growth performance).

If one stretches the poverty limit to $2 per day, the results are even more discouraging. Most of them are found in populous developing nations, such as Nigeria, Bangladesh, India, Indonesia and China, where the share of total population under the $2 poverty line is an astounding 85, 76, 69, 43 and 27 per cent respectively. For most sub-Saharan nations, the share consistently exceeds 70 per cent of the total population. These are the Earth's 'bottom billions', a staggering 2.4 billion people, or 35 per cent of the global population, that live – and die prematurely – on only a tiny fraction of the richest countries' per capita GDP.[3] At the same time, aid from the leading developed economies of the OECD remains much smaller than their subsidies for the most polluting fossil fuels, or for their richest big farmers. The US continues to provide only 0.19 per cent of GDP as development aid, which is the smallest share in the OECD (while the US military budget is almost half of the world's total).

There are thus two reasons for a chapter on development under the growing threat of climate change. Firstly, the poorest countries and the poorest segments of their societies will suffer the most from global warming. Low incomes prevent both governments and individuals from investing much in either adapting to – or preventing – climate change.[4] Many of the poorest countries contain some of the already most environmentally degraded regions, where the effects of climate change will be particularly devastating. Farmers in these regions are especially vulnerable to the expected increased frequency of droughts, heatwaves and floods. Large-scale agricultural collapse due to warming and water shortages will almost certainly be the most important climate change impact on the world's poor if present trends continue much longer, leading to astronomical food prices, mass starvation and migration, as we discussed in Chapter 3. While worldwide economic recession

and the financial crisis in late 2008 generated sharp falls in food prices, even slow economic recovery has in the meantime raised the FAO global food price index to above its pre-crisis level, with little chance of substantial decline in the future, also discussed in Chapter 3.

Apart from the fact that the less developed countries will be hardest hit by changes in climatic conditions, there is another major reason why they deserve our particular attention – developing nations are increasing their carbon emissions much more rapidly than the old industrial countries. China has surpassed the US as the largest contributor to global emissions, coupled with rapidly progressing domestic environmental degradation. This suggests that unilateral reductions of emissions by the Annex-I industrialized nations of Kyoto may simply be counter-balanced by increases across developing countries. Unless there is some concerted global effort by all nations simultaneously, any efforts by developed nations to reduce their GHG emissions will have only limited effects.[5]

Time to double: 70/x

There is a rule of thumb in mathematics that gives a practical sense of what a growth rate implies. We know, for instance, that China's economy has been growing by about 10 per cent annually for many years. We also know that India's population grew at an average annual rate of 1.5 per cent over the last decade. It is sometimes useful to translate such numbers into an alternative and more intuitive measure. Dividing the number 70 by the growth rate of any statistic, we obtain the number of years it takes for the variable to double.[6] Assuming that the above growth rates persist over time, it follows that China could *double* its output in 70/10 = 7 years. With emissions increasing nearly as rapidly, China could be producing half the world's output of GHGs in a decade or two, without radical policy changes. China's GDP growth has recently slowed down to about 7 per cent and it has become the world's biggest investor in alternative energy, but it also burns nearly half the world's coal, and is still rapidly expanding production. Similarly, a sustained growth rate of 1.5 per cent implies that India could double its population size in 70/1.5 = 47 years.

The dragon is rising

Though not one of the poorest countries, and in spite of its success in lifting many out of poverty, China still has a large, impoverished and vulnerable 'underclass' that has benefited little from growth hitherto. In addition, the sheer size of its economy and GHG emissions imply that this fast-developing country already has major impacts on commodity markets and prices, and in the long run on global climate. China's GDP in 2014 was estimated at approximately $18 trillion on a Purchasing Power Parity basis (i.e. taking into account that many commodities

are relatively cheaper in China than in the US, and that the official exchange rate undervalues the Chinese currency). India's GDP is also rapidly expanding and is about $7 trillion. The US GDP stands at about $17 trillion but with a population that is only about a quarter of China's (all figures for 2014).

While there is a strong relationship between economic activity and carbon emissions, it is noteworthy that China, with only about one sixth of US GDP per capita, uses much 'dirtier' and more energy-intensive technologies than the US, which in turn is nearly twice as energy intensive as Europe. China's total carbon emissions are about twice the US emissions, and increasing rapidly from expanding coal use and road traffic, in spite of already appalling pollution and growing public health concerns in major cities. However, China's per capita emissions are about half the US level, and similar to Europe's, though output and energy efficiency in Europe are much higher than in China.

Luckily for the world, the double-digit growth rates of many large, developing economies and their emissions are unlikely to continue unabated (and the Chinese economy is slowing down amid market turbulence and serious concerns about domestic debt). Air pollution in China, for example, was already so bad that half of Beijing's traffic and much industry had to be banished for the duration of the Olympic Games in August 2008. Catastrophic air and water pollution has reduced life expectancy in Northern China by 5.5 years compared to the less-polluted South, with at least a million premature deaths annually, and the cost of pollution has been estimated at 12–15 per cent of GDP. Pressures to provide environmental public goods such as clean air and water, and restrain excessive polluting growth, are now growing, as basic consumption needs are met. However, the persistently low fossil fuel prices in international markets (driven, to a large extent, by the increase in global, unconventional, shale gas output by fracking), might delay the transition to renewable energy, at least in the absence of any meaningful carbon or pollution tax.

There are, of course, still major pressures for material growth, not least from the rapidly growing (albeit still relatively small) middle classes of the big developing countries. Average income per person in China (in terms of purchasing power), after three decades of fast economic growth, is still only about one sixth of its American equivalent. China still has only one car for 12 inhabitants, while the US has nearly 1.2 cars per person. Meat consumption has already reached two fifths of the US level, adding major strains to agriculture already threatened by growing water shortages, as we discussed in Chapter 3.

Just before the 2008 global recession, China's carbon emissions were growing by about 8 per cent annually, nearly as fast as the economy, suggesting that the country was making only slow progress in becoming more energy efficient. Since then, the government has set extensive industry targets for greater energy efficiency, and the annual growth rate in carbon emissions has approximately halved. Nevertheless, a new coal-fired power station is completed every week, and despite world-leading investment in renewable energy, total emissions could double in a decade without major policy changes.[7] At the same time, no one measures the

innumerable forms of local toxic air and water pollution or their growth, since most of them are illegal and unrecorded. Rampant corruption among local officials means that existing legislation for environmental protection is largely unenforced.

China already has the world's largest renewable generating capacity and plans to expand this to 15 per cent of power generation by 2020. China is also a leading producer and exporter of all kinds of renewable technology, and already has 60 per cent of the world's solar water-heating capacity. However, with most of its energy still coming from dirty coal and its positioning as the second largest consumer of oil globally, this is an entirely inadequate response to the country's own looming public health crisis, let alone to the threat of climate change. China's central planners also have the world's most ambitious plan to develop nuclear power, though in the West, at least, this is the most expensive form of energy supply, requiring large-scale government subsidies and guarantees for the few new units currently planned or under construction.[8] Just how long the Chinese central authorities can continue to inflict ever-worsening pollution on most of its population, as the price for material growth, remains to be seen.

The burgeoning middle classes who everywhere demand more cars and more meat are beginning to feel many of the environmental effects of these products in the form of congestion, pollution and food price inflation. Higher incomes and flight to the suburbs, traditional routes for prosperous individuals to escape the environmental consequences of economic growth, cannot avert the local and regional devastation being inflicted by old-fashioned, dirty technology throughout the developing world. The upsurge in fossil fuel prices between 2002 and 2008 (dictated by the traditional market forces of scarcity and surging demand for energy from emerging economies like China and India) provided a temporary glimpse of hope for a long-overdue change to cleaner technology, at the same time as imminent, and potentially devastating, public health and environmental problems were becoming increasingly political issues. While the Great Recession that started in 2008 might have undermined such a process of change by shifting attention away from longer-term environmental problems, tackling global warming and addressing a global recession should not be seen as competing goals, particularly when investment in greener technologies and infrastructure can provide the solution to high and persistent un- and under-employment.

It comes as no surprise that China's astounding takeoff dominates the international development debate (and fears of a possible slowdown cause global investors to panic!). China has achieved remarkable economic progress, with fast rates of GDP growth, large inflows of foreign direct investment, huge trade surpluses and drastic reductions in domestic poverty. Today, less than 10 per cent of the population lives below the $1 per day poverty line compared to 60 per cent in the late 1970s. Sustained economic growth has had enormous effects, not all of them positive, that have radically transformed Chinese economy and society within a generation. The Chinese development model gradually reduced the state sector and intervention in favour of private entrepreneurship, gave control of land to farmers and welcomed foreign direct investment. At the same time,

higher average consumption and improved literacy rates played a key role in reducing infant mortality rates and raising life expectancy at birth. However, 'diseases of civilization', such as diabetes, lung cancer and obesity, have increased dramatically with the spread of Western diet and pollution, and are likely to reduce life expectancy unless major policy changes are enforced.[9]

The Chinese development model has been widely praised for raising large numbers out of extreme poverty and improving living conditions for perhaps a majority of Chinese families, particularly in eastern provinces. While achievements on the poverty front are generally recognized, China's rapid industrial development has come at the expense of devastating air and water pollution and soil degradation. Economic growth has also generated rising inequality, with rural areas particularly in Western China lagging behind the booming urban centres of the East. The urban–rural income ratio increased from 1.8 in the early 1980s to 3.3 by 2006 (and has only slightly declined since then, still remaining above 3).[10] China now has the most unequal income distribution of all large developing countries except Brazil.

Recent research on measures of subjective well-being (SWB) also provides evidence of the costs of reckless economic growth and social disruption. Subjective happiness or life satisfaction for the average Chinese has not risen from 1990 to 2010, despite a fourfold increase in household income. Easterlin shows a similar *lack* of correlation between long-term growth of income and average life satisfaction in many developing, transition and developed countries, in spite of the positive cross-sectional relationship between income and life satisfaction for both individuals and countries.[11] As well as the importance of *relative* income, another reason may be that most of the benefits of growth have accrued to the highest earners in most countries in recent decades, while real incomes for most people have grown slowly or stagnated. This applies to both developing and developed countries; thus, in the US with its dramatic rise in inequality, 60 per cent of all male workers experienced *declining real hourly wages* from 1973 to 2012.[12] Global wealth inequality has increased even more rapidly than income inequality, with the world's wealthiest 1 per cent now owning nearly half of all wealth, while the richest 85 individuals own as much as the poorest half of the global population, or about 1 per cent of total assets.

The world keeps a close eye on Chinese developments in the economic and political sphere. China has approximately a fifth of the world's population, and globalization has linked the rest of the world with the Chinese economy. But it is certainly not only a matter of size. The Chinese development model is widely perceived as one of the most successful examples of recent economic development. This largely ignores the fact that China will have to pay an enormous price for its break-neck pace of development in terms of environmental degradation and future health costs. Less developed nations may be tempted to try to replicate the economic policies and development model of a country whose economy expanded six times in the course of 20 years. The allure of the Chinese model may put other developing nations on track to repeat its policy mistakes of inequitable and environmentally destructive industrialization.

China has gradually become not only a major recipient of foreign direct investment from developed nations, but also a key investor herself in other developing economies. There is increasing evidence, however, that Chinese foreign investors are less likely to comply with already insufficient international standards and norms on environmental protection and labour rights when compared to American and European investors. This is likely to instigate a race to the bottom in environmental standards for many developing countries, where domestic firms choose trading partners according to criteria of profit and cost effectiveness, and do not necessarily view environmental protection as an integral part of their corporate social responsibility.[13]

The impacts of climate change on the poor

The effects of global warming will be felt across the whole planet, but some regions will be hit harder than others. It is now widely acknowledged that the poorest nations and the poorest segments of their populations will bear the largest costs of climate change, interacting with already severe water shortages and pollution problems. Halting and reversing existing environmental degradation, as well as adapting to adverse new climatic conditions, is particularly difficult when resources are lacking and governments are corrupt and undemocratic. As usual, the poorest individuals in those 'bottom billion' countries are the worst equipped and the least prepared to cope with deteriorating environments and future complex climate change impacts.

In Chapter 3 we discussed in detail the devastating impact climate change is expected to have on agricultural productivity. Higher temperatures, increased frequency of droughts and floods, and growing water scarcity will all adversely affect agricultural production in vulnerable areas. In some regions in higher latitudes and temperate/continental climates, increased temperatures may extend growing seasons and allow more multiple cropping, but any positive impacts will be dominated by the threat of major droughts in hot and arid parts of the planet. The majority of the Earth's bottom billions live in these areas, and will experience the largest declines in agricultural productivity – and soaring food prices in consequence.

For most developing countries, with the exception of some mineral-rich nations, agriculture plays the dominant role in the economy. In many areas where agricultural productivity is expected to decline, the majority of the economically active population derives its livelihood from activities dependent on agriculture. In developed economies, by contrast, only a small fraction of the labour force is employed in the agricultural sector. Even in fast industrializing and urbanizing China, almost half of the vast population is still rural, and largely dependent on agriculture. The dramatic food price inflation that will follow any large-scale collapse of agriculture in major food growing areas, will of course also expose the urban poor to mass starvation, wherever the resources or political will to implement aid and redistribution are lacking.

The list of climate change impacts on the poorest billions is of course much longer and discussed in detail throughout the book. Increasing populations will exacerbate all those problems in the poorest countries with the highest birth rates. Rising sea levels will disrupt agriculture and pollute ground water in coastal areas and result in massive population migration. In hot environments, water scarcity, land degradation and food shortage may result in serious conflict over these ever-scarcer resources. Extreme weather events and intensified ocean acidification will have devastating effects on coral populations, the dependent marine life and human populations in nearby areas. Even before these effects become severe, most ocean fish stocks have been decimated by overfishing, and many are close to collapse.

Much attention has been given to the impact of rising temperatures on health and the spread of infectious diseases. As temperatures rise more in northern latitudes, warmer winters will bring some benefits, but many pests will also be able to spread and survive the cold season. In contrast, even moderate warming will have devastating health effects for many of the world's poorest billions living in tropical and semi-tropical regions.

For example, the spread of malaria is limited by temperature. In warmer conditions, malaria-carrying mosquitoes will spread more easily to areas north and south of the tropics, as well as into higher elevations.[14] Dengue fever, an infectious disease related to yellow fever, is also on the rise in many tropical climates. New and essentially untreatable infections, such as avian flu, antibiotic-resistant tuberculosis and a growing number of other infections, or the black stem wheat rust fungus Ug99, threaten human, animal and plant populations with increasing frequency, even without help from climate change. The health impacts of old and new epidemics, as well as of global warming, are magnified by modern mobility and transport. But as usual, the worst impact will be on the world's poorest nations and populations, where most households have little capacity to relocate or protect themselves, and public medical care is rudimentary.

Climate and conflict

Climate change is likely to have severe implications for future global security and state stability.[15] History has taught us that adverse environmental conditions often trigger conflict and social discord. The example of Easter Island is one of the most famous paradigms in human history, where deforestation, soil erosion and food scarcity led to a collapse of a whole civilization – by the early eighteenth century the population had fallen to almost a fifth of its peak level (approximately 15,000) a century earlier. While the collapse of the local population had nothing to do with climatic conditions (or any change in them), the Easter Island example is often used to exemplify the role of human-induced environmental stresses in determining human fate.

Recent data analysis has shown that climate change and conflict often go hand in hand – African nations that suffer from reduced precipitation (and corresponding food shortages) face a much higher risk of civil conflict.[16] Even the infamous genocide

in Rwanda, although exacerbated by ethnic tensions, was also largely motivated by adverse environmental conditions. Climate-induced food shortages often force local populations to seek land and livelihoods elsewhere. This creates frictions among groups (often divided along ethnic, linguistic or religious lines) who compete for the same land or water resources. In most cases, it is not only local climatic conditions and environmental pressures that cause conflict – their interaction with rapid population growth and weak governance, as is often the case in many of the fragile states found in the developing world, creates ideal conditions for conflict to erupt. The causal relationship between climate and conflict is also likely to be much more complex. While climate change may fuel conflict in fragile states, conflict itself is likely to further exacerbate exposure to climate change damage as a result of diverting precious limited resources (financial and other) away from climate adaptation.

To a certain extent, environmental migration can function as a suitable adaptation strategy to climate change, in the same way that economic migration often becomes an effective adaptation option in periods of economic crises. When climate-induced migration, however, reaches a large enough scale in already fragile states with degraded land and water resources, it is more likely to have a destabilizing effect. There can even be a domino effect where climate change (and corresponding food/water shortages) increases migration, which then fuels tensions and conflict that further exacerbate population displacement.

Individuals forced to migrate as a result of changes in climatic conditions (and subsequent desertification, sea level rise, disruption of seasonal weather patterns, etc.) are often referred to as climate refugees. The majority of studies place the expected number of climate refugees in the range of 150–200 million people by mid-century, though in the worst cases of large-scale crop failure the numbers could be many times higher.[17] Bangladesh, for example, is expected to lose almost a fifth of its land as a result of sea level rise and climate-induced flooding, while already in 1995, the permanent submergence of half of Bhola (Bangladesh's largest island) left half a million people homeless.

Naturally it is difficult to predict the exact scale of conflict that one could anticipate as a result of climatic change, given that environmental conditions are only one of the manifold factors that influence local stability. A recent publication in *Science* has attempted to put a number on what to expect. A rise in global temperature by 2°C could result in an increase of global conflict incidence by 15 per cent.[18] As with climate refugees, such estimates are again not very meaningful, ignoring the effects of possible major global famines in the future, due to growing water shortages and extreme weather events.

Development and sustainability as conflicting goals

Climate change, unless concerted effort takes place soon, will in effect be a tragedy of the global commons. We need to learn to manage our global footprint, not as

single independent nations, but rather by coordinating our actions. This applies most particularly to our carbon emissions as they accumulate in the atmosphere, irrespective of where they are emitted. Increased pollution by the large and fast-growing developing countries, especially China and India, can offset mitigation efforts by most other sovereign states.[19]

The problem with most developing nations is that the environment is not an overarching priority at this stage of their development. Many of the largest developing economies have been growing at 7–10 per cent annual rates, and are still unwilling to sacrifice economic growth for the sake of a global environmental good, or even for their own local environment and public health. A common argument from developing nations is that they are not to blame for most of the unprecedented increase of greenhouse gases in the atmosphere since pre-industrial times. Rich countries that built their previous successful economic development on natural resource exploitation, are responsible for most of the existing stock of GHGs, and hence should contribute most to clean-up costs and mitigation efforts.

The argument is, of course, valid to some extent (though increasingly undermined by devastating local pollution) and this is exactly the reason developing nations were given no binding targets for carbon emissions under the Kyoto Protocol. But is there any way we can take them on board in a concerted effort to constrain global emissions? It all boils down to what extent the environment and economic development remain conflicting goals for the developing world. We need to implement a development strategy that combines carbon management and environmental protection with healthy economic growth, to meet the concerns of the global South. Lower emissions and sustainable growth can be simultaneously attained with the right policies, market initiatives and interventions, as we explain in the following chapters.

Thinking on an empty stomach

Climate change mitigation should not be an exclusively top-down approach, relying on government agencies and international donors to take all the action against carbon emissions. Local communities and individuals have an important role to play in curbing global emissions by adopting environmentally friendly modes of agriculture and transportation, minimizing energy consumption at home, and putting pressure on their elected representatives to take action on environmental issues. Nevertheless, environmental awareness tends to be a rather exclusive prerogative of the small urban elites in most developing countries. Limited access to education for the world's bottom billions necessarily inhibits environmental awareness for the global poor. Governments often lack necessary funds for public investment in education, and poor households have more urgent and immediate survival needs than environmental quality and its usually less obvious and deferred benefits, let alone the longer-term threats of further, climate-enhanced degradation.

For these reasons, many of the world's poor are either unaware of climate change and its consequences, or have a rather partial and often distorted perception of the problem. A study conducted in Nairobi, Kenya, in 2007, examined local perceptions of climate change and concluded that global warming is generally not considered a significant problem, in contrast to corruption, unemployment, street crime, HIV/AIDS and poverty.[20] While farmers in the developing world are often aware of changes in temperatures and precipitation in recent years, they have very limited knowledge of the underlying causes.[21] The complexity of the climate change problem, the large uncertainties involved and relentless lobbying to discredit the relevant scientific evidence, all work against a wider public awareness of climate change. However, the increasing frequency and impact of extreme weather events may begin to change this perception in the near future – and in China at least, the severity of local air pollution episodes and resulting health problems has generated serious political discussion of the costs of coal-based growth.

There is also still widespread ignorance about the most basic scientific facts of climate change. Stratospheric ozone depletion is most commonly confused with global warming, although there is a long list of irrelevant responses in questionnaires, ranging from space exploration to acid rain. Even in highly developed nations, such as the US and the UK, close to a quarter of respondents regarded ozone depletion as the major cause of climate change in surveys conducted about ten years ago; while awareness on climate change issues has increased somewhat since then, still only a minority of respondents (in several surveys repeated annually) consider climate change as a major threat.[22]

Aid and technology transfers

The rich countries currently provide about 0.4 per cent of their total national incomes as development aid – and this is nearly twice the share of the lowest ranking (and richest) donor, the US. Leading development economist Jeffrey Sachs estimates that about 2.4 per cent of global GDP would be necessary to achieve all the Millennium Development Goals, and essentially a zero-carbon economy in two or three decades.[23] This is only about twice current US military expenditure or global fossil fuel subsidies, and is comparable to the amount spent on wasteful and perverse subsidies in the rich countries. For aid to be more effective than in the past, a larger flow would need much more careful monitoring to avoid diversion to corrupt governments and greedy multinationals. Sensible saving and redirection of public spending could thus essentially ensure a stable and sustainable future world. In the short term, the poorest countries would be the most direct beneficiaries, but from a longer-run perspective, the donor countries can only thus ensure their own future prosperity (and perhaps even survival) in a cooperating rather than collapsing international order (where the technological basis of biological and chemical weapons of mass destruction becomes increasingly accessible on the internet).

Much of the apparent conflict between growth and the environment in the developing countries arises from their reliance on outdated technology, instead of using the well-tried and -tested alternatives that are already available. These issues are discussed in detail in Chapter 9, but the point here is that these alternatives have largely been developed in the rich economies, with little effort to transfer or adapt the newer, cleaner technologies to the poor countries. There is thus a widespread misperception that environmental degradation today is the necessary price for economic growth and higher consumption in the future. There is also little awareness in developing countries of the health costs of current pollution (though this may be changing in the extreme conditions affecting big Chinese cities), and of how realistic accounting for mortality and morbidity would reveal huge social returns to environmental clean-up. Thus, the World Health Organization has recently doubled its estimates of mortality from air pollution to 7 million premature deaths in 2012, or 1 in 8 of all global deaths, mostly in South and South-East Asia.[24]

Western consumers benefit from cheap imports as long as wages and environmental, health and safety standards remain low in the developing economies. In the long run, these consumers will also suffer from the consequences of climate change for agricultural productivity. However, the poor nations remain the most vulnerable, and part of any serious aid effort (reinforced by self-interest) should provide support for the clean technologies that are already competitive with – or cheaper than – dirty coal. These include combined heat and power from smaller, decentralized generating units using biogas from bio-waste in appropriate areas, and modern wind turbines in suitable locations. Solar energy is already often the cheapest source in many off-grid rural regions. The rapid growth of a large-scale alternative energy sector in China offers an ideal partner for implementing the mass production and further cost reduction of these technologies, as well as the major new breakthroughs in solar energy coming from specialist companies.

It is widely recognized that one of the most cost-effective forms of aid for climate change mitigation and sustainability is to provide appropriate incentives for developing countries to stop tropical deforestation and biomass burning. Preserving biodiversity and other ecological services for future biotechnology and ecotourism in particular, as well as for their wider climate benefits and existence values, offers huge returns to modest investments. However, the enforcement of both existing laws and new agreements under pervasive corruption and pressures for short-term exploitation is fraught with problems. Cheap solar cookers can be manufactured locally and provide an economic alternative to domestic biomass burning – a major source of indoor air pollution (and deforestation) – and an inexpensive means to reduce carbon emissions in the poorest regions. The subsequent health benefits of removing indoor air pollution are much longer term than the immediate effects of providing clean water and sanitation (the lack of which is the major cause of child mortality), and hence tend to be neglected in spite of their very low cost.

To prevent carbon emissions and local pollution from industrial activities in developing countries on a larger scale, though, more funds will be needed from richer nations. Technologies that either improve energy efficiency or rely on

renewable resources need to be subsidized and transferred to developing markets, in cooperation with domestic policy initiatives, such as China's rapidly growing renewable energy sector. In time, learning-by-doing will render the new technologies competitive without the support of external funding. In the meantime, rich countries should provide financial assistance (either directly or via the Green Development Fund and Clean Development Mechanism we discuss later in Chapter 7) to achieve carbon reductions in the developing world. Currently, the World Bank claims to be a key player in financing clean energy transitions (with its Prototype Carbon Fund and more recent Climate Investment Funds) aiming at transferring technologies and know-how that reduce carbon emissions in developing economies. Although a step in the right direction, the World Bank unfortunately still remains a large underwriter of fossil fuel energy projects in many parts of the developing world, hence playing a counterproductive role in the dissemination and adoption of greener technologies.

On a more positive note, many donor governments have started allocating a larger share of their aid towards activities that fund climate change mitigation (and adaptation to a lesser extent). Japan and Germany allocated the largest share of aid to climate change mitigation (an average of 12.5 and 11 per cent respectively for the 2002–2009 period). For the major donors, the overall share has increased from a mediocre 1 per cent in 2001 to above 5 per cent by 2009.[25]

While this trend might be welcomed by many, there have been parallel concerns about a possible diversion of resources from poverty alleviation (which is often considered to be the primary objective of development assistance).[26] Naturally the synergies found in several types of climate mitigation activities ease some of these tensions (as in the case of no-tillage farming that can benefit both carbon sequestration as well as rural livelihoods). The time dimension is also of paramount importance when reflecting on these issues. While the key objective of climate aid is to reduce carbon concentrations in the atmosphere, it will also prevent a rise in poverty *in the longer run* as a result of climate change impacts on developing countries. While almost everyone acknowledges this, the challenge here is to provide generous climate aid that complements rather than decreases the volume of aid that aims at more *short-term* poverty relief. Even in the presence of synergies between poverty alleviation and GHG mitigation, certain climate-related projects are likely to be less efficient in reducing poverty compared to other projects that are explicitly dedicated to this objective. In the *very short term*, a few climate-related projects might even conflict with the objective of poverty alleviation – for example, land use changes in the case of afforestation or dams can at least temporarily disrupt local economic activities for the poor, even if the same people affected benefit in the longer term.

The geographic distribution of climate aid also suggests that it is often the middle-income countries rather than the poorest ones who receive the majority of the funds. This might not come as a surprise given that middle-income developing countries (in comparison to low-income economies) have a larger potential for emission reductions, given their heavier reliance on industry. For

example, while sub-Saharan Africa receives approximately 20 per cent of overall poverty-related aid, it receives less than 5 per cent of aid for climate mitigation.

A last concern relates to the potential perverse effect that climate aid can have on the domestic mitigation efforts of recipient countries. Currently, developing countries do not face any concrete targets in terms of GHG reductions. The prospect of receiving aid to mitigate carbon emissions could reduce domestic incentives for green public investment, given that governments in developing countries might expect that this will be funded anyhow with the help of external aid. Even worse, it might even incentivize carbon-intensive activities, given that these offer future potential for international transfers in the form of climate aid.

Transportation

Worldwide, transport accounts for about 14 per cent of total carbon emissions, nearly as much as deforestation. The share of the developing countries is rising rapidly, and as with other technologies, they seem determined to imitate the most destructive aspects of earlier, Western urban development. Car and oil lobbies have helped to generally suppress the alternative model of urban planning based on public transport and cycling, which has been spectacularly successful in at least one developing city, Curitiba in Brazil. China initially promoted the use of bicycles as the main urban transport mode, and some 500 million bicycles provided unprecedented mobility by the 1980s. But the subsequent switch to priority for cars has exacerbated already appalling air pollution and traffic congestion, and displaced bicycles, which are often perceived by middle-class drivers as obstacles to 'progress'.

Growing political awareness of these problems (initially aided perhaps by the Beijing Olympics and the Chinese authorities' intention to restrict motorized traffic prior to the Games), has triggered the beginnings of an interesting U-turn in the shape of the e-bicycle. This has a rechargeable battery to power a light electric motor, providing an economical and clean, powered transport option. Restrictions on driving to reduce air pollution in urban centres can rapidly increase its demand (and China alone is already producing more than 30 million e-bikes annually, with restrictions on conventional motorcycle use implemented in several major cities).

Curitiba has been at the same time a remarkable and rare example of green and integrated urban development in a developing country, of immense importance and relevance for the rest of the world. Surprisingly, only Colombia's capital city, Bogotá, seems to have taken some steps in this direction. Conspicuous failure to replicate the enormous welfare and environmental benefits of this model more widely is difficult to explain. Curitiba does seem to have features of a historical accident, owing much to a talented town planner, Jaime Lerner, who founded the Urban Planning Institute of Curitiba (IPPUC), and then became long-term mayor of this rapidly growing city in the 1970s and 1980s. He finally became Governor of the State of Paraná, and recipient of innumerable international honours and awards.

The integrated, green development of Curitiba has accommodated above-average population growth for decades, with a population now reaching 1.8 million. There are several key elements for this successful experiment in the developing world. Much of the central area is pedestrianized, combining high-quality residential and commercial use. Main routes are served by frequent, cheap and fast buses (running on biodiesel) on dedicated lanes, with convenient, covered stops for rapid access and exit. Cycling is encouraged by 200 kilometres of cycle tracks, and about one fifth of the city area has been converted to green parkland. Though car ownership is relatively high, car use and air pollution are lower than in any other Brazilian city, while the share of public transport is much greater, accounting for 75 per cent of weekday commuting. No less than 70 per cent of the garbage is recycled. The most remarkable statistics are reported by environmental writer Bill McKibben: 'In a recent survey, 60 percent of New Yorkers wanted to leave their rich and cosmopolitan city; 99 percent of Curitibans told pollsters that they were happy with their town; and 70 percent of the residents of Sao Paulo said they thought life would be better in Curitiba'.[27]

It is, of course, much more difficult to implement integrated green planning in the megacities that have become environmental disasters after decades of domination by the dirtiest technologies, for the sake of private profit and at the expense of public health. Curitiba had the huge advantage of starting on the right track as a relatively small city. However, the urgency of change grows with the costs of congestion and damage to health and welfare. The newest technologies of hybrid buses, electric light rail and e-bikes offer major further environmental benefits and cost savings as fuel prices rise, and the incentives for change are greatest in the poorest countries that can least afford extravagant use of energy. But these innovations will be much more rapidly adopted under appropriate planning that provides dedicated road space for clean and public transport, and extended pedestrian areas.

Deforestation

There is an urgent need to slow down and finally halt deforestation in tropical and semi-tropical countries. Forest clearance – particularly in Brazil, which has the largest forest cover globally – has reached unprecedented levels in recent years and accounts for perhaps a fifth of our carbon footprint. While difficult to measure precisely, probably around 15 million hectares annually suffer degradation and destruction, largely driven by slash-and-burn farming, global demand for timber, and increasingly by biofuel production that requires forest clearance for palm oil and sugar cane plantations, particularly in Indonesia and Brazil. Similarly, changing consumer habits in China and other fast-developing countries exert pressure to convert forest into farmland, for meat and soy production for their expanding, middle-income populations. Perhaps half the original mature tropical forest has been lost in the past 50 years.[28]

Much of this destruction is illegal, and facilitated by corrupt local officials. Interestingly, though, well-defined property rights protection and alternative economic incentives could decrease the current rate of deforestation in the Amazon and other tropical regions rather inexpensively with appropriate government commitment. In tropical regions, forest clearance creates grazing or crop land of low quality that is quickly exhausted and abandoned. Small economic incentives, either in the form of a 'payment for environmental service' scheme by developed countries or ecotourism charges, could easily create attractive, alternative and sustainable livelihoods for local communities.[29]

The causal links between global warming and deforestation are certainly complex and climate change is also expected to have direct impacts on forest cover. Reduced rainfall, increased frequency of droughts and higher temperatures will result in recurrent and extensive forest fires. Forest fires also release stored carbon back into the atmosphere, further enhancing the greenhouse effect. This is partially compensated by a northward migration of forests, as northern colder latitudes gradually become more suitable for tree growth. However, this is a slow process, while deforestation and forest fires are already accelerating at an alarming rate. Tropical rainforest also contains much of the world's biodiversity, with many species not yet discovered, let alone studied – an irreplaceable and essential resource for future medication and biotechnology that is rapidly being destroyed.

Constraining population growth needs to be an integral element of any successful strategy to curb global deforestation. There has been a tenfold increase in global population in the last three centuries, with another 2 billion people expected by mid-century on present trends, and enormous pressure to clear land for crops and pasture. Fast-expanding GDP levels and consumer habits have all contributed to the current unsustainable rates of deforestation, with China in particular importing rapidly increasing quantities of tropical hardwood and soy beans. Providing tradable carbon credits for reforestation and conservation projects can create the right incentives, but the market price for such credits would need to exceed the monetary benefits from deforestation (which increase with food prices and global demand for hardwood).

Multinationals and the poor

While globalization interconnects the world with increased trade, capital movement and migration, it also opens up new markets to the rich-world multinational corporations. Multinational firms already play an increasing role in developing countries' economies, particularly through foreign direct investment (FDI). China, Mexico and Brazil are some of the major recipients of foreign investment, with multinational corporations now taking advantage of their export-processing zones and low labour costs. In China alone, FDI amounted to $118 billion in 2013.

While multinationals create numerous job opportunities in some of the world's poorest regions, they are by no means philanthropic foundations. They are widely

criticized for their overarching priorities – maximizing shareholder value or corporate profits, minimizing wages, and creating rapidly rising rewards for top managers – often at the cost of local communities' livelihoods, environmental degradation and other externalities. They often seek pollution havens, where they can initiate production without incurring the costs of environmental regulation. Multinational corporations often supply products that have been manufactured with environmentally unsustainable methods (and unethical practices including child labour, hazardous working conditions and failure to share profits with local communities). And lack of transparency suggests that consumers are still largely unaware of how products ending up in their homes are manufactured thousands of miles away.

The gradual removal of capital controls has allowed foreign direct investment to exit a recipient country as easily as it entered. Acquiring assets in a foreign economy may be costly for multinational companies, and it is not to their interest to relocate shortly after initial investments. But ultimately, multinationals are searching for ways to escape trade tariffs, taxes and regulatory fees, as well as minimize production costs. If opportunities that appear to be more profitable for their shareholders arise in due time, they may relocate their activities, whatever the cost to their former host communities. This also challenges the effectiveness of agreements such as the Kyoto Protocol in curbing carbon emissions in Annex-I industrialized nations, if carbon-intensive production is gradually displaced to China or other countries with looser environmental regulations.[30]

Nobel Laureate Joseph Stiglitz has severely criticized the role of multinational corporations, and their support by the rich countries, in the economic development of many of the world's poorest nations.[31] Governments in these countries have little bargaining power to negotiate with multinational firms and their highly skilled corporate lawyers. Multinationals generally exaggerate any positive side-effects their activities may have on both the local – and national – economy. They tend to stress the importance of their operations on local employment and infrastructure, while largely downplaying the huge environmental costs their activities frequently impose. These externalities range from river and ground water pollution, deforestation, soil erosion and carbon emissions, and often ruin the livelihoods of surrounding resource-dependent communities. In very few cases are clauses incorporated in FDI agreements that subject multinational corporations to strict environmental regulation and standards, and penalties for non-compliance.

Certainly multinationals are not the only parties at fault. Bribery paves the way for agreements that explicitly ignore environmental impacts. Extensive corruption among (often poorly paid) public officials suggests that the pursuit of private benefit often takes priority over public duties, social welfare and the environment. Bribes entice public officials and politicians to protect multinationals from whatever environmental regulations may exist, and to block any more stringent constraints. Governments in richer nations and the managers of large corporations have for many years engaged in non-transparent transactions, widely treating bribes as facilitating fees rather than an illegal practice. The stakes are often too high for the voices of local communities and activists to be heard.

In recent years, there has been mounting pressure on multinational corporations to take action on environmental issues. Consumers increasingly demand greater transparency and more detailed information on the production methods and consequences behind the commodities they purchase. Multinationals have been forced to take some action for fear of losing consumer support. It often appears that multinational corporations voluntarily take actions that protect the interests of their employees, local communities and surrounding environment. In most cases, such corporate social responsibility (CSR) is directly or indirectly the result of activism and campaigning by organized consumer groups. Ethical consumerism is on the rise and customers are increasingly aware of the social and environmental implications of their purchase choices. The recent success of fair trade and ecolabelling schemes reveals that things are changing, even if slowly.

Corporate social responsibility may be driven by other forces as well. Shareholders increasingly scrutinize decisions taken by firms, and try to cooperate with management. Some shareholders and consumers are also putting pressure on firms to invest according to CSR and strike a balance between financial returns to shareholders and social welfare. Pressure does not need to come exclusively from owners or consumers. Co-determination in Germany involves employee representatives taking an active role in the company's management. Together with trade unions, they usually cooperate with management on a range of decisions, and exercise the right to be informed on important corporate issues. Employee involvement in works councils and corporate boards may result in more socially equitable and environmentally friendly policies. However, while employees and their unions have an active stake in corporate decisions that affect local pollution and working conditions, they are likely to be less concerned about global pollution and carbon emissions.[32] In any case, as environmentalist James Speth and many others have argued, large corporations and multinationals should not be allowed to exercise their often substantial market power for the exclusive benefit of distant shareholders and top managers without social accountability.[33]

Fair or free trade?

In our ever more interconnected, global economy, the exchange and mobility of commodities, technologies, funds, labour, ideas and pollution have been increasing rapidly. Many observers – Stiglitz being one of the most prominent advocates – have shown that the rules of the game are far from fair, and the economic benefits of globalization are distributed quite unevenly. As we discussed earlier, multinationals play a major role in this process, but they are not solely to blame. Governments of developed nations and their international agencies are also largely responsible for shaping international policies that place poorer countries at a disadvantage. Development economist Ha-Joon Chang from the University of Cambridge calls them the 'bad Samaritans' in international policy; that is, international agencies and governments that adopt double standards by forcing specific free-market and

free-trade policies on poor countries that are often painful and ill planned, and prevent new competitors from emerging in particular sectors. Where the irony lies is in the fact that the rich countries preaching 'laissez-faire economics' largely resorted to the exact opposite policies of protectionism and regulation to support their initial phases of industrialization. In effect, some industrialized nations appear to 'kick away the ladder' by prescribing the opposite policies that led to their own economic success in the past.

There is a big difference between unconditionally free and conditionally freer trade, and industrial nations have been so far much opposed to opening up trade to sectors they consider vulnerable to foreign competition (and sensitive for domestic voters). One of the most blatant examples of such unfair, asymmetric trading has been the Common Agricultural Policy (CAP) of the European Union. Around 40 per cent of the current EU budget is misused for wasteful agricultural subsidies and programmes. This makes it harder for farmers in developing nations to compete with heavily subsidized and tariff-free European commodities (although environmental taxes, rather than trade tariffs, should actually be imposed to reflect the environmental cost of transportation from remote regions, even if this disadvantages farmers in poorer countries to a certain extent). At the same time, public funds that should be available for educational programmes, research and development initiatives, conservation agriculture and environmental protection, are captured mainly by a minority of the largest and wealthiest farmers and landowners.

Globalized trade usually opens up markets in developing countries to products from industrialized nations. At the same time, these rich countries, and the international organizations they dominate, have blocked access by poor countries to their own markets, and obstructed their development with unfair conditions. They largely fail to recognize that the poorer nations' infant industries require at least short- to medium-term financial support (through tariffs and subsidies) in order to attain maturity and compete with long-established foreign companies in richer economies. Governments in industrial nations generally impose higher tariffs on processed imports rather than raw materials, thus discouraging the development of manufacturing in the poorer nations. They generally preach elimination of trade barriers, but maintain generous subsidies for their own rich farmers and agricultural products, which place millions of poor farmers in the developing countries at a major disadvantage.

The very fact that tariffs and subsidies are mainly eliminated for manufactured goods rather than agricultural commodities and textiles produced by developing nations, reflects the weak bargaining power of the latter in trade negotiations and their smaller representation in international organizations. Industrial nations and international bodies need to recognize that developing countries require assistance rather than discrimination. They need greater access to markets for their agricultural products, liberalization of unskilled labour intensive sectors and less restriction on labour mobility. As long as developed nations control the trade agenda and largely determine the outcomes of negotiations, globalization will remain a largely uneven playing field for poorer nations.

This is not to say that globalization cannot assist the development process of poorer nations. When trade liberalization is accompanied by government support and redistribution of income from those who gain from trade to those who lose, economic progress is likely to follow. However, many countries in the developing world, and particularly the weakest states of sub-Saharan Africa, have little infrastructure, feeble flows of foreign direct investment and inefficient or corrupt political institutions inherited from their colonial history. These countries seem unable to help their local producers take advantage of the new opportunities that arise from trade.

An ominous new development is in the form of secretive trade agreements, such as the Transatlantic Trade and Investment Partnership (TTIP), being pushed by President Obama, which would give corporate interests unprecedented powers to take legal action against sovereign states for any regulations, such as health or safety, that reduced expected profits in future. The TTIP negotiations have been taking place in a general climate of distrust after repeated revelations about US intelligence surveillance of EU citizens and politicians. The TTIP agreement can potentially compromise important public health protections, including food safety regulation and access to essential medicine.[34]

Poor governance

Many developing countries suffer from extensive corruption, weak property rights and malfunctioning government institutions. Of course, weak governance and corruption are problems everywhere, although often more pervasive and frequent in the developing world. In poor countries with chronically underpaid government employees, the misuse of public office for private gain is widespread. Patronage, nepotism and bribery have been a development curse for many of the world's poorest nations. Although much malpractice in developing countries is covered up in the absence of effective democracy and independent media, some cases have been widely reported, although often in the aftermath of the events. The former Congolese dictator Mobutu Sese Seko and Indonesian President Suharto embezzled many billions of dollars during their more than 30 years in power, while brutally suppressing human rights with the full support of Western powers, and the US in particular.

Corruption, especially, has been closely linked to poor environmental management and environmental degradation. Governments in the developing world tend to neglect long-term environmental problems, maintaining ill-defined property rights, weak regulation and unsustainable resource use. Inefficiency in public administration is exacerbated by insufficient resources (lack of expertise, infrastructure and equipment). But this is only part of the story. Much of current and widespread illegal logging, hunting that threatens endangered species, non-compliance of companies with whatever environmental standards there are in place, and tax evasion, are the result of corrupt practices by governments and their officials in developing countries.[35]

Frequent economic scandals demonstrate how public officials often fail to make decisions in the public interest. Governments under-invest in the provision of environmental assets (and other public goods), and instead allocate a large share of public funds to subsidies for private goods and large corporations, to benefit a wealthy minority of vested interests. Generous tax rebates and indirect subsidies for powerful corporations do not help either, as they are in effect foregone government revenues and therefore reduce the overall public budget. As we discuss in Chapter 6, such mismanagement is likely to be worse in ethnically fragmented countries, where governments often neglect the rights of minorities.

Country-specific examples abound. In many developing countries, Brazil and Indonesia in particular, logging companies regularly violate existing environmental legislation and quotas with impunity by bribing local officials, with the companies themselves often being directly controlled by government members.[36] These countries suffer the greatest extent of tropical deforestation as a result of this extensive corruption, and, in consequence, imported timber at European or American ports of entry often exceeds the exported amount declared at the country of origin.

The consequences of corruption and poor governance extend beyond environmental protection and sustainable resource use. Poorer nations that suffer from weak governance and institutions also forego economic development as a consequence. In other words, unless they find the means and political strength to address issues of corruption and malpractice, they are likely to find themselves in a prolonged poverty trap. Inefficient institutions generally pose severe obstacles to a country's economic development, entrepreneurship and investment. Foreign investors are deterred, while bureaucracy and bribery increase costs and prices, and public revenues disappear into the pockets of government administrators or are squandered on inefficient investments with very low returns. While developed economies could invest in several projects that reduce emissions in sub-Saharan Africa as an alternative to more expensive emission reductions at home (via the Clean Development Mechanism, which we discuss in Chapter 7), Western investors become extremely frustrated by the high levels of corruption and poor complementary infrastructure.[37] Paul Collier, in his much-acclaimed book *The Bottom Billion*, identifies bad governance and corruption as one of the major four underdevelopment traps for the world's poorest populations (along with conflict, natural resource mismanagement and landlockedness).[38]

Mismanagement appears to be particularly insidious in many mineral-rich economies, where resource rents are highly concentrated and hence easily captured by corrupt officials and governments. Many other factors influence the extent of government dysfunction and general economic mismanagement.[39] Culture, religion, and openness to trade all play a role in explaining differences in governance. Countries open to trade, and with a long history of British rule and Protestant traditions, appear to tackle corruption more effectively than others. Income per capita complements the list of explanatory variables. Richer countries enjoy more transparency, a cleaner environment and better governance, because they have

more resources to supply these public goods, and face greater demand for them by populations whose more immediate, basic needs have been satisfied.

It would be at least hypocritical and decidedly unfair to focus exclusively on developing nations, and only blame home-grown corruption and poor governance for their socio-economic and environmental ills. After all, bribes are determined by demand and supply, as in any other market. Public officials and firms in developing countries demand bribes, when their negotiating partners in 'developed' nations are equally eager to supply them. Western governments often criticize developing nations for their lack of democracy, political instability and continuous conflict, while their arms industries and mineral firms benefit from trade with repressive regimes. The trade in uncertified 'blood diamonds' from conflict areas and unsustainably harvested tropical timber has been largely tolerated if not encouraged by Western nations. Similarly, governments in developed nations criticize developing countries for inadequate environmental policies, while their own multinational corporations impose environmental damage in the remotest parts of the planet.

Western governments are far from committed to transparency and accountability, as their ongoing support of the most notorious tax havens embarrassingly reveals. These offshore tax havens, such as the Channel Islands and Liechtenstein, help to divert hundreds of billions of dollars annually from developing countries, money that could have boosted public spending in many of the world's poorest economies. Most of Britain's overseas territories are tax havens, and as George Monbiot puts it, 'The obvious conclusion is that Britain retains these colonies for one purpose: to help banks, corporations and the ultra-rich to avoid tax.'[40] Britain has campaigned against international attempts to eradicate tax evasion, even while such tax havens are often used for money laundering and terrorist financing, without disclosing information to protect business confidentiality.[41]

Public goods and their underprovision

One of the fundamental roles of government is to provide public goods that are undersupplied by the private sector, when appropriate markets, say for clean air, do not exist. Similarly, necessities such as safe drinking water, primary education or medical care may be too expensive for the poorest classes when they are 'privatized'. However, governments in the least developed countries usually fail to fulfil this basic obligation. They often misuse public resources (by allocating them to projects with low returns, or appropriating them for personal benefit),[42] and are generally constrained by both poverty – which is exacerbated by policies of the rich nations and corporations – and by the lobbying power of the latter. Without sound public policies, there is always serious underinvestment in education and environmental protection. Social returns to investment in education, health and environmental assets in developing countries exceed private sector returns to most investment. Of course, such investment also provides non-pecuniary benefits to health and overall welfare that are difficult to quantify in monetary terms, but no less important.

Ramón López of the University of Maryland provides a long list of cases where the provision of underfunded public goods yields much higher pecuniary returns than private sector investment, in addition to intangible benefits.[43] Of course, the provision of public goods should not be guided by comparing pecuniary rates of returns alone. But in many developing countries there is such extreme underinvestment in environmental and human (education and health) assets, that large benefits can be anticipated with minimal increases in public spending. Additional enrolment in primary schooling or some small investment in sewage treatment or pollution abatement in ecologically distressed areas will yield large future benefits in terms of income opportunities, lower mortality and improved health.

At national level, development from a low-income economy to a middle-income emerging market (with average income increasing from a few hundred dollars per person to a few thousand) requires only modest public investment in infrastructure, primary and secondary education, and environmental quality. In contrast, Jeffrey Sachs argues that transition to high-income status requires major policy interventions and public investment as prerequisites. These include widespread tertiary education (30 per cent of the relevant age group), generous public funding of research and development (at least 1 per cent of GDP), and adequate investment in telecommunications and information technology. At the same time, climate change is expected to undermine the capacity of states to provide these productive opportunities that sustain livelihoods, as a result of foregone production, public revenues and increased cost of public infrastructure.[44]

Governments in the world's poorest nations struggle to finance even the most basic public investment in local infrastructure (power grids, transportation network, effective ports), universal primary education and access to health care (family planning, improved sanitation, safe drinking water, maternity care, malaria protection). Sub-Saharan Africa's lack of sufficient public investment is sometimes attributed to former colonial rule and priority for short-term extraction policies over long-run development planning, as well as inadequate or misdirected aid. The result has been zero or negative income growth for some of the fastest-growing populations, and the world's worst development record.

While cereal yields (tonnes per hectare) have more than tripled in the developing world between 1960 and 2015, they have remained largely stagnant for sub-Saharan Africa. Since the green revolution inflicted huge environmental costs, there is an urgent need – and potential – for *sustainable* agricultural improvement everywhere, as discussed in Chapter 3. Similarly, inexpensive provision of mosquito bed nets and indoor insecticide spraying can dramatically reduce the incidence of malaria. Public investment in education yields high rates of return by increasing labour productivity, empowering women, reducing birth rates and mortality, and improving health. In sub-Sahara Africa only 75 per cent of children are enrolled in primary school, while the private rate of return to primary education is estimated to be three times higher than the average rate in the OECD countries, where primary schooling is universal.

The World Bank and the IMF: good prescriptions or bad advice?

There is another explanation why public goods are particularly undersupplied in developing countries. Ramón López links the underfunding of environmental assets and other public services to the structural adjustment pursued in many developing countries, under the auspices of the International Monetary Fund and the World Bank (see also the concluding Chapter 10, which touches upon similar issues but with a closer focus on the effects of IMF–EU imposed austerity on European economies).[45] Neoliberal policies advocated by the two sister organizations put much emphasis on trade liberalization, elimination of price controls and privatization of public enterprises, with little attention to the provision of public goods or the distribution of income and wealth. Governments were regularly encouraged to cut public spending and reduce budget deficits, without consideration of the environment, or the distributional effects of major price increases for privatized utility services.

As we discussed above, cuts in public spending (generally a precondition for financial aid by the World Bank and the International Monetary Fund) face only limited resistance from the public, since the initial impact may be small. Underfunded protection for tropical rainforest and reduced environmental subsidies and programmes may hardly be noticed in the short run. However, any attempt to decrease subsidies to powerful corporations usually faces fierce resistance from well-organized interest groups. For that reason, public transport has been widely neglected, while middle-class motorists are subsidized in various ways. Obviously, such policies exert multiple environmental damages by increasing carbon emissions, local pollution and traffic congestion.

Trade liberalization also imposes additional restraints on public spending. For many governments in developing countries, tariffs and duties on imports are the easiest way to collect revenues. Governments eliminate tariffs without developing a sophisticated Value Added Tax (VAT) system as an alternative source of public revenues. Again, as public budgets are constrained, public goods and environmental programmes suffer.

Conclusions

Any discussion of climate change would be incomplete without devoting sufficient space to the particularities of developing nations. People living in extreme poverty with less than a dollar (or two) per day are highly vulnerable to even small external shocks that may affect their everyday production activities and living conditions. The urban poor spend most of their meagre incomes on food, and therefore they are the hardest hit by food price hikes. Lack of savings and limited support from the state make these people unable to hedge against risks that disrupt their livelihood security. Climate change will simply reinforce this existing vulnerability of

the poorest nations, where individuals, communities and governments have few if any resources to adapt to (let alone prevent) global warming. Addressing their increasing vulnerability to a climate change catastrophe requires us to take a step back and evaluate these domestic and external conditions that have exposed the poorest countries to extreme poverty and environmental degradation, even long before the threat of global warming was recognized.

In a speech to the UN Commission on Sustainable Development in 2007, the UN Secretary-General Ban Ki-moon said: 'Energy, climate change, industrial development and air pollution are critical items on the international agenda. Addressing them in unison creates many win–win opportunities and is crucial for sustainable development.' Economic development and sustainability should not be seen as conflicting objectives, particularly since the dramatic decline in the cost of solar energy in recent years, and growing recognition of the potential of conservation agriculture. Technology and aid transfers from richer nations should help developing countries embark on a development path of green and sustainable economic growth. Yet China has become by far the biggest emitter of greenhouse gases, and like other big developing countries continues to expand the use of dirty coal and polluting vehicles, even as public unrest over catastrophic air pollution grows.

The world's poor will bear the largest cost of global warming, as agricultural collapse and water scarcity lead to mass starvation and rise in infectious diseases. Yet many of the world's poor are still unaware of the imminent global warming threat and consequences. While green investment could provide multiple environmental and health benefits, as the successful urban development of Curitiba in Brazil or Costa Rica's domination of the Happy Planet Index demonstrate, such initiatives require strong support and public investment by well-functioning transparent governments. Unfortunately, poor governance, corruption and weak property rights in most of the developing world all contribute to accelerating deforestation and pollution, chaotic urban planning, and underprovision of public goods that mostly affect the poor.

However, it is easy to point the finger at weak governments and corrupt politicians in developing countries. Much of the unsustainable use of local and global environmental resources is a direct result of Western rampant consumerism and the relentless pursuit of profit by multinational corporations and their executives. Western governments have blatantly imposed rules on developing nations to benefit their wealthy corporations rather than fair trade, with little concern for the impacts on local communities and their environmental assets. The urgent environmental and development challenges we face in our global village require coordinated efforts both by developed and developing partners, in the interests of their populations rather than the global plutocracies and their profits.

Notes

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5 This argument has been extensively used (and misused) by the previous US administration in order to justify the decision to abstain from the Kyoto Protocol. The Bush Administration objected to China and India being exempted from Kyoto requirements, as these countries are two of the world's top greenhouse gas emitters. The Americans preferred to opt out of the treaty rather than participate and actively assist developing nations in reducing their carbon emissions (by transferring greener technologies and funds).
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6

ETHICS AND CLIMATE CHANGE

Ethics of climate change for today and tomorrow

Climate change does not affect everyone on our planet in the same way. It is well known that the poorest people in the poorest countries – mainly in semi-tropical and tropical regions – bear by far the greatest risk from global warming. Most of the GHGs have been produced by the rich developed economies of the North, which may even benefit initially from climate change, and this raises important ethical considerations about the distribution of damages.[1] The disproportionate burden of future warming on poorer regions (and poorer people within countries) is exacerbated by the current injustice of extreme poverty for much of the world's population in the most threatened countries. This poverty is likely to persist as rich minorities continue to capture most of the gains from economic growth, and suggests that affected populations will not have the resources to survive agricultural collapse or rapid sea level rise resulting from climate change without outside help.

An additional ethical problem arises from the fact that the current build-up of greenhouse gases in the atmosphere will have its greatest impact on future generations, adding an *intergenerational* ethical dimension to the climate change debate. Furthermore, the poorest regions today are likely to be the worst victims of unconstrained global warming in the future. While everyone tries to ensure the survival and welfare of their own children, the billions who currently survive at subsistence level have no spare resources to save or invest in 'insurance' for the uncertain future. The developed countries have hitherto failed to alleviate poverty in the developing world, and they continue to threaten the survival of the children of the poorest in a world that will be ravaged by the consequences of their own extravagant consumption. In attempting to catch up with the West, the fastest-growing developing country – China – has been reducing poverty, but also devastating its environment – and it now produces 50 per cent more emissions than the US (though much less per capita).

As we developed in Chapter 3, the greatest threat from global warming in the medium term is to food production in already hot and arid regions, including Northern China, and much of India and Africa.[2] Rising temperatures and

more frequent droughts in these areas will interact with current trends and consequences of industrial agriculture, to exacerbate erosion, desertification, and growing shortages of water for irrigation and industry. These developments are likely to dramatically reduce the yields of high-input modern varieties as well as accelerate the loss of agricultural land. As we discuss further in Chapter 10, there are many practical measures that could avert these risks at low cost, but as yet no political commitment except to inadequate targets without policies.

Major food shortages and price rises would condemn billions of the world's poorest people to starvation – a scale of disaster that is difficult to imagine today. Precisely this difficulty is blocking the rich nations from assuming the moral responsibility for averting this risk of disaster from the poorest or their descendents in the future. While northern countries may benefit directly from warming, they are unlikely to escape the consequences of a collapsing global economy and mass starvation in nuclear-armed but dysfunctional nations such as Pakistan, or even India. Selfish concern for our own children should thus support the ethics of caring for our poorest neighbours and their children, and all the coming generations who are unrepresented in current lobbying and political decision making. Edward Page stresses the merits of what he calls a 'global sufficientarian ethic', where 'as many persons as possible should enjoy a satisfactory level of well-being regardless of when or where they live'.[3]

This chapter explains these complex interactions between ethical, economic and scientific aspects of global warming. Economics as a social science cannot be value-free like physics or chemistry, despite claims to the contrary. Economists not only try to understand how economies function, but also try to design policies to increase their conception of 'welfare'. Ethical assumptions and values, regarding what is desirable and what is not, are a central feature of much economic analysis, though not always made explicit. In that context, economists approach problems in a way that reflects (or should reflect) the generally agreed value premises of society. The traditional neoclassical approach to economics has often ignored distributional impacts on the poor and on future generations, and the resulting neoliberal policy focus on a narrow concept of 'efficiency' and aggregate economic performance in terms of GDP (while neglecting life-satisfaction) has dominated current thinking on the economics of climate change. However, there is growing criticism that existing cost–benefit analyses of climate change are fundamentally flawed, a point we develop in Chapter 9.

Economics and utilitarianism

The utilitarian philosophers and economists of the eighteenth and nineteenth centuries (such as Jeremy Bentham and John Stuart Mill) argued that the ultimate goal of all activity should be to maximize the sum total of human welfare or happiness.[4] They saw no intrinsic value in other forms of life or the environment, let alone 'rights' for non-human animals. The neoclassical economics that followed

essentially identified welfare with consumption, which could include the use of environmental services or animals, though without any regard for their welfare. Only more recently has it become clear that happiness depends on much more than consumption, once basic needs have been met (as discussed in Chapter 4).

Even the early economists did recognize clearly that additional consumption would generally be less important for a wealthy individual than for a poor person. This observation provides strong support for the idea of redistributing income or wealth from the rich to the poor, in order to maximize the sum of all individual welfare levels – the utilitarian goal. It is thus ironic that, as income inequality increases everywhere under globalization and unfettered capitalism, there is less concern with redistribution than ever before. Instead, the priority is to lower taxes for the rich to avoid capital and corporate 'flight', and to reduce wages and benefits for the poor to save jobs from outsourcing. International efforts to alleviate poverty also make little headway, while the US spends just 0.19 percent of its GDP on (often ineffective) aid for the poorest countries, and smaller states are only slightly more generous.

The utilitarian goal of maximizing total welfare has essentially been forced into the straitjacket of neoliberal or 'market fundamentalist' economics. This ideology claims that taxation or redistribution always reduces economic performance, usually measured as total output (GDP in money terms), which is, quite incorrectly, taken to be a measure of national welfare. The utilitarian goal is apparently maintained, but now without regard for the real determinants of well-being, the distribution of gains, or the fate of the losers. At the same time, purely individual selfishness and greed are assumed to be the main motivators of human activity in most of modern neoclassical economics. These motivations are then assumed to produce the greatest possible output and welfare through the 'invisible hand' of sufficiently competitive markets, provided that government interference is minimized.

This view of the world is wrong in almost every aspect, as behavioural economists and others have shown over the last 30 years. Since *relative* income is much more important than absolute income (above poverty levels) for subjective well-being, people in rich countries are motivated to work too hard and compete too much. In the long run, relative gains for some are always accompanied by relative losses for others, while 'social capital' is lost, and average well-being fails to increase.[5] Taxation provides an incentive to spend more time on leisure and social relationships, with friends and family, which are major determinants of happiness. Some taxation of personal income is thus actually *necessary* to achieve true, Pareto efficiency, and reduce wasteful personal exhaustion and environmental destruction in the competitive 'rat-race' to 'keep up with the Joneses'. Furthermore, most people have an inborn sense of fairness and justice that tempers greed in many situations for good evolutionary reasons. Without such instincts, societies based on cooperation and communication could hardly evolve and function.

The evolution of moral sentiments, which are essential for cooperation in society, has also left a tribal legacy that is exploited by nationalist politics and the neoliberal ideology of individualism and consumption. This originally rather

natural preoccupation with linguistic or geographical neighbours – now nation-states – makes it too easy to ignore the victims of climate change or globalization in an uncertain future or in faraway places. However, there is also a growing recognition that tribal ethics or clan solidarity are both inconsistent, and dangerously inadequate for the modern 'global village' of our interconnected world. Among those who know the facts and consider the issues, there is widespread concern about endangered species and environments today, as well as the future effects of climate change. Natural environments and the incredible range of life they contain do have intrinsic value for many individuals, even if they do not expect to benefit directly from them as consumers or tourists. Philosophers of diverse backgrounds stress the urgency, for our very survival, of an encompassing global ethics and morality.[6]

Most economists agree that at least the 'deserving poor' should be supported by society, though not too generously! Opposition to the impacts of technological change and globalization is reduced if the losers in the resulting economic and social upheaval are compensated in some way by the winners. A frequent justification for the utilitarian focus on the sum of individual welfare as a criterion for progress is that the winners *could* compensate the losers when the total or sum of welfare increases. Of course, in practice, compensation is often not paid. This in turn is justified by the claim that, in the long run, *everyone* will benefit from change and growth as economic mobility – both upward and downward, or 'rags-to-riches' and 'riches-to-rags' – redistributes the gains and the losses.

This is yet another neoliberal claim that has been disproved by recent history. The clearest measures of income mobility have actually been declining in the recent decades of globalization and restructuring, while income inequality has been rising rapidly, not only in the UK and US, but even in traditionally more egalitarian countries like Germany. In an unprecedented historical record, the real hourly wages of the majority of American workers have actually been falling or stagnating over several decades of rapid economic growth. Most of the benefits of growth have been going to the richest classes, in what Nobel Prize-winning economist Joseph Stiglitz calls the 'trickle-up' economy, that has supplanted the 'trickle-down' economy of the past, in which growth in the long run also raised the incomes of the poor.[7]

Even the best-intentioned compensation schemes – and indeed the whole utilitarian idea of adding up individual welfare – break down completely under the major threat from climate change discussed above: a large-scale loss of human life. The ultimate victims of runaway warming cannot be compensated, or indeed consulted, if they have not yet been born. Endangering their lives for the sake of more consumption today (or tomorrow) is equivalent to simply dropping their welfare from the utilitarian sum, and contradicts fairly universal ethical principles of protecting life. In the extreme situation that climate change can ultimately impose upon us, utilitarianism without compensation is reminiscent of the mass exterminations perpetrated by Stalin and other tyrants, supposedly in the interests of a glorious future for the survivors. Of course, future lives are abstract and uncertain concepts today,

and thus fail to elicit our empathy in the same way as the victims of contemporary atrocities, or an earthquake or other natural disaster. As Kurt Tucholsky observed, 'The death of one person, that is a catastrophe. 100,000 deaths: that is a statistic!'

Social welfare and externalities

Modern economics defines costs imposed by a producer or individual on others or the rest of society as 'externalities'. If polluters face a 'green tax' on their emissions, they have an incentive to reduce these externalities, perhaps by investing in cleaner technology, and thus increase social welfare.[8] Dangerous technologies or products that directly threaten lives or health may also be simply prohibited by government regulation when practical alternatives are available. Competitive markets are widely believed to be efficient and to maximize utilitarian social welfare, but this classical result only holds when the costs of information and externalities are neglected. In the real world of uncertainty and unregulated speculation, the financial crash of 2008 has revealed the fragility and inefficiency of market economies run primarily for the benefit of the super-rich. The pervasive externalities of modern economies, including ever-rising greenhouse gas emissions, also reveal the persistent failure of governments to resist industry lobbying and protect the wider society. As discussed in Chapter 7, efforts to curb emissions such as the Kyoto Agreement and the EU carbon trading scheme have had little success so far.

Externalities are often described as market failures, and the *Stern Review* described climate change as the greatest market failure of all. It could also be argued that despoiling the environment and endangering future lives for private profit represent ethical failure as well. If loss of life can be directly attributed to toxic waste emissions, then those responsible can face severe legal penalties. This rarely happens because the effects are usually delayed, perhaps by many years as in the case of asbestos, so legal proof is difficult in the face of corporate cover-up and denial. However, the principle of responsibility – sometimes called the 'polluter pays principle' (PPP) – is clearly accepted. It would thus be quite logical to hold individuals and firms morally responsible for their carbon footprint, as one (albeit small) contribution to future global warming. In fact, a still modest, but growing, number of consumers and businesses are beginning to assume some ethical responsibility for the effects of their individual decisions on the environment, including climate change. As people become better informed about the scale of likely catastrophe under continued 'business as usual', both selfish and altruistic or empathetic concern about the world we bequeath to our children and grandchildren should strengthen the 'one world' ethics of caring for other species and poorer populations.

Oxford philosopher John Broome refers extensively to issues of *private morality* and climate change; that is, the moral responsibilities of individuals in contrast to what governments ought to do in response to climate change.[9] As individuals we often try to downplay our contribution to the externalities (described above) that we collectively impose on the poorest citizens of our global interconnected world.

While most of us recognize the serious implications of climate change, many of us take little responsibility for them – this is simply because at the individual level one's emissions have a negligible effect on global climate change; when you share the blame with so many others, the immorality of one's actions simply becomes too diluted in the global collective pool of millions of 'climate offenders'. Many of our individual actions that contribute to climate change (such as the use of private transport or consumption of imported goods that could have been easily substituted with more local products) are not accidental and are preventable. And perhaps one of the best routes to tackling climate change as an individual is simply through political actions – that is, by being active citizens who make informed choices when selecting our political representatives.

Just society and unjust climate change: Rawls and his theory of justice

As we have explained, nineteenth-century utilitarianism just adds up all individual welfare; some people usually benefit while others become worse-off under any particular policy, but as long as average welfare improves, the policy is justified. This ethical position underpins much modern economic policy, but significantly fails to address the fundamental issues of distribution and equity and is therefore seriously misleading when applied to climate change (and many other areas). One of the most influential philosophers who shaped modern thinking on social justice and environmental ethics, and provided an alternative to utilitarianism, is John Rawls.[10] In his seminal book *A Theory of Justice*, Rawls proposes a social contract for equality of opportunity – where individuals agree to limit their own rights, for the sake of achieving this common objective.

Rawls argues compellingly that utilitarian indifference to how welfare is distributed across individuals or generations – and, we may add, how climate change affects particularly vulnerable groups of people and future generations – violates fundamental human rights of the victims. Equal access to resources (whether this is the right to adequate consumption, access to fresh air or the right to live) can be an achievable social arrangement. And even more importantly, it does not need to be imposed by an external force. People may voluntarily and freely agree to arrangements that protect a common right and secure equality of opportunity, thus achieving social justice.

Rawls uses a construct, which he calls the 'original position', namely a hypothetical state of affairs that precedes any other social arrangements and agreements. Imagine a situation where we all find ourselves without prior experiences, knowledge and memories, and come together in a room to negotiate for the rights we are entitled to. In effect it would be as if we were all under a 'veil of ignorance', without any information regarding our own personal characteristics, preferences, social status, abilities, expected outcomes, the beliefs and traits of others, society's features, or our position in time. More importantly, we would not know how to compare

ourselves with anyone else in the room at that particular moment. By not pursuing particular objectives (influenced by personal interests), individuals would then agree to a social contract with equal access to environmental and other resources.

Under the veil of ignorance, everyone is in the same position. In such circumstances, rational people should unanimously agree on two fundamental principles of justice. First, they would agree that each individual (or generation, if people represented different generations without prior knowledge of their position) has equal access to a range of basic liberties. Since we do not know whether we would find ourselves in a better or worse position in an alternative scenario (of unequal access to resources and rights), the prudent choice is equal access or equality of opportunity.[11]

The second principle (often called 'the Difference Principle') states that deviations from equality are only justified if they improve the welfare of the worst-off.[12] In other words, richer nations would be justified in using more environmental or other resources (e.g. burning more fossil fuels), only if this (permanently) raises the welfare of the poorest countries. Since unhindered climate change will deprive the poorest in future generations of the basic capability of survival, for which there is no compensation, current polluting practices are simply ethically unacceptable. The argument that the current generation is actually poorer than future generations, and hence entitled to use up irreplaceable resources, makes the implausible assumption that economic growth will continue unabated, and of course ignores issues of distribution. The worst victims of our profligacy will actually be impoverished and starving, rather than beneficiaries of whatever growth does take place.

Rawls's theory of justice builds on socialist ideals, and the social democratic tradition of Sweden and other Scandinavian countries. Its main emphasis on distribution and equity is certainly completely absent from neoliberal economic thinking, where unconstrained private ownership for private profit (particularly of the wealthiest and most powerful) is the fundamental right. Private ownership works perfectly well as an allocation mechanism, if the distribution is equitable and markets are functioning competitively (which is far from the case for environmental amenities). In practice, though, the dominance of concentrated owners and their interests not only maintains poverty and destitution today, but also endangers the future of the planet. The current obsession with destructive material growth in the global economy has a depressing historical precedent. Central planning by groups of bureaucrats in the misnamed and non-democratic 'socialist' economies of the former Soviet Bloc also sacrificed environmental quality, and the fundamental liberties emphasized by Rawls, for the sake of wasteful and destructive growth.

Equalizing access to rights beyond income: Sen's capabilities approach

Another renowned approach to achieving equity and justice, is that of Nobel laureate Amartya Sen on capabilities. Sen's conceptual framework is based on the assumption that true development lies in equalizing capabilities, namely the potential of

people to achieve the life they value.[13] Poverty and deprivation imply not only lack of income but particularly the inability to achieve such capabilities and objectives that are not necessarily related to material consumption. Those things we truly value in life (which Sen calls 'functionings') may range from elementary needs such as adequate food and clothing, to more complex needs such as self-respect, community participation, ability to feel emotional affinity and use of complex imagination. For such reasons, the Human Development Index calculated by the United Nations as a measure of development takes into account both life expectancy and literacy standards, in addition to income levels. This recognizes that income is an input in determining human welfare rather than the final output we should wish to maximize, as confirmed by the numerous surveys on subjective well-being or happiness discussed in Chapter 4 – though, as we mentioned, the HDI is actually too closely correlated with per capita GDP to be a very useful guide to SWB.

Climate catastrophe, or just unequal access to environmental resources, may also prevent individuals today or in the future from 'functioning'. The philosopher Martha Nussbaum, who has further developed Sen's capabilities theory, provides a list of ten 'central human functional capabilities', many of which are closely related to the status of our surrounding natural environment.[14] Living a long and healthy life, for instance, will undoubtedly depend on food production and food security both within and between generations, which is expected to be at severe risk from climate change-induced soil erosion and water scarcity. Being able to live harmoniously with other plants, animals and our natural world in general, is one of the ten capabilities analysed by Nussbaum, and the most obvious one to be impaired by anthropogenic climate change.

What is important is not necessarily the functioning itself, but the capability or potential for the functioning. For instance, the loss of biodiversity due to climate change is likely to impair discoveries of new medicines, and removing the capability to expand our scientific knowledge is considered unethical, despite the fact that we know little of what there is still to be discovered. Many farmers in developing countries have been practising unsustainable agriculture for decades, but this does not justify the fact that our emissions are damaging their environment. And we may appreciate that the Great Barrier Reef and its corals still exist, even though we may have no immediate plans to visit the area and we may simply never do so!

The day after tomorrow (the precautionary principle)

There is still much scientific uncertainty about the details of climate change impact and particularly the timing of damage it may inflict on the poorest regions, future generations and the Earth's ecosystems. But we are confident that anthropogenic climatic change is already underway, and it will be too late when everyone realizes that these threats are imminent. If temperature exceeds the threshold level of

two additional degrees of warming, the risk of runaway warming and associated cataclysmic events will increase dramatically.

In health and safety regulation, the 'precautionary principle' is meant to be a safeguard against potentially severe or irreversible damage to life and limb. In practice, under the pressure of industry lobbying, regulators usually wait for years or decades until public pressure becomes irresistible, before taking action against toxic but profitable substances such as tetraethyl lead additives in petrol, tobacco or asbestos. In these cases, tens of thousands or even millions of victims and their families have to struggle to obtain compensation for the most blatant corporate and government malfeasance. In the case of climate change, restricting use of fossil fuels and switching from industrial to conservation agriculture is necessary to avoid jeopardizing the very existence of future generations, yet these measures are still opposed by massively funded campaigns of deliberate disinformation, uncritically disseminated by complicit media.[15]

People tend to be risk averse, particularly about their own children, and those who are well informed about the dangers of global warming are likely to favour serious abatement measures (although climate change involves a range of subjective risks that cannot be precisely quantified – and agreed upon for policymaking as a scientific consensus). As John Broome has summarized, there is no ethical justification to 'discount' the value of future lives likely to be lost as a result of catastrophic climate change.[16] So sacrificing these – as yet unknown – victims, to avoid reducing the extravagant consumption of the rich today, is ethically quite indefensible.

Agenda 21 at the UN Earth Summit in Rio in 1992 (where climate change entered the international political agenda as a potential global threat for the first time) explicitly urged participating countries to adopt the precautionary principle in environmental planning.[17] Unfortunately, there was not much political will to implement the principle for an environmental issue with such global dimensions as climate change. At an individual level, we all buy insurance policies for our private property, but coordination failures prevent sovereign states from adopting sufficient precautionary measures, not to 'compensate' for but to avoid the loss of irreplaceable human and natural life. While climate science deniers often accuse climate scientists of being alarmist, and hence favour less – or no – 'precaution', the actual evidence today points in the opposite direction. As we discussed in Chapter 2, scientists anxious for consensus have actually been rather conservative and cautious in the past with their predictions of climate change impacts. Given the complexities of our climate system, it is likely that even the most up-to-date assessments still largely underestimate future damages, particularly from the worst case of much longer delayed mitigation.[18]

The 2004 blockbuster movie *The Day After Tomorrow* is based on a hypothetical climate change apocalypse, where global warming causes the Greenland and Antarctic ice caps to melt and interrupt the North Atlantic Circulation, triggering a series of superstorms in the Northern Hemisphere that freeze everything in their path in just a few days. Even if all this is obviously science fiction, we certainly know that global warming is capable of causing irreversible disasters (even if we

are not absolutely confident about the exact nature of causalities, their magnitudes or statistical probabilities). In perverse contrast, consumers are sensibly keen to insure against accident and theft, but short-sighted and opportunistic politicians cannot agree on the same need for protecting future generations from the risk of cataclysmic events by reducing greenhouse gas emissions (as the precautionary principle would suggest).

The precautionary principle is often attacked for obstructing 'progress', usually by industry lobbies that try to profit from risky products or innovations, that may indeed benefit some individuals while imposing severe damage on others. Health and safety regulations often raise costs, as well as saving lives, but of course can never prevent all accidents. Balancing costs and benefits is the topic of Chapter 9, where we argue that the ethical response to climate change, guided by the principles of Rawlsian justice, will not be exorbitantly costly if implemented early enough, and will instead yield major health and welfare co-benefits *in addition* to mitigation. Contrary claims are mainly based on lobbying by energy producers, the science deniers largely funded by them, and others who stand to lose from carbon taxation, a switch to alternative energy, and related measures for abatement. Due in part to this lobbying, and also lack of a determined effort at public education by governments in the face of complacent or corrupt media and the ongoing Great Recession, there is still widespread – and even growing – ignorance among voters about the science of climate change and the likelihood of future catastrophe. This ignorance unfortunately extends to many economists, who predict only trivial damage from another century of rising emissions and temperatures under 'business as usual'.

Risk-loving, risk-avoiding and the risk of a catastrophe

Most studies evaluating the costs of climate change underestimate the risks of extreme, catastrophic events by not incorporating runaway warming due to positive feedback mechanisms. Research on many of these feedbacks is only just beginning, and the lack of detailed forecasts and quantification of these effects makes it much easier to ignore the real threats behind these very complex processes. Yet there is a surprising analogy with private insurance. Few individuals have any idea of their own personal probability of accident in any particular situation. Most car owners think they drive with above-average skill and care! While complaining about premiums, most people would also agree that legal requirements for insurance are sensible – a widely accepted social contract under the 'veil of ignorance' concerning one's own luck and care in the accident 'lottery'.

Perhaps a better analogy with climate policy is protective or 'defensive' investment in safety, such as seatbelts, or smoke detectors. We rationally spend money, and vote for limitations on our freedom to be (perhaps fatally) negligent, in order to avert unknown but potentially catastrophic risks. Saving the premiums, in

order to buy better medical care after the accident, seems absurd. Yet this is essentially the collective response urged by economists and politicians in the richest economies who oppose serious mitigation policies. This response is not consistent with prudent risk aversion and awareness of the scientific findings on climate change. It also violates the human rights of the poorest members of the current and future generations, who will be the worst-affected victims if increasing water shortages and agricultural collapse lead to mass starvation. Reckless or risk-loving drivers who endanger others directly, or fail to buy insurance, impose externalities on other road users, and are subject to prosecution. What is missing today is recognition of the need for similar measures to reduce the risk of future climate catastrophes, externalities that will just as surely be caused by continuing our current reckless emissions.

The Rawlsian ethics of maximizing the welfare of the least advantaged provides fairly clear prescriptions for policy, prescriptions that are obviously nowhere near to being implemented. Anyone whose life is threatened by climate change and its consequences, even if only at some uncertain time in the future, can be seen as one of these least advantaged members of human society – at that particular point in time. While there is no ethical justification for 'discounting' these future lives, or valuing them less than current victims of natural or other disasters, the temptation to do so is strong. The actions of any one individual today will probably have little effect on future climate, so it is easy to 'free ride' and wait for collective action, which is certainly needed to ensure that abatement is effective and the burden is fairly shared.

'An old man's grandchildren are his crowning glory' (Proverbs 17:6): or perhaps not?

As we discussed earlier, as individuals we buy insurance against major dangers that threaten our lives, our health or property. We are aware of the small probability that these threats will materialize, but nevertheless we prefer to hedge against the risk of their taking place. This can be accomplished through insurance companies: we pay a fee and transfer the risk to an organization, which avoids aggregate uncertainty by pooling many independent, small risks. We can also do this implicitly and informally, without the help of insurance contracts. As individual parents, we generally wish to see our children enjoying at least the same quality of life as our own. In order to do that, we often sacrifice part of our consumption and invest in our children's education, and we accumulate savings and assets, which we bequeath to them at a later stage. We feel a strong moral responsibility to assist our descendants in their own risk management – helping them to start their first business, to purchase their first property or to cope through hard times. Why are we then so reluctant to provide similar insurance for future generations when it comes to climate change catastrophe? Why does altruism work in some cases but not in others?

After all, it should not be the nature of the threat that matters. We would not like to leave our children alone at home when a burglar might break in, and we do not abandon them during extreme weather. Why is it, then, that we do so little to prevent extremes of climate change?

There are often great difficulties in visualizing climate change damages. Certainly Earth has experienced climate change before and oscillated from one ice age to another (as we discussed earlier in Chapter 2), but we have no memories of a climate change catastrophe. And this makes a big difference in raising awareness for climate change issues and ethical responsibility for those we bring to life. We certainly feel ethically responsible for educating our children and providing food and shelter for them, and developed societies add legal responsibility to parental instincts. In order to be good parents, we build on the past experience of others: we receive help from our own parents and advice from friends and the media. Of course, we may not be sure whether we were good parents or not, until long after our children have flown the nest.

The difficulty in recognizing a similar moral responsibility with respect to climate change lies in the nature of its impacts; they are not as evident, direct and immediate. And even more importantly, climate change is a global problem and therefore concern for climate stability is a public good that benefits all, rather than just the concerned individual. Our private actions as parents are not sufficient by themselves to protect our children from this threat; they need to be accompanied by similar sentiments and reactions from many other parents.

There may be yet another reason why individuals perversely ignore their ethical responsibility to prevent global warming. Even under business as usual, many believe that it will take decades before the worst impact of climate change is felt. As individuals, we may feel a stronger responsibility for our children, than for our great-great-grandchildren, due to 'genetic dilution'.[19] The further we look into the future, the less concerned we tend to be about the damage we may inflict. If a climate catastrophe was obviously imminent, we would probably adjust our destructive behaviour immediately, to protect ourselves and our children. If the worst consequences of climate change under 'business as usual' were delayed until 2100, (as some economists believe, in contrast to the scientific evidence), then this burden would fall on our great-great-grandchildren.

Now, every child has two parents, but sixteen great-great-grandparents, and so forth. As the time horizon extends, so does the number of our predecessors. We are in effect the great-great-grandparents of those children whose world may be devastated at the end of the century. As parents, we each share responsibility for our children with a partner. As great-great-grandparents we share the same ethical responsibility with (at least) fifteen other people. Perhaps this 'dilution' explains what economists call the 'pure time rate of discount', though this is rejected by moral philosophers as a valid justification for inaction.

The consequences of our current environmental destruction may develop rapidly and unpredictably, just like the financial crisis of 2008. The ill-founded but still common belief that they will only fall on later generations is undoubtedly

another obstacle to adjusting our energy-intensive consumption. Nevertheless, most of us want our great-great-grandchildren to think highly of us for what we have achieved and left to them. It is certainly not the first time humanity has caused irreversible damage – we have already destroyed numerous species and habitats, and brought many more to the brink of extinction.[20] We are certainly not proud of our ancestors' environmental record, and few would want to be remembered by their descendents for contributing to a climate catastrophe.

Oh brother, where art thou?

Many people are aware that unhindered climate change will devastate the lives of billions of people in developing countries, leading to mass starvation and epidemics. Why, then, are we so slow to react? Part of the explanation may lie in the fact that as individuals we tend to favour welfare and support for people of a similar background to ours (ethnic, linguistic, religious). Reciprocity and generosity appear to be stronger among people of the same 'tribe' or group, with differences in ethnicity, religion and language leading to increased socio-cultural alienation.

This suggests that homogenous societies are likely to function more efficiently. Social capital and trust are usually higher in societies where people belong to the same ethnic group. Even in a highly developed economy such as Belgium, long-standing frictions between the Flemish and Francophone communities and political parties created a major political crisis in 2007–2008. Economists Alberto Alesina and Edward Glaeser have argued that the welfare state is less developed in the US compared to Europe, as a result of ethnic heterogeneity.[21] Rich white communities are less likely to support cash transfers and state intervention that largely benefit poorer Black and Hispanic communities. Indices of ethnic fractionalization, capturing the probability that two randomly selected individuals belong to different ethnic groups, have been used to explain disparities in economic development, policies and institutions. Ethnically fractionalized countries lag behind in terms of income levels, political stability and provision of public services. They often suffer from violent conflict between ethnically diverse groups, which destroys local infrastructure and diverts public funds away from education, health and environmental assets.[22]

Could ethnic heterogeneity have repercussions for environmental management? The answer is yes. In Côte d'Ivoire, for instance, the extent of environmental degradation and soil erosion was greater across ethnically heterogeneous than homogenous agricultural communities.[23] Recent research also suggests that ethnically fractionalized communities in sub-Saharan Africa suffer from more limited access to piped, safe drinking water.[24] Even in the context of climate change, there is evidence that countries with ethnically fragmented populations tend to emit more greenhouse gases, even when one controls for the corresponding size of population and the economy.[25] As a general rule of thumb, ethnically homogenous communities are more likely to cooperate and sustainably harvest a common

resource base, while across heterogeneous groups mistrust and frictions often result in a 'tragedy of the commons' where resources are exploited unsustainably.

In a largely ethnically fractionalized world, divided into separate entities by political borders and socio-cultural barriers, our limited generosity outside our own borders does not come as a surprise. Governments devote a much larger share of public expenditure for domestic public goods and income redistribution, compared with miserly provision for international aid, debt relief and technology transfers. This priority for domestic public goods seems to depend on electoral preferences. We do tend to be much more tolerant of absolute poverty, malnutrition and extensive illiteracy in other countries, or sometimes even in different neighbourhoods in the same city. The feeling of belonging to a nation-state rather than a common planet hence makes policymaking more myopic and self-centred. In order to tackle environmental issues of global dimensions, such as global warming, we will need to extend our social empathy beyond our own geographic and ethnic borders.

Willingness to pay and willingness to accept

Economists use the Contingent Valuation Method (CVM) to estimate the value people attach to non-marketed environmental goods. As we will discuss in detail in Chapter 9, this is a central part of climate change cost–benefit analysis, where costs of climate change mitigation are contrasted with estimates of climate change damages. People are asked how much they would be willing to pay to protect an endangered species or habitat, or to reduce personal risk. This is claimed to provide a measure of the utility people derive from such environmental assets, imperfect as it may be. A major problem is that the answers to such questions depend on how many similar questions are being asked at the same time! All-encompassing and decisive questions such as 'How much would you be willing to pay to prevent further global warming?' depend on so many unstated assumptions that their meaning and interpretation become very questionable themselves. Given that these questions are in most cases hypothetical (with respondents having no market experience with respect to the public good or bad they are asked to value), such guesstimates might only poorly capture true intentions.[26]

Sometimes economists can derive a more accurate valuation of environmental services by examining the revealed preferences of individuals (rather than the stated preferences, as in the case of CVM). Home-owners, for instance, may pay higher prices for houses in cleaner environments or closer to nature reserves, with the price premium reflecting the value attached to these environmental amenities. For many environmental services, though, especially in the context of climate change where benefits are less localized, revealed preferences are difficult to identify.

We have already questioned the interpretation of willingness to pay (WTP) surveys. Many economists believe that they underestimate the true value people

attach to the environment. When individuals are asked instead for their willingness to accept (WTA) compensation for loss of an environmental asset, they tend to give higher values for the same environmental good. Although the WTP and WTA methods should provide similar estimates, most studies find that this is not the case! People seem to suffer the loss of something much more than they value gaining the same thing, often around twice as much. This psychological paradox, first identified by Nobel laureate Daniel Kahneman and Amos Tversky in the early 1970s, has been verified in many subsequent environmental economics studies.[27] In the context of climate change, this may suggest that people are likely to have a much stronger preference for preserving the environmental status quo, and hence demand a much higher compensation than revealed by WTP methods for environmental damages related to climate change.

Some economists also believe there is a moral dimension to the problem. Willingness-to-accept estimates are higher because people demand a larger compensation for actions they regard as morally wrong.[28] When people feel they have a 'right' to environmental quality, biodiversity and climate stability, they generally require a much higher payment to accept damage or loss that is perceived to be unethical. The WTA transfer resembles in that respect a bribe as compensation for unethical or criminal conduct. Individuals may also require larger monetary compensation for environmental degradation, simply because of the uncertainties involved in how environmental losses might affect them.

Attaching monetary values to the loss of human lives is another ethically debatable issue (and one that we discuss extensively in Chapter 9). Killing some innocent person intentionally and then compensating his or her family with a sum of money, such as the 'value of a statistical life' (VSL), would hardly be ethically acceptable (even worse is the standard military practice, in all Western democracies, of disguising 'enemy' civilian casualties with the euphemism 'collateral damage', and generally refusing to pay any compensation to the victims). But climate change will also kill millions of people particularly in the developing world, and attaching a value to such loss in a cost–benefit comparison makes it no more ethically justifiable, particularly since there is little prospect for any compensation of next-of-kin by current polluters or their descendants. John Nolt in a recent paper suggests that one should express climate change damages in human terms such as mortality and morbidity (rather than in monetary terms or GDP shares) – this would emphasize a clearer moral significance of our climate change actions and imposed harm.[29]

Environmental protection as a human right

In recent years, many lawyers have also expressed concerns about the ethical implications of climate change and violation of human rights. They explore how global environmental issues can fall within international environmental law, and make actors and states accountable for their environmental impact. Global warming

violates a broad range of human rights, which are internationally protected by treaties and conventions. Human rights to health, food, water security for themselves and for their children are all at stake, for billions of people in developing countries, in a world of rising temperatures and declining soil fertility. These human rights are already enshrined in the Universal Declaration of Human Rights of the United Nations and the two international conventions that followed, i.e. the International Covenant on Civil and Political Rights and the International Covenant on Economic, Social and Cultural Rights. Environmental protection is unfortunately not recognized as a separate human right per se, but nevertheless it can fall within international legal jurisdiction to the extent that it affects other broader human rights, such as the right to life, health, adequate food and water.[30] Some scholars go as far as to suggest that misinformation about climate change should be considered criminal negligence.[31] Indeed, most of the climate science denial that 'pollutes' media and blogosphere is also more or less obviously fraudulent, funded directly or indirectly by fossil fuel interests for financial gain.

Countries ratifying international human rights treaties commit themselves to respecting and protecting the rights involved. For local (in contrast to global) environmental pollution, the state is generally more proactive in facilitating human rights protection and ensuring legal procedures are in place in case of violation. For environmental issues of global dimensions, the pressure on states to act is usually less formal unless international conventions are incorporated into domestic law. Pressure from other signatory members and international organizations ensures compliance to a large extent, and the International Court of Justice, as the primary judicial organ of the United Nations, also has the jurisdiction to settle legal disputes and provide advisory opinions on legal questions submitted to it by UN member states. Although a special chamber within the International Court of Justice has been established to deal with transnational environmental issues, the chamber has remained generally inactive (whereas the European Court of Human Rights, representing the nations participating in the Council of Europe, has examined a few cases of environmental damage, although always at a national level). Strengthening the domestic and international legal framework for human rights protection is particularly needed for low-income countries, where human rights are generally less respected due to weak institutions, corruption and lack of public resources.

Climate change is expected to increase environmental displacement, immigration, loss of livelihoods and violent conflict. Despite the primary role of the United Nations as a safeguard of international peace and security, the UN Security Council has not considered climate change as an imminent threat to global stability. The Security Council has generally avoided taking action on international environmental issues, with the sole notable exception being the resolution to hold Iraq accountable for environmental damage inflicted on Kuwait during the 1991 Gulf War (while, subsequently, UN inaction following the US–British aggression against Iraq, resulted in hundreds of thousands of civilian deaths, wholesale destruction of civilian and social infrastructure, and an ongoing devastation of the whole

region, culminating in the rise of the so-called 'Islamic State'). The United Nations Environment Programme (UNEP) was established in 1971 as a separate UN body specializing in environmental issues, but still remains a UN programme rather than a UN semi-independent agency such as the World Trade Organization or the World Health Organization, hence limiting its political influence.

As we discuss in Chapter 9 in more detail, it is extremely difficult to weigh the benefits of current emissions against the risks of climate change, and hence give the concept of 'sustainable development' concrete content within international law. The very fact that future generations will mainly bear the cost of climate change further complicates court decisions, although representative proceedings on behalf of the unborn are common in English law, and could subsequently be extended at an international level.[32]

Spoiling nature or being spoiled?

So far, we have discussed the rights of the poor and future generations, and how these are violated in the context of climate change. But this approach obviously does not give much consideration to nature itself! Allocating rights exclusively between human beings (whether poor, rich, in the future or present) ignores the implicit rights of other species to coexist with us. We (sometimes) feel ethically responsible for inflicting damage on other human beings, but we usually ignore the fact that we are not the sole sentient species capable of experiencing pleasure and pain. This attitude has been termed 'speciesism', in analogy with the racism traditionally used to justify discrimination and cruelty to allegedly 'inferior' human races, by more powerful rulers and conquerors. There is, therefore, an imperative to extend our altruism beyond humankind to encompass the whole of our biosphere, on which all life depends, when evaluating the consequences of our present behaviour.[33]

We often think of the value of nature in terms of its direct utility to humans. And indeed, nature provides a whole range of invaluable services to us either in the form of primary materials or amenity values. Climate change damages many of these services. To some extent, we may try to estimate such damages, either by looking at market values for environmental services if they exist, or more usually by approximating them with the Contingent Valuation Method we discussed earlier.

Are we, though, only ethically responsible for preserving those environmental services that are directly useful to us? Most people recognize that there is also an intrinsic value of nature: for instance, we may feel an ethical responsibility to preserve rare plant or insect species, remote habitats and landscapes, beyond any direct benefits we are likely to enjoy. Some of us may benefit directly by visiting these locations. Many, though, would simply prefer that these ecosystems remain unspoiled, even if this yields no direct benefits to them. Similarly, we often donate money to help the destitute and the vulnerable without expecting anything in return. This altruism does sometimes extend beyond our own species. Unfortunately, when

economists try to estimate a monetary value for climate change or other environmental damages, they tend to ignore this inherent or intrinsic value of nature, in part because of the great difficulties in measuring it.

Desacrilizing nature

Moral responsibilities towards nature are largely shaped by our cultural and religious heritage. Tim Jenkins of Cambridge University argues that Western religion and philosophy generally assume nature to be non-sacred, and hence permit its use and exploitation for human benefit.[34] The era of Enlightenment further estranged humans from nature, with the view that humankind 'owns' the natural environment, rather than being an integral part of it. Enlightenment endorsed critical free thinking and promoted the emancipation of the individual from religious authority, traditions and natural constraints. There was nothing divine about nature, which was simply seen as a means to expand production and improve living standards.[35] The ancient Greeks, however, regarded environmental hazards (such as earthquakes, drought and crop failure) as signs of divine punishment (nemesis). Natural events and disasters were associated directly with the gods – for instance, thunder with Zeus, and an earthquake with Poseidon.

Our moral responsibilities within the Christian faith deserve particular scrutiny, with Christianity being the dominant religion in the Western world. Sallie McFague in her new book, *A New Climate for Theology*, provides a fascinating study of how global environmental thinking could fit within a reformed Christian theology.[36] She suggests that our environmentally destructive attitude is a direct result of how we perceive ourselves in relation to God. We largely see ourselves as privileged entities, superior to other forms of life on the planet (and these feelings of personal superiority even extend towards other human beings of different socio-cultural and/or educational background). We often feel ourselves isolated both from other human and non-human beings, God included. For most Christians, God is the supernatural creator of our planet, but also remains rather distant from our human world by residing and making judgements somewhere 'above' and far away from it. Isolating ourselves from our supernatural creator naturally gives us the perception of superiority in our day-to-day affairs and diminishes our feeling of responsibility towards other individuals and the environment.

McFague suggests moving towards an *ecological church* that is truly catholic and ecumenical in embracing all human and non-human beings, and nature as a whole. The Sunday sermons are, at best, dominated by moral guidance on how to improve human welfare and decrease human suffering (though often more concerned with dogma, such as opposition to contraception, that has the opposite effect). There is little mention of the need for a more encompassing well-being of all God's creation, which would be a big step forward from the current anthropocentric messages of the Church. A more wide-reaching and all-embracing Church would then be able to include in its agenda environmental issues of global concern, such

as climate change – and, even more importantly, it could relate these issues to the inevitable increase in poverty and human suffering under unconstrained global warming, particularly for those living in poorer regions of the planet.

Currently, it is often those who describe themselves as non-religious, atheist or agnostic who have the strongest environmental concerns and favour the highest spending on environmental protection and climate-friendly technologies.[37] A potentially important development might be the new 2015 encyclical by Pope Francis, which urges Catholics to fight climate change. In his 100-page encyclical *Laudato Si': On Care for Our Common Home*, Pope Francis explicitly acknowledges that climate change is the fault of man, urges for drastic mitigation and phasing out of fossil fuels, and stresses that the foremost victims of global warming will be the poor.[38] He emphasizes that it has become very easy to uncritically embrace the utopian 'idea of infinite or unlimited growth, which proves so attractive to economists, financiers and experts in technology. It is based on the lie that there is an infinite supply of the Earth's goods, and this leads to the planet being squeezed dry beyond every limit'. In his message, the Pope challenges the anthropocentrism of traditional Judeo-Christian theology, according to which God created the world to serve humans: he says, 'the Bible has no place for a tyrannical anthropocentrism unconcerned for other creatures'.[39] Many of his suggestions on ways to tackle climate change, for example on extending the use of public transportation and encouraging small-scale, sustainable agriculture, are in line with recent scientific evidence and the recommendations put forward in this book. While a few evangelical Christians in the US have taken a strong stand against climate change, they are dominated by the 'Christian Right' and fundamentalists who support conservative, Republican denial of climate science, evolution and more.[40] In the same vein, an Islamic Declaration on Global Climate Change, signed after a 2-day symposium on Islam and climate change in Istanbul in August 2015 by prominent Muslim scholars, urges action (and a global agreement) in order to limit global warming to 2°C above pre-industrial levels (and preferably below 1.5°C). These religious statements sent a strong signal ahead of the UN climate talks in Paris (in November 2015) that there is a religious moral duty to address human-caused climate change.

While environmentalists are likely to welcome McFague's suggestions, whatever their religious position, she seems to miss the key point that even restrictive traditional ethics should be concerned with the threat of a climate catastrophe that in the worst case could cost billions of lives in the future. Christian and other religious leaders have largely ignored the basic warnings from climate scientists, which should have been quite sufficient to put climate change on the top of their agenda. While an 'ecological church' might be seen as a substantial improvement by many observers, such reform hardly seems to be necessary in order to take a decisive stance on climate change.

McFague's criticism of Christian egocentricity is also far from new. A series of essays published in 1904–1905 by the famous German economist and sociologist Max Weber, also emphasized the human-centred ethos of the Protestant church. In his book *The Protestant Ethic and the Rise of Capitalism*, Weber claims that Protestantism,

and Calvinism in particular, favoured hard work, economic gain and wealth accumulation by giving them a moral significance.[41] While the Catholic Church assured salvation for everyone accepting the Church's sacraments, Calvinism put forward a theory of double predestination, in which God predetermined which Christians were destined for salvation or damnation. According to Weber, material wealth and related self-confidence provided individuals with a much-needed sign of salvation and God's grace. Donations to the poor were largely frowned upon, for promoting begging and laziness rather than encouraging the hard-working ethos that was favoured by God. Religious devotion was hence primarily linked to personal economic gain rather than respect for other human beings or nature as a whole.

Michael Northcott, a leading international ethicist from the University of Edinburgh, provides a more outspoken critique, when analysing the immorality of global warming within the spectrum of Christian tradition. Humans produce modest carbon emissions to satisfy their food, clean water and shelter necessities, which Northcott calls 'livelihoods' or 'subsistence' emissions. The emissions per person attributed to the poor in the world's most deprived areas often fall short of even this minimum 'subsistence' level, which could prevent human suffering and poverty for millions in the future if adopted universally. This comes in sharp contrast to the 'luxury' emissions needed to sustain the extravagant, wasteful consumerism of the rich, largely based in Europe and North America, but also as growing minorities in many developing countries. These luxury emissions, determined by greed and status rivalry, overshadow the minimal emissions of the world's poor, determined by necessity.

The Christian ethos is particularly critical of such pursuit of luxury, especially when common property (such as our global environmental commons) is appropriated for private benefit. The current consumerism and luxury emissions of the rich are immoral, as they will in effect deny the poor of the opportunity to meet even their most basic survival needs, as agricultural collapse and water shortages kick in. Accelerating global warming, fuelled by the lavish lifestyle of the rich, is a theft of common resources that should be in principle available to those living in ecologically vulnerable parts of the planet.[42]

The loss of spiritual connection with nature creates the false impression that we can fully control the Earth's ecosystems through advances in science and technology. As we discussed earlier in Chapter 4, economic growth has become the overriding policy objective everywhere, although the average happiness of rich nations in particular, is much less affected by material consumption than by intangible aspects of 'social capital' such as trust and democracy. The materialism that is encouraged by constant exposure to commercial TV from early infancy, and competition for status by wasteful consumption of 'positional' goods, combine with job insecurity to cause unhappiness and even neuroses or depression. In addition, material growth is devastating environments and ecosystems everywhere, and accelerating emissions of GHGs that threaten our future, and above all the most vulnerable, poorest populations. The ethical contradictions underlying growth policy and the lack of serious environmental policy have not yet been widely recognized.

The broken link between consumption and production: is climate change on the agenda?

Since the end of WW2, the world economy has become increasingly globalized. Countries trade more with each other, based on what economists call 'comparative advantage' or specialization in what they can produce relatively cheaply, as already described in the early nineteenth century by the English classical economist David Ricardo.[43] Over the last few decades, the World Bank and the International Monetary Fund have included trade liberalization as one of their main policy prescriptions for developing countries, and encouraged them to reduce tariffs, quotas and other trade obstacles.[44] As a result of freer trade, multinational corporations have gained wider access to markets in developing countries. They are now able to purchase primary materials cheaply, relocate production to countries where labour costs are low, and transport the final products back to markets in Western nations, all without regard to environmental or 'external' costs. They are also able to flood developing markets with goods that consumers did not even know the existence of a few years back, as well as destroy the livelihoods of local farmers with heavily subsidized exports from industrial agriculture in the EU and the US.

There is of course a fierce debate between economists and anti-globalists on how freer trade addresses the needs of the poor, inequality and exploitation of labour. Irrespective of differing views on globalization, it is indisputable that local small-scale production is shrinking, and our markets are flooded with products flown in from thousands of miles away. Freer trade secured lower prices for a wide range of products, with the average consumer knowing little if anything about the production and transport of the goods. Few customers realize, for instance, that most flowers bought in American and European supermarkets are flown from countries as far away as Ethiopia, Kenya and Ecuador. Even worse, they do not seem to realize or care that low prices for imported products do not include the environmental costs of transportation and production, and that only a few per cent of what they pay actually goes to the producers.[45] In the UK, the supermarket sector accounts for almost 1 per cent of all GHG emissions – this rough calculation only includes the sector's direct emissions, with indirect emissions estimated at ten times as much.[46] Online shopping, long opening hours, aggressive marketing, and price competition without attention to quality and externalities, have created a pattern of unplanned 'consumer impulse shopping' that now accounts for almost 60 per cent of total consumption.[47]

There are some signs of change, however. The Fair Trade movement encompasses a variety of organizations supporting small, local farmers and craftsmen in bargaining with multinationals, and promoting sustainable methods that protect the income and health of growers, workers and consumers. The retail share of Fair Trade products, though still tiny, is growing rapidly, jumping by 15 per cent in 2014 (with global sales value close to $6.5 billion). Without such support, small-scale farmers find it virtually impossible to compete against the market power of large multinational corporations.[48]

The (modest) success of the Fair Trade initiative is part of the rise of 'ethical consumption'. Over the past few decades, globalization, increased trade and lower transportation costs have broken the link between consumption and production. Consumers bought products with little knowledge of methods of production, country of origin, environmental and social consequences, with their choices largely influenced by pricing and marketing. Well-founded health and ethical concerns (though still only among a small minority) have driven rising demand for organically and locally produced food that supports local employment, and reduces carbon emissions. The celebrity chef Jamie Oliver has written a book (*Jamie at Home: Cook Your Way to the Good Life*) that lists recipes according to seasons, so that one can easily plan meals according to local produce available.[49]

Ethical consumption – and indeed any rational and informed choice – requires transparent and honest labelling. Most 'prepared' food nowadays does display a long list of information, though not always the most relevant, but buyers of fresh fruit and vegetables have no information on pesticide residues, nutrient content, or methods of production and distribution. 'Ecolabelling' can help consumers choose environmentally friendly products, although its use is still rather limited. The 'dolphin safe label', for instance, is used on canned tuna to demonstrate that the fish has been caught without harming or killing dolphins. Improvements in labelling with colour codes for carbon footprint and nutritional value are under discussion, but generally being resisted or 'diluted' by the powerful supermarket chains.[50]

More detailed information would help environmentally sensitive consumers to make choices in accord with their values, and reduce their ecological footprint. This is particularly relevant for industrial meat production, where health hazards for consumers and appalling animal welfare conditions have been systematically concealed by the supermarkets that depend on this industry, as we discussed in Chapter 3.[51] In addition, the meat industry is a major producer of GHGs, in particular methane, and cause of environmental degradation.[52] There are thus several reasons, in addition to health concerns, for ethical consumers to reduce or cease consumption of industrial meat and dairy products, and comprehensive labelling could do much to provide information about these vital issues.

Conclusions

Although often not apparent at first sight, ethical values permeate economic thinking and policy. The way we approach social issues with economic theories and policies mirrors our ethical value judgements. Our ethical stance influences the way we answer questions, such as the following: How much pollution is too much for whom? How does social welfare depend on the distribution of social capital and environmental quality, as well as material consumption? How do we weigh impacts on future generations against current decisions? With increasing recognition of imminent environmental threats and a climate change catastrophe,

economic analysis needs to recognize moral responsibility to treat the Earth with respect and protect those vulnerable to environmental degradation.

Managing our global commons requires much beyond adopting relevant policy measures, market solutions and technological transfers. Even more fundamentally it is important that we collectively recognize the ethical responsibilities of our current actions towards the present and future poor. Our failure to stabilize GHG concentrations at lower levels will have devastating impacts, particularly for developing nations, but also for our own future. Economists mistakenly consider material consumption as the ultimate determinant of happiness and welfare, thus neglecting the importance of social capital and environmental protection, and helping to justify continuing policy priority for destructive and wasteful growth. The global economic crisis of 2008–2009, followed by slow recovery under austerity, with threatening deflation and even 'secular stagnation', offers a rare opportunity for countercyclical investment in labour-intensive, alternative energy and environmental protection, which would also combat rapidly rising unemployment. But this opportunity has been largely wasted.

As we have repeatedly emphasized, mitigation of climate change is a form of insurance against future humanitarian crises, widespread poverty and agricultural collapse. Such defensive investment is urgently needed, supported by the continuously increasing scientific evidence on anthropogenic climate change and its positive feedback processes. In spite of uncertainty, we need to take precautionary measures to minimize the risk of catastrophe, and protect the most vulnerable. To achieve this, we have to extend our moral obligations to our direct descendants to include all future generations, and particularly the poor of the developing world.

As consumers and producers, we need to recognize the threat and look beyond private profit. Broken links between consumption and production, nature and faith and distant communities of different background (though sharing a common planet) need to be rejoined. In a world of increasing inequality and ecological crises, the need for international cooperation, to promote both climate stability and social justice, is a moral imperative under the emerging risks of climate catastrophe and mass starvation.

Notes

1 Regional climate models show clearly the uneven distribution of expected changes in temperature and rainfall – see the 2007 IPCC Report: Intergovernmental Panel on Climate Change (2007) *Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Fourth Assessment Report of the IPCC*, Cambridge University Press, Cambridge.

2 A recent pattern of gradual increases in droughts and desertification in the Chinese northwestern provinces is now broadly recognized by Chinese academics themselves – see for instance, Qian, W. and Zhu, Y. (2001) 'Climate change in China from 1880 to 1998 and its impact on the environmental condition', *Climatic Change*, vol 50, no 4, 1480–1573, as well as Wu. B. and Ci, L. J. (2002) 'Landscape change and desertification development in the Mu Us Sandland, Northern China', *Journal of Arid Environments*, vol 50, no 3, 429–444.

3 The likelihood and impact of water shortages and rising sea levels are discussed in Chapter 2. To read more on Edward Page's ideas on a 'global sufficientarian ethic', see

Page, E. (2007) 'Justice between generations: Investigating a sufficientarian approach', *Journal of Global Ethics*, vol 3, no 1, 3–20.

4 See Bentham, J. (1789) *An Introduction to the Principles of Morals and Legislation*, Reprint 2005, Kessinger Publishing, Whitefish, MT, and Mill, J. S. (1861) *Utilitarianism*, Reprint 1998, Oxford University Press, Oxford.

5 These issues are discussed in detail in Chapter 4.

6 Princeton philosopher Peter Singer develops these ideas in his book *One World* – see Singer, P. (2001) *One World*, Yale University Press, New Haven, CT. For comprehensive accounts of the evolution of morality, see Greene, J. (2013) *Moral Tribes: Emotion, Reason, and the Gap between Us and Them*, Penguin Press, London, UK, and Joyce, R. (2006) *The Evolution of Morality (Life and Mind)*, MIT Press, Cambridge, MA. Renowned Harvard entomologist Edward O. Wilson has developed related ideas in many books, most recently in Wilson, E. (2014) *The Meaning of Human Existence*, Liveright, London, UK.

7 See Stiglitz, J. (2007) *Making Globalization Work*, Penguin Books, London, UK, as well as Barry, B. (2005) *Why Social Justice Matters*, Polity Press, Cambridge, UK.

8 Taxes imposed on consumers of carbon-intensive products are essentially equivalent.

9 See Broome, J. (2012) *Climate Matters: Ethics in a Warming World*, Norton, London, UK.

10 See Rawls, J. (1961) *A Theory of Justice*, Harvard University Press, Cambridge, MA.

11 The conventional economics of declining marginal utility of income or consumption also supports the welfare gains of redistribution from rich to poor, provided of course that loss of incentives, say from redistributive taxes, does not end up making everyone worse off.

12 This is often referred to as the 'maximin rule', namely a rule that maximizes the position of the worst-off (individuals, countries or generations).

13 Sen, A. (1985) *Commodities and Capabilities*, Oxford University Press, Oxford, UK.

14 Martha Nussbaum claims that these capabilities may be revisable over time according to changing cultural patterns. Nussbaum, M. (2000) *Women and Human Development: The Capabilities Approach*, Cambridge University Press, Cambridge, UK.

15 The precautionary principle is particularly relevant for environmental problems that depend on stocks of pollutants, or GHGs in the atmosphere, that accumulate over time under business as usual, rather than just on the current level of emissions. For that reason, delayed action on emissions may not be able to avert an environmental catastrophe. See Gollier, C., Jullien, B. and Treich, N. (2000) 'Scientific progress and irreversibility: An economic interpretation of the "precautionary principle"', *Journal of Public Economics*, vol 75, no 2, 229–253.

16 Broome, J. (2006) 'Valuing policies in response to climate change: Some ethical issues', mimeo, University of Oxford, Oxford, UK.

17 United Nations (1992) *Agenda 21 Earth Summit: United Nations Program of Action from Rio*, United Nations, New York, NY.

18 Brysse, K., Oreskes, N., O'Reilly, J. and Oppenheimer, M. (2013) 'Climate change prediction: Erring on the side of least drama?', *Global Environmental Change*, vol 23, 327–337.

19 Pezzey, J. C.V. (1994) 'Concern for sustainability in a sexual world', Centre for Social and Economic Research on the Global Environment, London, UK. There is also a summary of the main arguments in Dresner, S. (2002) *The Principles of Sustainability*, Earthscan, London, UK.

20 The Fourth IPCC Assessment Report estimates that around 20–30 per cent of known plant and animal species face a large risk of extinction if global warming exceeds 1.5–2.5°C – see Intergovernmental Panel on Climate Change (2007).

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22 Alesina, A., Devleeschauwer, A., Easterly, W., Kurlat, S. and Wacziarg, R. (2003) 'Fractionalization', *Journal of Economic Growth*, vol 8, no 2, 155–194.

23 Ahuja, V. (1998) 'Land degradation, agricultural productivity, and common property: Evidence from Côte d'Ivoire', *Environment and Development Economics*, vol 3, no 1, 7–34.
24 Jackson, K. (2008) 'Why does ethnic diversity affect public good provision? An empirical analysis of water provision in Africa', mimeo, University of British Columbia, Vancouver, Canada.
25 Papyrakis, E. (2013) 'Environmental performance in socially fragmented countries', *Environmental and Resource Economics*, vol 55, no 1, 119–140.
26 A recent comprehensive critique of valuation methods is Hausman, J. (2012) 'Contingent valuation: From dubious to hopeless', *Journal of Economic Perspectives*, vol 26, 23–56.
27 For a comprehensive overview of willingness to pay and willingness to accept studies, see Horowitz, J. K. and McConnell, K. E. (2002) 'A review of WTA/WTP studies', *Journal of Environmental Economics and Management*, vol 44, no 3, 426–447. See also Mendelsohn, R. and Olmstead, S. (2009) 'The economic valuation of environmental amenities and disamenities: Methods and applications', *Annual Review of Environment and Resources*, vol 34, 325–347.
28 Biel, A., Johansson-Stenman, O. and Nilsson, A. (2006) 'Emotions, morality, and public goods: The WTA–WTP disparity revisited', Working Papers in Economics 193, University of Göteborg, Göteborg, Sweden.
29 Nolt, J. (2014) 'Casualties as a moral measure of climate change', *Climatic Change*, vol 130, no 3, 347–358. This point was also emphasized in our first edition of this book, published 2010.
30 The Australian Human Rights and Equal Opportunity Commission has produced an excellent overview of human rights issues linked to climate change: http://www.humanrights.gov.au/pdf/about/media/papers/hrandclimate_change.pdf.
31 Kramer, R. C. (2013) 'Carbon in the atmosphere and power in America: Climate change as state-corporate crime', *Journal of Crime and Justice*, vol 36, 153–170.
32 For a more in-depth discussion on the United Nations' role in international environmental law, see Birnie, P. and Boyle, A. (2002) *International Law and the Environment*, Oxford University Press, Oxford, UK, and Cordonier Segger, M.-C. and Khalfan, A. (2004) *Sustainable Development Law: Principles, Practices and Prospects*, Oxford University Press, Oxford, UK.
33 There are two broad philosophical approaches regarding the allocation of rights. On the one hand, humanist moral philosophies allocate rights exclusively to human beings. On the other hand, naturalist moral philosophies extend rights broadly to the natural world, of which humans are part. Princeton philosopher Peter Singer pioneered the case for animal rights in two books – Singer, P. (1975) *Animal Liberation*, Random House, London, UK, and Singer, P. (1979) *Practical Ethics*, Cambridge University Press, Cambridge, UK. In a similar vein, Oxford evolutionary biologist and critic of religion, Richard Dawkins, wrote: 'Such is the breathtaking speciesism of our Christian-inspired attitudes, the abortion of a single human zygote (most of them are destined to be spontaneously aborted anyway) can arouse more moral solicitude and righteous indignation than the vivisection of any number of intelligent adult chimpanzees! . . . The only reason we can be comfortable with such a double standard is that the intermediates between humans and chimps are all dead' – Dawkins, R. (1986) *The Blind Watchmaker*, Norton, New York, NY.
34 Jenkins, T. M. (1998) 'Economics and the environment: A case of ethical neglect', *Ecological Economics*, vol 26, no 2, 151–163.
35 For a discussion on how modern science and technologies desacralized nature, see Northcott, M. S. (2007) *A Moral Climate*: *The Ethics of Global Warming*, Longman, London, UK.
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40 Griffin, D. R. (2015) *Unprecedented*: *Can Civilization Survive the CO2 Crisis?*, Clarity Press, London, UK.
41 Weber, M. (1904–1905) *The Protestant Ethic and the Spirit of Capitalism*, Routledge, Reprint 2001, London, UK.
42 Northcott (2007). The distinction between 'subsistence' and 'luxury' emissions was first discussed in Shue, H. (1993) 'Subsistence emissions and luxury emissions', *Law and Policy*, vol 15, no 1, 39–59. The psychology behind widespread reluctance to even think about – let alone act on – climate change is explored in detail by Marshall, G. (2014) *Don't Even Think About It: Why Our Brains Are Wired to Ignore Climate Change*, Bloomsbury, London, UK.
43 Ricardo, D. (1817) *Principles of Political Economy and Taxation*, Dover Publications, Reprint 2004, Mineola, NY.
44 These policy prescriptions advocated by the International Monetary Fund and the World Bank (which included extensive privatization, deregulation of markets and fiscal policy discipline as well as trade liberalization), are often referred to as the 'Washington Consensus', and powerfully criticized by former 'insider' and Nobel economist Joseph Stiglitz – see Stiglitz (2007).
45 Peter Dauvergne suggests that current global patterns of trade displace our current environmental costs of consumption away from the current rich towards distant (in time and space) ecosystems and vulnerable communities. He calls these environmental and social costs – a direct result of the current unsustainable mass-producing frenzy of powerful multinational corporations – the (ecological) shadows of consumption. See Dauvergne, P. (2008) *The Shadows of Consumption*: *Consequences for the Global Environment*, MIT Press, Cambridge, MA.
46 Gouldson, A. and Sullivan, R. (2013) 'Long-term corporate climate change targets: What could they deliver?', *Environmental Science and Policy*, vol 27, 1–10.
47 Amos, C., Holmes, G. R. and Keneson, W. C. (2014) 'A meta-analysis of consumer impulse buying', *Journal of Retailing and Consumer Services*, vol 21, 86–97.
48 The webpage of the Fairtrade Labelling Organizations (FLO) International provides details of the scheme's certification and active projects around the world (www.fairtrade.net). For a discussion of how current trade patterns have largely failed to both alleviate poverty and improve environmental standards, see Stiglitz, J. E. and Charlton, A. (2007) *Fair Trade for All: How Trade Can Promote Development*, Oxford University Press, Oxford, UK.
49 Oliver, J. (2007) *Jamie at Home: Cook Your Way to the Good Life*, Penguin, London, UK.
50 The UK supermarket chain Tesco launched a carbon-labelling scheme for approximately 20 of its products, ranging from potatoes to light bulbs, in 2008. Consumers were informed about carbon emissions emitted over the life of the product from its earlier stages of production to consumption. The scheme, though, proved to be short lived. In 2012 Tesco dropped its carbon-label pledge, blaming this on costs and failure of other major retailers to follow its lead.
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52 For estimates of the impact of meat production on carbon emissions, see McMichael, A. J., Powles, J. W., Butler, C. D. and Uauy, R. (2007) 'Food, livestock production, energy, climate change, and health', *The Lancet*, vol 370, no 9594, 1253–1263.

7

KYOTO, PARIS AND OTHER INTERNATIONAL ENVIRONMENTAL AGREEMENTS

Climate change as a 'global public good' problem

Extreme weather is already becoming the 'new normal' according to many climate scientists. A recent study claims that already heatwaves that previously occurred once every three years are currently happening every 200 days on average.[1] The year 2014 was the warmest since records began in 1880, and 2015 was even warmer. Several parts of the world are currently experiencing their worst droughts ever (South-East Brazil, California). In 2013, Typhoon Haiyan became the strongest tropical typhoon to hit land, killing more than 6,000 people in the Philippines alone. In 2015, India and Pakistan suffered severe heatwaves, with nearly 4,000 victims of dehydration and heat stroke. The 2003 European – and the 2010 Russian – heatwaves broke all records, each causing the loss of at least 50,000 lives with unprecedented temperatures of around 40°C or more for several weeks. As we discussed in Chapter 2, even if these anomalies are not necessarily or exclusively attributed to climate change, it is now well accepted that rising global average temperature will increase the frequency of extreme weather conditions. The geographic distribution of such events makes it apparent that climate change does not concern just a few countries or people; it is an environmental problem of global dimensions and, hence, requires coordinated global action.

Concerns about rising global temperatures due to anthropogenic GHG emissions became increasingly urgent during the 1980s. The first report in 1990 of the Intergovernmental Panel on Climate Change (IPCC) – the scientific body operating under the auspices of the United Nations to evaluate the risk of global warming – explicitly linked temperature changes to global greenhouse gas emissions and created momentum for global action. The 1992 United Nations Conference on Environment and Development in Rio tabled an agreement on global warming called the UN Framework Convention on Climate Change, building on the scientific evidence of the first IPCC report. Industrialized nations were reluctant to take any strong action against greenhouse gases, and there was no agreement on binding commitments apart from an abstract and modest target of stabilizing carbon emissions at 1990 levels by 2000. This lukewarm response

to the threat of climate change was mainly due to American opposition towards stronger action and reluctance to incur any abatement costs. Developing countries were not expected to reduce their carbon emissions, and almost 200 nations signed the Convention and left Rio, content with a decision committing them to doing very little – or nothing!

Since the ratification of the Convention, there have been annual conference meetings of its parties, with the first held in Berlin in 1995. Opposition to binding targets by many industrialized nations remained fierce (the US and Australia among them), but a decision was taken to negotiate a protocol of compulsory commitments and have it ratified at the third meeting of the parties in Kyoto in 1997. In Kyoto, it became apparent once again that there was no will to take strong action against carbon emissions. Participating countries were coming to the negotiations with conflicting objectives in mind. Many developed and most developing nations were simply not happy to sacrifice current or future income for environmental protection, especially to the extent that they anticipated no severe damages from climate change to their own economies. However, some (but few) countries particularly vulnerable to climate change (especially island nations) had a keen self-interest in reaching an agreement on climate change and curbing global carbon emissions.[2] The rather disappointing negotiations in Kyoto ended with industrialized nations (the so-called Annex-I countries) committing to a very modest target of reducing emissions by 5 per cent during 2008–2012, compared with 1990 levels. In March 2001, the Bush Administration withdrew from the protocol – and shortly after, Australia followed suit.[3] The Protocol finally came into force in February 2005 after the Russian Duma ratified the treaty.

Given the very modest targets (and facilitated by the post-2008 financial crisis and fall in energy demand), most countries did not find it difficult to meet the agreed carbon reductions. As often happens, some countries managed better than others (the EU, for example, reduced its total carbon emissions by approximately 13 per cent compared with 1990 levels, while the official target was close to 8 per cent). Other countries failed spectacularly (Canada stands out, where carbon emissions increased by almost 20 per cent instead of decreasing by 6 per cent!). Closer to 2012, it was becoming increasingly clear that the world was failing to design an ambitious successor to the Kyoto Protocol. The lack of political ambition led to simply extending the life of the existing protocol and comfortably postponing any more serious decisions (for a new treaty) to the future. A second 8-year commitment period (2013–20) of the Kyoto Protocol was agreed upon (at the last minute, in 2012!), with more ambitious targets (a reduction of overall GHG emissions by at least 18 per cent below 1990 levels), which continues to fall far short of what is necessary to stabilize our climate. In the last December 2015 UN Conference on Climate Change in Paris there was a consensus among almost 200 participating nations (both developed and developing ones) on the need to unite forces in the battle against climate change (although there is still little clarity about how good intentions will translate into real action, as has happened in the past!).

Attempts to reach consensus on global action have always been a thorny, nerve-wracking process (and even in the recent 2015 UN Conference on Climate Change, agreement was only reached at the very last minute). At least until now, why has it been so difficult to find common ground and coordinate our actions on climate change? The answer lies in the global nature of the climate change issue. Climate change is a global public problem, which means that all countries will suffer the consequences, though to varying degrees according to geographical accident. Just how much and how fast the climate really will change, and how much any one country will suffer, depends on the behaviour of all the main emitting nations, rather than on any individual actions to minimize damage. This is not necessarily the case for all kinds of environmental pollution. For instance, we can personally choose how much garbage to leave lying around our house, and how much to bin for collection and (hopefully) safe disposal.

More commonly, though, individuals or countries suffer from environmental problems that have originated as side effects of the actions of another party (as we have mentioned earlier on, this is often called 'an externality' in economists' jargon). When the environmental damage is local (as may be the case for local air pollution or deforestation or in the household waste example above), polluters and victims are neighbours, and it may be easier for the latter to claim compensation from the former (unless, as so often, the polluter is a powerful corporation!). For global environmental problems (such as climate change or ozone depletion), the polluter and the victim may be geographically very far from each other. This explains why countries have failed so far to take strong action on averting global environmental damage. Developing countries may suffer from agricultural collapse or increased malaria despite curbing their own greenhouse gas emissions, unless many other states take similar actions. To reverse the argument, countries that do not commit to any binding targets for CO_2 emissions, will still benefit from reduced emissions of Kyoto signatories.[4] As a result of this inability to influence outcomes independently and in a predictable way, there is little incentive for individual countries to take firm action on such global environmental issues.

Carrots and sticks

Incentives (carrots) and sanctions (sticks) can encourage participation in environmental agreements. Developing nations are simply reluctant to sacrifice economic growth for the sake of preventing climate change, and industrialized nations will need to provide financial transfers if we want to see LDCs curbing their own carbon emissions. Much of this can be based on some kind of technology transfer, where we will simply help poorer states replace dirty polluting technologies with carbon-friendly alternatives. Climate finance is another way forward and currently developing nations have been promised a minimum of $100 billion dollars per year by 2020 (and although most acknowledge that this is a completely inadequate amount, they also stress that this is a 'floor' likely to be raised further after 2020).

Such transfers are needed urgently, particularly as China's emissions of carbon dioxide already exceed US levels, thanks to extensive reliance on coal. Of course, this technology transfer has already been happening via the Clean Development Mechanism (CDM), where Annex-I countries meet their Kyoto targets by investing in carbon-saving projects in developing countries. Some very modest progress has taken place in strengthening an adaptation fund already (this, although established in 1997 alongside Kyoto, only became operational in 2010), which helps poorer nations to improve their infrastructure and gradually prepare for changes in climatic conditions. Once developing countries agree on specific binding targets for their carbon emissions, the carbon trading schemes could be extended to all LDCs, creating a global market for them to sell their saved carbon emissions.

While carrots tend to be most popular, sticks are rather difficult to implement. There is no supranational authority authorized to sanction non-cooperative countries that do not meet their commitments. Nobel-laureate economist Joseph Stiglitz has long argued for trade sanctions such as carbon taxes on US exports of fossil fuel intensive products.[5] Similarly, imports of carbon-intensive goods, say from China, should also be proportionately taxed. Such sanctions or taxes could be imposed by the World Trade Organization (WTO), with the organization interpreting non-compliance as a form of dumping (having WTO deciding on the type of sanctions will likely prevent bilateral retaliatory protectionist policies). Non-compliance with a carbon agreement (for example in the form of shortfall of carbon permits) could even be converted to public debt using market prices.[6] The WTO is probably in the best position to impose sanctions in the future, since failure to abide by CO_2 emissions targets will create an advantage in international markets for those energy-intensive industries that fail to comply with their commitments. Most urgently, some mix of carrots and sticks to combat tropical deforestation, responsible for about a fifth of total GHG emissions, requires international agreement to fill one of the most glaring omissions in the Kyoto Protocol.

Carbon trading

Carbon trading markets where emission reduction credits are purchased and sold has been put forward as a flexible mechanism to reduce carbon dioxide emissions and meet binding targets. The way carbon trading works in practice is the following. Nations have a binding cap on the level of carbon emissions they are allowed to emit, which is divided into tradeable permits, quotas or allowances, in tonnes of carbon. Countries face two options or strategies in order to reduce carbon emissions. They may simply reduce emissions at home, or, if the price of permits is low enough, decide to enter the carbon market, go over its limit for CO_2 emissions, and buy permits that compensate for this excessive pollution from another country or producer that has emission permits to spare.[7] An emissions trading scheme of some kind is usually preferred to carbon taxes by environmentalists, since it is a direct policy instrument for constraining emissions. Of course, industry obviously prefers free permits – that

effectively reward the biggest polluters – and has lobbied intensively against auctioning permits. But without taxes or auctions, governments lose an important policy instrument, as we discuss in detail next in Chapter 8.

The trading of pollution permits has functioned successfully even before the implementation of the Kyoto Protocol. In the US, in the mid-1990s, an emissions trading system for sulphur dioxide quotas had been set up to reduce acid rain, and seemed to be effective.[8] The first voluntary carbon emissions trading schemes were implemented in the UK and Denmark; these quickly became merged in 2005 into the European Union Emissions Trading System (EU 149 ETS), which is currently the largest carbon trading programme globally.[9] Participation in the EU ETS scheme is already compulsory for a number of carbon-intensive industries (such as power plants and paper and cement factories), but excludes transport and households.

The European Union trading scheme has been much criticized for the way permits have been allocated to industries. Until 2013 EU governments decided how to distribute permits across sectors and firms, a process that is often called 'grandfathering' (where permits are given out for free rather than sold in an auction, usually to those sectors with historically high levels of emissions). Since 2013, the permits have been allocated through a more centralized benchmark scheme. In early 2005, almost 95 per cent of all permits were given out for free. In the current third phase of the EU ETS scheme (2013–20), more emphasis is given on auctioning versus grandfathering, although still the majority of permits is freely allocated. The system is still very protectionist – sectors considered to be at risk of carbon leakage (that is, where businesses transfer production abroad for reasons of costs related to climate policies) receive free allocations, at least until 2020! – and this covers the vast majority of manufacturing industrial emissions.[10]

The EU ETS trading market operates similarly to any other market with a demand and supply side. Initially, demand and supply conditions determined the price of carbon emissions per tonne between €10 and €20 in 2005. Carbon prices have been on the decline, reaching their all-time low in January 2013 (€2.81) – they have been consistently below €10 since mid-2011. The price of permits has been kept low as too many permits had been distributed, with supply exceeding demand by a wide margin.

The deep and lasting economic crisis in the EU since 2008 certainly also contributed to the persistently low carbon prices. The large allowance surplus banked from the two earlier phases of the EU ETS will also keep carbon prices low at least for the medium term. In the short term, some postponing (called 'back-loading') of auctioning of allowances has been agreed to rebalance supply and demand. In the longer term, a 'market stability reserve' will achieve this, although it is unlikely to be operational before 2019. Since 2010, the total quantity of allowances needs to decrease linearly by 1.74 per cent per year – this is called the 'EU ETS linear reduction factor' and the plan is to increase it to 2.2 per cent after 2021.[11] Since 2013, emissions from aviation fall into the EU ETS scheme, but this is currently restricted to emissions from flights within the European Economic Area.

Beyond 2020 (coinciding with the beginning of the fourth phase of the EU ETS scheme), even more radical measures have been proposed, such as an auctioning of

all carbon permits (with no grandfathering allowed), a reduction of carbon allowances by 43 per cent compared to 2005 levels and the inclusion of nitrous oxide and perfluorinated compounds (PFCs) in the scheme. Any price fluctuations (which often create market uncertainty and discourage investment in renewables) can be further smoothed out with a combination of taxes and transferable allowances between periods (which we discuss in more detail in Chapter 8). What still remains contentious, however, is how efficiently governments will utilize the public revenues they earn from auctioning carbon allowances, and whether a substantial share will be allocated to investment in energy efficiency and renewable energy.

US president Barack Obama had initially committed to a similar US carbon cap-and-trade scheme, which in time could become harmonized and linked to the EU ETS scheme (or even merge), although plans have been put on hold indefinitely (due to congressional Republican opposition, and perhaps also as a result of the observed weaknesses of the EU ETS market). The first step in this direction happened when ten northeastern US states set their own regional CO_2 cap-and-trade system (the Regional Greenhouse Gas Initiative or RGGI), which became operational in late 2008. Unfortunately, things have stalled also on that front, with carbon prices lower than in the EU ETS market and New Jersey suspending its participation in 2011. In comparison with the EU ETS, the RGGI scheme has been relying (from the beginning) almost exclusively on auctions rather than grandfathering to allocate emission permits (and has thus been more successful in defying industry opposition).

Other regional carbon trading schemes exist, such as the Japanese Voluntary Emissions Trading Scheme (since 2005) and the Emissions Trading Schemes in New Zealand (since 2008), California (since 2013), Kazakhstan (since 2013) and Korea (since 2015). China will launch its own national Emissions Trading System (ETS) in 2016, after experimenting with seven regional carbon market pilots in four big cities (including Beijing and Shanghai) and three provinces.

Sooner rather than later there will be a need for all the schemes to merge to avoid multiple pricing of carbon in fragmented markets; there will also be a need to gradually achieve universal participation by both developed and developing nations with concrete commitments to reduce carbon emissions. A more radical (and hence less politically realistic) carbon trading proposal is based on the 'contraction and convergence' framework discussed later in this chapter. Allocating permits according to population would in effect disproportionately benefit developing countries and result in large flows of funds from richer nations to them for the purchase of carbon permits.[12]

The Montreal Protocol: a rare case of success

A rare glimpse of hope in the history of international environmental agreements is the success of the Montreal Protocol, an international treaty designed to protect the ozone layer by gradually eliminating the production of ozone-depleting

chlorofluorocarbons (CFCs).[13] The agreement was reached in 1987 and implemented in 1989. This is in stark contrast to the Kyoto Protocol, which took more than 7 years to ensure broad participation and hence come into force (and was subsequently 'plagued' by inefficiencies in implementation and the repeated failure of numerous UN conferences to reach agreement on any successor treaty). The production of CFCs under the treaty had to be halved by 1999 compared to their 1986 levels. The rate of phase-out of CFCs was in practice much faster than initially expected. By 1990, industrialized countries had already achieved a 20 per cent reduction in the production of CFCs. In the fourth meeting of the parties in Copenhagen in 1992, binding targets became tighter, requiring more to be done in a shorter period of time. The number of restricted substances increased and a gradual implementation of a total ban on CFCs was agreed (with most CFCs being phased out by 1996). Even more remarkably, the Montreal Protocol is the first universally ratified treaty in the United Nations history and endorsed by the US from the very beginning.[14]

To some extent, the inspiration for a treaty on climate change came from the earlier, striking success of the Montreal agreement in restricting CFC production. The outstanding difference, of course, was that the cost of replacing CFCs was minimal, and only affected a few specialized producers. From its inception, it was quite clear that countries were keen to take strong action against CFCs. There was little controversy about the effects of accumulating CFCs in the atmosphere on ozone depletion. Since the discovery of the Antarctic ozone hole in the mid-1980s, a series of satellite pictures proved that ozone depletion was an eminent threat to humanity rather than an uncertain theory yet to be proven.[15] The fact that a thinning of the ozone layer would result in increased exposure to ultraviolet (UV) radiation and hence higher risk of skin cancer was not considered controversial or denied by any major industrial lobby.

Part of the success of the Montreal Protocol certainly had to do with extensive, accurate media coverage, undisputed scientific evidence, and rapid public reaction and broad support. The other part had to do with economics! Industrialized countries, such as the United States, had an incentive to reduce CFC production even unilaterally, because the cost was relatively low. Action by one country would certainly not prevent ozone depletion to the same extent that a simultaneous global effort would have done. But nevertheless, even a small reduction of cancer incidence was considered sufficient to outweigh the rather low abatement cost. As countries started implementing their binding targets, the cost of alternative technology and abatement fell further, making compliance easier. At the same time, a Multilateral Fund for the Implementation of the Montreal Protocol was established to provide funds to developing countries to eliminate CFC production. Projects focusing on modernizing manufacturing processes, encouraging technology transfer and training relevant personnel were financed by the fund. In this way, developing countries were given a financial 'carrot' in order to participate. For those who did not want to take the offer, there was also a financial 'stick', an explicit threat of trade sanctions, which certainly made non-signatory countries think twice![16]

What next?

It is obvious that there is a long way to go before we can hail the Kyoto Protocol as even a successful beginning, especially when we compare it with the Montreal treaty on ozone depletion. It would certainly be unfair to regard Kyoto as a total failure, and it is probably of some use as a starting point. But it could have been a much better starting point if binding targets for emission reductions had been closer to recommendations for more drastic cuts that are realistically needed to stay below the 2°C threshold, as we discussed in Chapter 2.

The very fact that industrialized nations, such as Australia and Norway, were even allowed increases in their carbon emissions during Kyoto's first commitment period, suggests that there has been little enthusiasm to take strong action against climate change. The Kyoto Protocol should have quickly paved the way for a much more ambitious treaty with universal participation – unfortunately, it turned into a long-lasting second-best deal in the absence of agreement for something to succeed it. Perhaps even more importantly, as environmental economist Dieter Helm puts it, Kyoto would have been more successful in tackling global GHG emissions, if it were based upon carbon consumption rather than production, which currently shifts responsibility away from the richer nations – namely the major importers of energy-intensive products from China and elsewhere.[17] Of course, if participation in the treaty was unanimous, such a distinction between consumption and production (or fears of firms losing competitiveness due to the costs of environmental regulation) would have been irrelevant.

Whatever a post-Kyoto treaty will look like, it is essential that more radical reductions of carbon emissions are attained, as well as a more active involvement of developing countries. The December 2015 UN Conference on Climate Change in Paris achieved for the first time an agreement on the 2°C temperature rise *target*, including almost all developed and developing nations (and ideally limit this to below 1.5°C). There is even an ambitious plan to achieve a completely carbon-neutral world during the second half of the century, where any carbon emissions will be fully absorbed by our natural carbon sinks. Euphoric reactions from politicians after two weeks of haggling glossed over the complete absence of binding policies such as carbon pricing or other sanctions on polluters, and adequate funding for mitigation by poor countries. Reliance on 'Intended Nationally Determined Contributions' (INDCs), even with five-year reviews, but no real incentives to overcome 'free-rider' problems, is unlikely to avert dangerous and perhaps irreversible climate change. Indeed, current INDCs allow cumulative emissions that would take the world close to a rise of around 3°C, enough to ultimately melt all polar ice.

For reasons of equity, there is much support for a 'contraction and convergence' scheme, which as we mentioned earlier would provide allowances for carbon emissions to all countries in proportion to their population. This also requires agreement among the main emitters that global emissions should be capped, by issuing a total number of permits that represents *less* than current global emissions.

The cap should then decrease over time (so that we can ideally reduce our global emissions by at least 90 per cent by 2050, or earlier). Developed countries would receive fewer permits than their current emissions, and would thus have to buy excess allowances from poor states that emit less than their allocated permits. This would generate a flow of aid from rich to poor countries, declining inequality and convergence of per capita income levels, though without any implication that actual equality would be reached in the foreseeable future.[18]

Another radical scheme, which secures rights to development in a carbon-constrained world, is the 'Greenhouse Development Rights' framework proposed by the Heinrich Böll Foundation and Christian Aid, among others. The main idea is that rich nations should face disproportionately larger obligations for reducing carbon emissions for two reasons. First, because they have greater *capacity* to collect green taxes and finance environmental mitigation, since the majority of their populations have already satisfied their basic needs (by earning above a 'development threshold level' of $20 per day). Second, because they have larger *responsibility* for the climate change threat, having produced most of the cumulative GHG emissions. The capacity and responsibility of individual countries would then jointly determine the obligatory financial contributions per country to an international fund financing mitigation and adaptation, with low-income nations left virtually off the hook until they develop sufficiently.[19]

Although such schemes may appear to be overly generous to developing countries, they do give them appropriate incentives for abatement, and also provide for large transfers to the least industrialized nations. Under Kyoto, on the contrary, non-Annex-I developing countries have been facing no penalties for growing emissions, or incentives for mitigation! The schemes, though, however appealing in terms of achieving equity and preventing climate change, appear to be politically unrealistic at the moment.

Any new treaty would need to focus more on long-term expected outcomes and necessary policies, rather than specify very modest targets for a small number of countries and for a short period of time. So far, Kyoto has focused too much on technical details and targets rather than on how to realistically achieve climate stability. Specifying new stricter targets for all economies, the US and China included, will have little effect unless countries comply fully with their specified obligations. Clearly the 2015 Paris Agreement is very far from meeting these requirements, and it remains to be seen whether the new recognition of the problem by all countries will actually lead to effective mitigation policies.

While trade restrictions can provide the 'stick' for participation and compliance (either in the form of carbon taxes or trade sanctions) and financial and knowledge transfers the 'carrot', action may well need to be taken at a more micro level. Climate change is a much more complex environmental problem than ozone depletion, depending on multiple greenhouse gases (i.e. carbon dioxide, methane, nitrous oxide, hydrofluorocarbons) emitted across numerous sectors. Scott Barrett proposes that, rather than having a single treaty regulating the production of all GHGs in all sectors, a more decentralized approach would be more

effective. Sectoral agreements could focus on relevant greenhouse gas emissions across sectors (as in the aluminium and steel industry), with a better chance for full participation and compliance among few producers. Compartmentalizing a broad and complicated issue, such as climate change, by adopting several smaller (and more focused) agreements, can offer flexibility – if negotiations stall in one issue area, faster progress can be made in others. This multiplicity of smaller (but interactive) agreements, for instance, has worked more efficiently in the weapons and trade regimes.[20]

Carbon taxes are most economists' preferred incentive for mitigation, and can be implemented at the national level with major co-benefits from reducing local pollution. In the form of a 'carbon fee and dividend', where receipts are returned as equal payments to all citizens, they could in principle gain majority support. However, global harmonization is needed for effective mitigation of climate change, and this again raises all the problems of international agreement reviewed here, including international distribution of 'dividends' to compensate poor countries.

Low energy prices are likely to delay a shift towards renewable energy and carbon abatement, and without really far-reaching new agreements and policies, changes will come too late to avert the high risk of catastrophic climate change! Funds to assist developing countries have been established, but the focus is often on adaptation rather than mitigation (such as the Adaptation Fund financed by levies on Clean Development Mechanism projects). It is critical that developed nations accept responsibility and assist poorer countries to embark on a carbon-friendly development track. Levying carbon taxes on products and imports (and hence overcoming WTO objections), while simultaneously offering easy access to existing carbon-saving know-how, would level the playing field. Whether governments will be politically capable of overcoming special-interest opposition for the sake of long-term survival goals, is of course something that remains to be seen.

Conclusions

Climatic stability is a global public good: Earth's climate is shared by everyone on the planet, which decreases individual incentives for its protection. As a result, we face a tragedy of our global commons, with Earth's climate subject to overexploitation. Each country's and individual's polluting behaviour contributes to the increase in GHG concentrations, and unilateral clean-up actions, if not followed by broader participation, normally entail higher costs than benefits. Cooperation among countries is vital for avoiding the climate catastrophe towards which we are heading, but the right balance of economic and political instruments needs to be in place to minimize free-riding and maximize compliance.

Up until now, climate change negotiations have revealed the conflicting interests of participating countries rather than any strong will for concerted action. Many countries (both developed and developing) have been reluctant to commit to drastic

cuts of their greenhouse gas emissions. Fears of trade leakage (relocation of industries abroad) or reduced economic growth for the sake of abatement have prevented setting ambitious long-term goals, capable of preventing a climate catastrophe. The December 2015 UN Conference in Paris achieved for the first time an almost universal agreement on the 2°C temperature rise target, but with only seriously inadequate policy commitments. The Kyoto Protocol, with its modest emission targets, has been a first, although insufficient, step in the right direction. Its Joint Implementation scheme, Clean Development Mechanism and carbon trading system have provided innovative, cost-effective ways for emission cuts. Nevertheless, with emission targets specified only for few industrialized countries, and no sanctions for exceeding them, global GHG emissions can in practice increase without limit (as has been happening, with the exception of very short-term modest declines during global recessions, such as after the 2008 financial crash.

Although there is currently little clarity about how this post-Kyoto agreement will ultimately be implemented, there needs to be a common but differentiated responsibility, with industrialized nations committing to more drastic emission cuts and generous transfers of funds and technology to developing nations. Countries that decide to abstain from a concerted effort against climate change should face trade sanctions, to provide compensation for carbon-saving producers. Similar retaliatory measures would need to be in place for countries failing to comply with their targets. Having everyone on board is crucial for a treaty to be successful. Climate change is a global public problem, and only action at a global level can prevent the climate catastrophe towards which we are currently heading.

Notes

1 Fischer, E. M. and Knutti, R. (2015) 'Anthropogenic contribution to global occurrence of heavy-precipitation and high-temperature extremes', *Nature Climate Change*, vol 5, 560–564.
2 It is no coincidence that Fiji, Antigua and Barbuda, Tuvalu and Maldives, with economies little dependent on carbon, were the first four countries to ratify the Kyoto Protocol in 1998.
3 Australia changed course and ratified the protocol in December 2007, shortly after Kevin Rudd's newly elected government assumed office.
4 This is related to the 'non-rival' characteristic of public goods and bads. The amount of environmental protection enjoyed by any person or country (e.g. in the form of climate change mitigation) does not reduce the amount of protection offered to any other party.
5 Stiglitz, J. E. (2015) 'Overcoming the Copenhagen failure with flexible commitments', *Economics of Energy and Environmental Policy*, vol 4, no 2, 29–36.
6 Gollier, C. and Tirole, J. (2015) 'Effective institutions against climate change', *Economics of Energy and Environmental Policy*, vol 4, no 2, 5–27.
7 Emissions trading is often referred to as 'cap and trade' in the climate change jargon.
8 For an early discussion of the successful US experience of the SO_2 cap-and-trade scheme, see Stavins, R. N. (1998) 'What can we learn from the grand policy experiment? Lessons from SO_2 allowance trading', *The Journal of Economic Perspectives*, vol 12, no 3, 69–88. Nevertheless, the SO_2 cap-and-trade scheme has also been criticized for failing to achieve maximum economic efficiency by grandfathering rather than auctioning SO_2 allowances – see Kroes, J., Subramanian, R. and Subramanyam, R. (2012) 'Operational

compliance levers, environmental performance, and firm performance under cap and trade regulation', *Manufacturing and Service Operations Management*, vol 14, no 2, 186–201.

9 Details of the EU ETS scheme can be found at the webpage of the European Commission: http://ec.europa.eu/clima/policies/ets/index_en.htm.

10 For a preliminary evaluation of the third phase of the EU ETS, see Stenqvist, C. and Åhman, M. (2014) 'Free allocation in the 3rd EU ETS period: Assessing two manufacturing sectors', *Climate Policy*, 27 November, doi: 10.1080/14693062.2014.979130, as well as Sartor, O., Palliére, C. and Lecourt, S. (2014) 'Benchmark-based allocations in EU ETS Phase 3: An early assessment', *Climate Policy*, vol 14, no 4, 507–524.

11 See Betz, R. (2015) 'Emissions trading in practice: Lessons learned from the European emissions trading scheme', in S. Managi (ed.), *The Routledge Handbook of Environmental Economics in Asia*, Routledge, London, UK.

12 See Saunders, F. P. (2015b) 'Planetary boundaries: at the threshold . . . again: Sustainable development ideas and politics', *Environment, Development and Sustainability*, vol 17, no 4, 823–835, as well as Tickell, O. (2008) *Kyoto 2: How to Manage the Global Greenhouse*, Zed Books, London, UK, for a discussion of a 'contraction and convergence' based cap-and-trade scheme and the political resistance it is likely to face.

13 A detailed discussion of the Montreal Protocol and its relative strengths, from which this subsection draws, can be found at Barrett (2003), chapter 8, as well as Jacobs, J. R. (2014) 'The precautionary principle as a provisional instrument in environmental policy: The Montreal Protocol case study', *Environmental Science and Policy*, vol 37, no 1, 161–171.

14 Details about the Montreal Protocol and its subsequent amendments can be found at the webpage of the United Nations Environment Programme: http://ozone.unep.org

15 See Farman, J. C., Gardiner, B. G. and Shanklin, J. D. (1985) 'Large losses of total ozone in Antarctica reveal seasonal ClOx/NOx interaction', *Nature*, vol 315, 207–210.

16 For an interesting discussion on the role of trade sanctions in international environmental agreements, see McEvoy, D. (2013) 'Enforcing compliance with international environmental agreements using a deposit-refund system', *International Environmental Agreements: Politics, Law and Economics*, vol 13, no 4, 481–496, as well as some earlier studies: Barrett, S. (1997) 'The strategy of trade sanctions in international environmental agreements', *Resource and Energy Economics*, vol 19, no 4, 345–361, and Werksman, J. W. (1992) 'Trade sanction under the Montreal Protocol', *Review of European Community and International Environmental Law*, vol 1, no 1, 69–72.

17 Helm, D. (2008) 'Climate change policy: Why has so little been achieved?', *Oxford Review of Economic Policy*, vol 24, no 2, 211–238. See also Steininger, K., Lininger, C., Droege, S., Roser, D., Tomlinson, L. and Meyer, L. (2014) 'Justice and cost effectiveness of consumption-based versus production-based approaches in the case of unilateral climate policies', *Global Environmental Change*, vol 24, no 1, 75–87.

18 It is useful here to remind the reader of some rather basic but nevertheless important figures. The developed economies currently contain about 15 per cent of the world population, while they account for almost 55 per cent of global GDP. The declining population share of the developed economies (likely to fall much below 10 per cent by mid-century) will suggest that proportionately more carbon entitlements will be allocated to poorer nations over time.

19 See Baer, P. (2013) 'The greenhouse development rights framework for global burden sharing: Reflection on principle sand prospects', *Wiley Interdisciplinary Reviews: Climate Change*, vol 4, no 1, 61–71.

20 Greenspan Bell, R., Ziegler, M. S., Blechman, B., Finlay, B. and Cottier, T. (2012) *Building International Climate Cooperation: Lessons for the Weapons and Trade Regimes for Achieving International Climate Goals*, World Resources Institute, Washington DC.

8

INCENTIVES FOR MITIGATION

Carbon taxes and emissions trading

Market forces are not enough

Carbon emissions will not be reduced by international agreement, government declarations or even commitments, unless there are clear economic incentives for abatement, or, alternatively, credible legal penalties for failure to comply with appropriate regulation. As we saw in Chapter 7, all these have been conspicuous by their absence in the Kyoto Protocol. Rising prices for fossil fuels for the decade up to mid-2008 provided an incentive in the right direction, but, together with related food price inflation from 2006, also caused hardship for poor people everywhere, and a massive transfer of income to the oil-producing states. Their growing wealth increased the power of authoritarian rulers, as in Russia or Saudi Arabia.

This changed dramatically with the global recession of 2008 and collapsing commodity prices (which remain subdued), followed by the fracking boom in 'unconventional' shale oil and natural gas that aided a US transition from import dependency to self-sufficiency and major export potential. Renewed weakness in the global economy, particularly in China and many developing countries, has helped to push oil prices down to about $30 per barrel in early 2016. In real, inflation-adjusted terms, this is the lowest level for 40 years. Thus, market prices of fossil fuels have not been persistently high enough (yet) to outweigh the huge government subsidies they receive and generate the really large-scale investment in alternative energy that is needed to reduce the risk of catastrophic climate change.

When the Organization of the Petroleum Exporting Countries (OPEC) first dramatically and suddenly raised oil prices in 1974, there was a severe, worldwide recession in consequence. Energy saving was encouraged, and efficiency improved in the following years, but oil exploration and development of new fields also received a major boost. Oil prices declined steeply over the next decades, as new fields were developed and production expanded, particularly by non-OPEC countries. Most recently, the US fracking boom and refusal of OPEC producers to curtail output have helped to keep prices low.

Coal remains the cheapest, most abundant and 'dirtiest' fossil fuel, though its use may peak soon in China, which produces half of the world's output, as pollution there becomes a major political problem. Most of the world's electricity is still

generated by fossil fuels, including 6 billion tonnes of coal per year. GHGs and local pollution from fossil fuels not only have devastating effects on health, but will also lead to catastrophic climate change if they continue unchecked. Lack of policies to correct what Nicholas Stern called the 'greatest of all market failures' and curb emissions, is more appropriately recognized as the most disastrous *government* failure in history. Even more perversely, fossil fuels (and nuclear power) continue to enjoy gigantic public subsidies compared to very limited support for renewable energy, under the influence of their powerful and well-established, traditional lobbies.

The main policy options for reducing emissions are well known: carbon taxes, related tradeable permits for emitting carbon, regulations such as limits on vehicle emissions or building insulation standards, and subsidies for energy saving and renewables, which will be discussed in detail below. All have been tried and tested in many different contexts, though not, of course, on a scale sufficient to have had much effect on the global problem of climate change. Any of these measures will reduce the demand for fossil fuels, and hence slow down the rate of price increase. Any form of carbon pricing will, of course, raise the price of fuel – and of energy-intensive products – for the final consumer, so investment in alternatives, such as cheap public transport and alternative energy, will be encouraged. Revenues from carbon taxation (or from auctioning carbon permits) can also be used to reduce taxes on labour for lower-income groups – or subsidize clean technology – which in turn will reduce unemployment, and help to gain political acceptance.

Simply returning the revenues from a carbon tax to all citizens as a uniform lump-sum transfer was first suggested at the height of the OPEC oil crisis in 1974 by David Wilson, a British–American engineer at MIT, but his idea was ridiculed by economists and others at the time. It was prominent climate scientist James Hansen who has finally popularized the same idea as a 'fee and dividend' scheme, but without acknowledgement of Wilson's pioneering insight.[1] Since the rich have much higher carbon footprints than the poor and middle classes, a majority would benefit from this scheme, though many economists claim that it would be less efficient than a reduction of distortionary taxes.

However, another major political advantage of 'fee and dividend' is that government discretion – and hence scope for corruption and lobbying – is virtually eliminated by the transparent and well-defined redistribution of *all* revenues as *equal* monthly cheques to *all* citizens (with smaller allowances for children). In many countries there is frequently a widespread public distrust of government and a general perception that public revenues are often wastefully or fraudulently used – such a 'fee and dividend' scheme can at least partly alleviate such concerns. The huge income transfers from the rest of the world to the fossil fuel producing countries, and the various negative consequences, will obviously also be reduced by carbon fees or taxes. While national schemes would of course be the easiest to initiate, and in the biggest polluters like the US and China could also have a global mitigation impact, the ideal, globally harmonized carbon tax runs into the same kind of international coordination problems we discussed in the previous chapter.

While the principle of carbon taxation has gained strong support from economists across the political spectrum, agreement on an adequate level and rate of increase of this tax will also be much more difficult.

In Chapter 9, we explain why the widely discussed 'marginal social cost of carbon' (as the 'optimal' carbon tax) is not a meaningful concept in the face of potentially catastrophic climate change. Instead, the priority must be to minimize the *probability* of catastrophe, *combining* economic and political considerations to maintain public support for radical mitigation. The 'optimal' carbon tax is just one component of a *package* of policies subject to political constraints, which cannot be defined by the usual 'optimal tax' calculations (and not least because the ultimate penalty includes the destruction of human civilization).

Regulation

Mandatory requirements, such as insulation and efficiency standards for buildings and appliances, cannot cater for differences in individual tastes or technology, and are therefore often criticized by economists as 'command-and-control' measures. With a high-enough tax on carbon, it might be argued, 'Why not leave energy consumption decisions to private individuals?' There are various arguments against this position. There is much potential for energy saving – both by households and industry – that is privately profitable, but these opportunities are frequently neglected for several reasons. Poorer households usually lack the knowledge, funds or access to credit required for investment in energy saving and efficiency, even when the investment could be funded by saving future fossil fuel costs. This problem has, of course, become more severe with the credit and banking crisis after 2008, and increased risk aversion by lending institutions. Finally, the considerable market power of traditional electricity suppliers, with large, centralized power stations, is threatened by the entry of small, decentralized units with combined heat and power (CHP), which can double their energy efficiency. The big producers have thus used their considerable influence to hinder the development of competing, decentralized and alternative power generation. These suppliers do not profit from energy saving, and so often do not encourage investment by customers that would reduce their sales.[2]

Safety standards for buildings, vehicles, toxic emissions and in industry, are widely accepted (though invariably resisted by lobbyists initially), so there is a need for public education about the role of energy saving in reducing the risks from continued global warming under business as usual. One component of this education would be to require explicit and transparent labelling that reveals the carbon 'footprint' of all products. This would help the growing number of environmentally responsible consumers to make their decisions accordingly, and perhaps alert others to the consequences of their irresponsibility. There is increasing evidence that price 'signals' on their own do not generate optimal decisions when economic actors are not entirely informed about all the effects of their actions. Consumers, for example,

are generally quite uncertain of their own energy consumption and carbon impact from domestic, travel and other activities, and respond more to given financial or other incentives when they know the effects of their actions on the environment. 'Smart meters', which display the rate and cost of domestic energy use at any time, similarly encourage economy.[3]

Any kind of environmental regulation invariably faces vehement opposition from the biggest polluters, who have the most to lose. The benefits of lower emissions are generally spread over a large population, and, in the short run at least, may be small or difficult to identify. Each of many individual beneficiaries has less reason – and fewer resources – to campaign for the regulation, than the major polluters have for opposing it. The shifting of jobs and industry to a less regulated (and more polluted) environment is a common threat by businesses, lobbying against environmental regulation, though there is little evidence that such regulation has so far been an important factor in outsourcing decisions.

Some types of emissions come from many, widely dispersed sources, such as vehicles, household appliances and buildings, which would be difficult to monitor and attribute individually. Hence, it is more sensible to tax fuel inputs, but mandatory standards for efficiency or average car emissions per kilometre can also help to accelerate the introduction of new and cleaner technologies, albeit in the face of customary protest from the affected manufacturers. When polluters, such as motorists, are actually a majority of the population, the political obstacles to serious mitigation measures are enormous. Major investments in public education, as well as in the alternatives of attractive and subsidized public transport and cycle facilities, are preconditions for progress. Simply banning inefficient incandescent light bulbs, pioneered by Australia, is a less controversial, long-overdue example that reduces both private costs and GHGs.

To realize the full potential of declining costs of alternative energy, new grid and other infrastructure will be needed, together with the appropriate regulatory framework, as discussed in Chapter 9. Efficiency standards can also provide an important incentive for innovation. Investment for research and development (R&D) to produce new energy-saving products and processes is often hampered by uncertainty about future prices and demand. Standards, however, provide a definite (and sometimes costly) target to meet if the firm is to stay in business, so appropriate innovation becomes a necessity, rather than a risky gamble on future market conditions.

Precisely for this reason, business lobbies typically claim that new standards, such as planned EU limits on car emissions, cannot be met in time without major losses of jobs and market share (the current limit of 130 grams of CO_2 per kilometre for new cars is only required to drop to 95 grams by 2021, thanks to heavy-handed German lobbying). Campaigns for weaker requirements, or postponement of their introduction, are usually successful, but can seriously delay technical progress. For example, since the German manufacturers of the largest and most polluting cars have only been subject to weak EU emissions regulation, they have been left far behind by their competitors in Japan and elsewhere in

the development of low-emission, hybrid and electric vehicles. The Volkswagen (VW) emissions testing scandal of 2015 is only the tip of the iceberg of a widespread and long-standing problem in pharmaceutical and chemical – as well as automobile – industries (as discussed in Chapter 3): lax regulators accepting manufacturers' claims and selective test results about their own products, instead of rigorous and independent safety studies.

Serious threats to health from substances – such as asbestos in buildings, tetraethyl lead in petrol, or smoking in public rooms – have finally led to widespread bans in many countries, after decades of deceptive lobbying and false claims by the industries.[4] Lung cancer sometimes only emerges after decades of exposure to carcinogens, similar to the time frame in which rising emissions of GHGs under business as usual will have disastrous effects on the poorest and most populous countries. Though most people in Europe, at least, believe that climate change is a serious problem, there is little awareness that non-toxic CO_2 is actually a lethal threat to many in the long run, endangering far more people than the worst of the traditional pollutants ever affected. And of course, there is no widespread support, as yet, for far-reaching and effective mitigation policies that do require changes in lifestyle and consumption patterns.

Another objection to tougher standards for energy efficiency, is that low-income families may be unable to afford the initial investments required. Regulation may thus need to be supplemented with a programme of subsidies or tax relief for poorer households, to avoid inequity and increased inequality. Similar problems arise when oil prices rise dramatically, as they did in 1973–74, and until July 2008 in the pre-crisis boom, or from carbon 'pricing' through taxes or permits. The disruptive effects of *large* price jumps, and the costs of adjustment to price change in general, are the fundamental reasons why radical mitigation cannot be 'left to the market' to respond to carbon taxation. The *rate* of response to *non-disruptive* carbon taxes, even with predicted increases over time, would be much too slow to avert the threat of catastrophic change. As developed in the next two chapters, large-scale government involvement through both regulation, and funding of energy saving, renewable energy and the necessary 'smart grid', international infrastructure is urgently needed. And as an added bonus, this investment would in fact pay for itself through the multiplier effect in the many currently depressed economies with persistent, high un- and under-employment, and interest rates close to zero (where monetary policy such as 'quantitative easing' is ineffective).

There are, of course, many examples of well-intentioned but entirely counter-productive regulation. EU legislation requiring that 5 per cent of petrol and diesel consist of biofuel by 2010 (and 10 per cent by 2020), along with huge subsidies for first-generation biofuels in the EU and the US, is actually *increasing* carbon emissions – as well as food prices – and also accelerating tropical deforestation. We discuss biofuel costs and benefits in more detail in Chapter 9, and show how directly destructive – and expensive – current policy is, while diverting valuable resources from development of improved biofuels, that do have a real potential for making a major contribution to mitigation.

Taxes and permits

Establishing a substantial price for carbon emissions is essential to provide the right incentives for abatement. Taxing all fossil fuels as petrol is taxed in the EU would be the simplest approach – individual countries could initiate this independently, and ultimately harmonize to achieve the ideal of a uniform, global carbon tax. Revenues from such a carbon tax could be used to reduce taxes on 'goods' such as labour, or returned as equal 'dividends' to all citizens as noted above, and hence avoid economic disruption and boost employment, without raising the total tax burden. A steadily rising carbon tax would provide a predictable planning framework, without the problems caused by fluctuating permit prices under a cap on emissions, as in the EU ETS. Though most economists favour shifting taxes from 'goods' to 'bads' such as emissions, there is very little public understanding of the benefits, and much irrational prejudice against any new tax after decades of neoliberal media domination and distortion.

However, as explained in the previous section, even in a revenue-neutral framework, 'too-large' tax hikes would be disruptive, and a purely market-driven response to modest tax increases would be much too slow to avoid dangerous climate change. Hence, essential *complementary* measures, such as rapidly increasing the supply of renewable energy and building large-scale, international 'smart grids' and improved public transport, would also require substantial public subsidy. We discuss the global costing issues of radical mitigation in the next chapter, and the multiple benefits of related green fiscal policy in the concluding Chapter 10.

As explained previously in Chapter 7, free distribution of carbon allowances (and subsequent trading) in the earlier phases of the EU ETS has allowed huge windfall profits for the biggest polluters, and had little effect on emissions. If permits were auctioned, as is beginning in the third phase – instead of being freely allocated according to past emissions (grandfathering) – revenues would accrue directly to government, as in a tax system. Issuing too many permits and setting the cap on emissions at too high a level in the EU, has meant that the price of carbon has been much too low to provide any real incentive for abatement so far. In the long run, the cap can be reduced from year to year, and the rising price of (fewer) permits over time would mimic the effects of an increasing carbon tax. However, a fundamental disadvantage of emissions trading is that, by capping the quantity of emissions in any period, permit prices may fluctuate excessively with unforeseen shifts in demand. This uncertainty naturally increases the riskiness of investment.

These problems can be mitigated by combining features of taxes and emissions trading in 'hybrid' systems. Thus, the fluctuation of permit prices can be restricted by 'banking' and 'borrowing' permits – supplying extra permits when the price exceeds an announced 'ceiling', and withdrawing permits when the price falls below a 'floor'. The extra permits are essentially 'borrowed' from future allocations, and caps in later years have to be reduced accordingly to maintain the target declining trend in emissions. Of course, these modifications would increase

complexity and administrative cost, but they would also offer insurance to users and allow more efficient planning.

In a (pure) tax system, by contrast, the price of carbon is fixed in the short run – between preannounced increases in the tax rate – and emissions fluctuate with changes in demand. Since the total stock of GHGs in the atmosphere is hardly affected by the flow of emissions in any short period of time, this is harmless provided that the long-term, downward trend in emissions is maintained. However, the response of the economy to a particular path of rising carbon taxes is very difficult to predict, and also depends on a host of other, complementary and regulatory measures. The challenge policymakers face is to set carbon taxes at an appropriate level initially, and to agree on a credible path of future increases that will be both acceptable and effective in conjunction with complementary policies, without being disruptive and hence counterproductive. As well as the usual obstructive industry lobbying against any taxation, there is also likely to be political pressure to raise a planned carbon tax if emissions are declining more slowly than anticipated, so uncertainty over the price of carbon can never be entirely eliminated. As we have already mentioned in Chapter 7, carbon trading is often seen to be vulnerable to industry lobbying for free distribution, which is certainly eroding EU plans for permit auctions. However, any attempt to impose carbon taxes would also be subject to lobbying for tax breaks and exemptions by major energy users, so neither system is corruption proof, and above all, both need broad political support for rapid and effective implementation.[5]

The most successful carbon tax to date still seems to be the little-noticed example introduced in the Canadian province of British Columbia in 2008, which is generally regarded as a model for other regional or national initiatives. The tax is highly progressive[6] and revenue neutral, refunded in the form of tax reductions and tax credits for low-income residents, covers 70 per cent of emissions, and peaked at under $30 per tonne of CO_2 in 2012, which is, though, still too low to have a major effect. Even so, according to the Carbon Tax Center (CTC),[7] per capita emissions in British Columbia have declined by about 9 per cent since its introduction, while emissions in the rest of Canada rose slightly. In contrast to the usual dire predictions prior to introduction, the tax seems to have had no negative effects on the economy. It is simple and transparent, and remains popular with voters, while no loopholes have been allowed, in spite of lobbying attempts.[8]

The other example of a comprehensive carbon tax was introduced in Ireland in 2010 explicitly to raise revenue instead of an income tax hike, under the draconian, recessionary–austerity diktats of the 'troika' comprising the European Commission, ECB and IMF. The tax has reduced emissions, which declined even as the economy began to grow again after the recession in 2011, while it is judged to have been much less disruptive than alternative income tax rises would have been, and as in British Columbia it has gained wide acceptance. Though quite limited, these examples do suggest that carbon taxes can be politically feasible with quite different designs, and have potential to become important instruments for radical mitigation if they continue to rise steadily over time.

In contrast to these success stories, the national carbon tax introduced in Australia in 2012 (as a compromise measure to enable a coalition with the minority Green Party) was repealed by newly elected, conservative and climate science denying Prime Minister Tony Abbott (who was replaced by Malcolm Turnbull in 2015). Though not supported by either of the main parties, the tax was effective, as emissions started to decline after introduction, but began to rise again when the tax was removed in 2014. The tax was designed to be progressive by simultaneously increasing the tax-free income threshold from AUS$6,000 to AUS$18,200 (in 2012, with plans to increase this ceiling further in the future) in combination with direct payments (the so-called Clean Energy Advances) for low- and middle-income households.

Another much-cited earlier example, where strong opposition by lobby groups led to removal of a tax, is the 'fuel price escalator' (FPE) in the United Kingdom. The key idea was that petrol taxes would increase year after year above the rate of inflation. This continuous increase in petrol taxes was envisaged to reduce both transport pollution and the pressure to convert green space into motorways, but unfortunately it was not accompanied by the necessary, complementary investment in affordable public transport. The tax that was initially introduced in 1993 had to be dropped in 2000 as a result of a series of very disruptive protests led by lorry drivers and farmers. The protesters blockaded the fuel distribution network, creating severe fuel shortages in many parts of the country. The general public reacted with panic and the government responded by dropping the FPE.

Nordic countries have had selective carbon taxes for a long time, but these countries' success in reducing emissions owes more to explicit support for energy efficiency and renewable power with regulation, subsidies and community involvement. Leading the race, although with few natural resources other than wind, Denmark is aiming for carbon neutrality by 2025, with generally strong popular support, and currently produces over 40 per cent of its electricity from mainly onshore wind power as world leader in the field. The Scandinavian countries, again headed by Denmark, have the highest marginal – and overall average – tax rates among developed nations, with none of the negative incentive effects or extensive evasion predicted by standard economic models in public finance. In spite of the evidence, all these negative effects remain an unassailable part of neoliberal ideology.[9]

It is important to emphasize that this green transition has not been at the cost of economic growth, as fossil fuel lobbies and their neoliberal supporters never tire of warning. In spite of high and progressive taxes, the rate of growth of productivity or output (GDP) *per hour worked* since 1970 has been higher in all the Nordic countries than in the US. Misleading comparisons of *per capita* GDP are often made, neglecting the important fact that some of this productivity growth has been used to reduce hours worked per worker, with Denmark recording one of the largest increases in leisure time, and lowest working hours, with important benefits for work–life balance.[10] At the same time, real wages for most workers have kept pace with productivity growth, in stark contrast to Anglo-American experience. Not

coincidentally, and as emphasized in Chapter 4, Denmark and the other Nordic states regularly appear among the top ranked in international life satisfaction or happiness surveys, well above the US and UK with their culture of overwork for full-time employees, and their failure to maintain wage growth in line with productivity growth for most workers.

Another market instrument that has received a lot of attention in recent years is the so-called *feed-in tariff* (FIT). This incentivizes individuals to participate more actively and directly in the production of green energy. Individuals who own a FIT renewable electricity generation facility (for instance, a rooftop solar photovoltaic system) receive a set price for the electricity they produce and provide to the grid. Utility companies typically enter into long-term contracts with those individuals owning the FIT facilities at rates above the retail price of electricity. The scheme has been particularly successful in Germany, where it assisted the transition to renewable energy in combination with a booming solar manufacturing sector (which, however, has been devastated by increasing competition from China in recent years).

Nevertheless, in spite of its manifest failures, EU carbon trading is doubtless here to stay, and is being slowly improved and extended over time. Perhaps even more importantly, China has been experimenting with regional emissions trading, and plans to introduce a national system in 2016. US President Obama failed to deliver any national carbon pricing scheme following campaign promises, although the idea was supported by economists from across the political spectrum, and congressional support might have been possible in his first term.[11] Sanctions on carbon-intensive imports from countries such as China have also been proposed by prominent economists, but so far nowhere implemented.

In the long run, national or regional cap-and-trade (or tax) systems should, of course, be harmonized to allow efficient international carbon trading, with the same carbon price in all markets. Such an evolutionary development from initially independent systems will provide governments with (growing) auction revenues to help gain public acceptance. This route seems to be politically much more realistic than plans that depend on far-reaching and comprehensive, international agreement, in order to implement an ideal, harmonized global cap-and-trade (or carbon tax) system. With fossil fuel prices not expected to rise again in the near future, the political climate for carbon pricing in some form could become more favourable as global warming and polar ice loss both accelerate, while the health costs from fossil fuel burning become ever more apparent.

Many variants of global cap and trade have been proposed, usually based on the idea of a fair or equal per capita distribution of allowances to all countries. Rich nations with high per capita emissions would then have to purchase extra allowances from poor countries, so carbon trading would be coupled with large flows of funds or aid from the developed to the developing economies. Politically, this represents a major additional obstacle to attaining significant carbon reduction in the advanced economies. These proposals are reviewed by environmental writer Oliver Tickell in his book *Kyoto 2*, and have little prospect of realization at the moment.

Unfortunately, the same problem arises for Tickell's preferred alternative, which is a global auction of permits to primary energy producers. This would be administered by an international authority, which would also distribute the proceeds to help the victims of climate change and invest in alternative energy. Such a body would require enormous powers and the full cooperation of national governments to avoid cheating, and, with around a trillion dollars of annual income to distribute worldwide, would also be subject to immense lobbying pressure for allocation of the funds. Given the weakness of today's United Nations, and the strength of international divisions, it seems utopian to expect national governments to relinquish control of such gigantic permit auction revenues from their domestic energy producers. The issues of providing foreign aid in general, and mitigating climate change, probably need to be kept separate to avoid blocking the latter with even more obstacles than already provided by existing lobbying.

Conclusions

Carbon taxes have been successful wherever tried, but the Nordic examples show that direct government and community involvement is a much more important component of radical mitigation. It remains to be seen whether taxes or 'fee and dividend' schemes will proliferate, or whether other countries will follow the example of the EU and China, and develop their own carbon trading systems, which may be more acceptable with at least some initial free distribution of permits, and a gradual extension of auctioning. Harmonizing differing national cap-and-trade or tax systems in the course of time is likely to be much easier than attempting to install 'top-down', global schemes in the aftermath of Kyoto. What is needed to contain climate change is a transparent and steadily rising carbon price in some form, that complements other essential measures, such as shifting subsidies from fossil fuels to alternative energy, and appropriate regulation, education and community involvement.

Notes

1 Berdik, C. (2014) 'The unsung inventor of the carbon tax', *The Boston Globe*, 10 August, available at https://www.bostonglobe.com/ideas/2014/08/09/the-unsung-inventor-carbon-tax/f1xFyWmaXf2XzW3nVxrNJK/story.html.

2 Tickell, O. (2008) *Kyoto 2*, Zed Books, London, UK, discusses the institutional background, and how energy-saving initiatives in the US have been effective and profitable. Such policies in California have helped to reduce electricity consumption there to almost half the US per capita average (although this is partly explained by the milder climate).

3 Sunstein, C. and Thaler, R. (2008) *Nudge*, Yale University Press, New Haven, CT, discuss advances in behavioural economics that explain these reactions.

4 A prominent epidemiologist, Devra Davis, provides a gripping account of these campaigns in her book Davis, D. (2002) *When Smoke Ran like Water: Tales of Environmental Deception and the Battle against Pollution*, Basic Books, New York, NY. See also Naomi

Klein's excellent account of contemporary climate science denial: Klein, N. (2014) *This Changes Everything: Capitalism vs. the Climate*, Simon and Schuster, New York, NY.

5 China initiated a differentiated pricing scheme for electricity a few years ago, based on the idea of an electricity surcharge imposed on energy-intensive enterprises with poor environmental records. Although electricity pricing is centrally controlled (by the government's National Development and Reform Commission), the implementation of the policy has been far from smooth, as a result of several local authorities refusing to comply (in an attempt to protect local industry interests).

6 For the distributional aspects of the tax, see Beck, M., Rivers, N., Wigle, R. and Yonezawa, H. (2015) 'Carbon tax and revenue recycling: Impacts on households in British Colombia', *Resource and Energy Economics*, vol 41, no 1, 40–69.

7 See http://www.carbontax.org/where-carbon-is-taxed.

8 Steffen Kallbekken and Håkon Sælen (2011) developed an empirical model to test the psychological factors behind the popularity of environmental taxes. The two researchers relied on an extensive survey of 1,177 Norwegian adults who had to comment on their support for fuel taxes and their own perceptions on the usefulness of the instrument. The study found that the most important factor explaining support for environmental taxes was trust in the effectiveness of the tax – in other words, when people believe that fuel taxes have positive environmental outcomes (e.g. by significantly reducing car emissions and climate change), they tend to exhibit stronger support for the adopted measures. The second most important factor was beliefs about consequences to others. Support for environmental taxes is higher when concerns about their negative distributional aspects are alleviated – individuals tend to dislike environmental taxes that are considered to be unfair or coercive. See Kallbekken, S. and Sælen, H. (2011) 'Public acceptance for environmental taxes: Self-interest, environmental and distributional concerns', *Energy Policy*, vol 39, no 4, 2966–2973.

9 Kleven, H. J. (2014) 'How can Scandinavians tax so much?', *Journal of Economic Perspectives*, vol 28, no 4, 77–98.

10 Bruenig, M. (2015) 'Why Jeb Bush is wrong to focus on growth alone', *Demos*, 13 July, available at www.demos.org/blog/7/13/15/why-jeb-bush-wrong-focus-growth-alone.

11 Stavins, R. (2008) 'Addressing climate change with a comprehensive US cap-and-trade system', *Oxford Review of Economic Policy*, vol 24, no 2, 298–321.

9

THE COSTS OF CLIMATE CHANGE AND THE BENEFITS OF MITIGATION

Cost–benefit analysis

Economists have made many attempts to compare the costs of reducing greenhouse gas emissions with the expected benefits of limiting damage from climate change in the long run. This kind of 'cost–benefit analysis' uses models of long-term economic growth and climate impact called 'integrated assessment models' (IAMs), which simply *extrapolate* past (and actually unsustainable) GDP growth rates into the long-term future, with no justification except faith in the magic of everlasting technological progress. In defiance of all the relevant science, these models *assume* only minor, monetary costs of warming (a few per cent of GDP), in a much richer – and far distant – future, to justify small (though rising) carbon taxes. IAMs also assume constant population growth, and hence exclude *by assumption* the possibility of catastrophic climate effects with large-scale loss of life. Economists often also claim that more conventional investment yields greater benefits from GDP growth to future generations than the really major mitigation efforts long demanded by environmentalists and scientists. These would reduce material growth, but, as we shall see below, they would also directly enhance well-being, and of course are essential insurance against future climate catastrophes.

Thus, American economist William Nordhaus, one of the first to use IAMs and applauded for his early advocacy of carbon taxes, still estimates impacts of only '1–5 per cent of output for a 3°C warming' over the next 50–100 years in his 2013 book *The Climate Casino*, while output is supposed to increase five- to tenfold![1] Although he emphasizes uncertainty, Nordhaus (together with most other economists) seems oblivious even to the possibility of catastrophic climate change with large-scale loss of life, and estimates much smaller damages than the earlier *Stern Review*. This much-cited cost–benefit analysis, based on equally unrealistic IAMs, found at most a 20 per cent loss (again of much greater future GDP, and without considering catastrophic change).

However, leading scientists and environmentalists have long warned that increasing GHG emissions under 'business as usual' will lead to devastating climate change unless emissions are rapidly reduced and most of the currently available fossil fuel reserves are left in the ground. Rather than only being a very unlikely outcome in

the 'tail' of the probability distribution (as economist Martin Weitzman has suggested), the more relevant perspective is emphasized by leading climate scientists such as James Hansen: catastrophic damage resulting from *irreversible* feedback effects and rendering much of the planet uninhabitable is ultimately *inevitable*, unless radical mitigation policies, going far beyond current national targets, are implemented soon.[2]

In his most recent book, aptly titled *Why Are We Waiting?*, Stern (2015) finally recognizes the absurdity of the standard IAM assumptions discussed above, and the nature of the real climate threat. He recognizes the 'possibilities of extinction of much of the human race. It is simply daft or worse to present that as a 15–20 per cent loss to GDP'.[3] However, he makes no mention of his own earlier use in the *Stern Review* of precisely 20 per cent of GDP as the upper limit of damage! In spite of his recognition of the risks of disastrous climate change and strong advocacy of substantial carbon taxes, Stern still – astonishingly – favours paths of slow emissions reduction, likely to generate nearly 450ppm of atmospheric CO_2 by mid-century.[4]

Stern's stated target is to have only a 50 per cent chance of remaining below the 2°C threshold, which is really a very high-risk policy indeed – a high-stakes gamble for human survival rather than prudent insurance. Even worse, Stern appears to be unaware that that the widely cited 2°C threshold itself has no scientific foundation. As environmentalist writer Elizabeth Kolbert summarizes, 'The two-degree goal offered in the Copenhagen Accord is more a reflection of what seemed politically feasible than what is scientifically advisable'.[5] And leading climate scientist James Hansen had already concluded from extensive paleoclimate evidence that 'a 2 degree Celsius global warming, or even a 1.7 degree warming, is a disaster scenario' in his seminal 2009 book.[6]

Although Hansen had already warned of the potential dangers of climate change in 1981, neither his early work nor his 2009 book is referenced by Stern in his newest book, who simply ignores all the paleoclimate evidence pointing to 350ppm of atmospheric CO_2 as the maximum 'safe' concentration in the medium term. Bill McKibben's award-winning climate action group, 350.org, which campaigns for the safe carbon limit, is never mentioned by Stern, Nordhaus or Weitzman, nor is McKibben's pioneering book *The End of Nature*, which provided the first warnings about catastrophic climate change for the general public in 1989, warnings that were much more realistic than IAM assumptions of no catastrophic climate effects in the 2007 *Stern Review*, and still maintained by Nordhaus in 2013.[7] Stern presents a plethora of probabilities relating emissions paths to temperatures, based on IPCC estimates, with no recognition that these are seriously downward biased due to their neglect of the slow, carbon and albedo feedback effects that are difficult to quantify, but still pose immense long-term risks.[8]

Another pioneering environmentalist is Lester Brown, winner of numerous awards, yet he is also systematically ignored by economists writing on climate change. He had already understood the risks in his 2003 book, *Plan B*, where he outlined a World War 2-type mobilization to stabilize climate by restructuring the global energy economy.[9] Brown has frequently compared the (global) efforts needed to avert climate catastrophe with total mobilization of the civilian economy

for WW2 in the US. This mobilization generated full employment after more than a decade of the Great Depression, and green fiscal policy for a zero-carbon global economy could have similar effects today, as well as providing co-benefits that exceed the additional investment required (see Chapter 10). Brown's analogy underlines the urgency of major mitigation and the inadequacy of policies proposed by economists such as Stern and others, which allow a 50 per cent chance of exceeding the 2°C threshold, itself a 'disaster scenario'.[10]

Stern and most other writers on climate change also follow the traditional economic assumption that happiness (life satisfaction or subjective well-being) will always increase with individual consumption and national GDP growth. This completely ignores the huge body of evidence from the last 50 years – discussed in Chapter 4 – that economic growth alone does little to increase average happiness or life satisfaction in developed countries. Even in China, average subjective well-being has *declined* over two decades of double-digit growth.

On this evidence, reducing the rate of GDP growth in rich economies by investing more in sustainable technologies (including energy-saving measures) would safeguard rather than lower future welfare (not only by helping to avert the risk of future disaster, but also by reducing the huge, *direct* health and well-being costs of local pollution), in contrast to conventional political and economic wisdom. In addition, such investment is generally more labour intensive than the traditional use of fossil fuels combined with labour-saving technologies. Green fiscal policy in support of such investment would thus create jobs and help to counter the still-persisting effects of the global financial crisis and economic downturn that erupted in late 2008, as we develop in detail in the concluding chapter of this volume, Chapter 10.

In developing countries, however, growth can raise average well-being and improve the lives of the poorest people in particular, though most of the benefits are often appropriated by the rich. Thus, more aid and 'greener technology' transfer from the rich countries could foster sustainable development, with both major short-run welfare and health gains from reduction of poverty and pollution, and of course the long-term benefits of reduced warming in the countries most at risk from climate change.

The 'co-benefits' from many greener technologies are widely recognized, and Stern mentions that, 'the pollution costs of current practices may already be 5 per cent of GDP in many countries',[11] and twice as much or more in China. These may well be underestimates. In a comprehensive new study, the World Health Organization (WHO) and the OECD estimate that about 600,000 premature deaths in the WHO European Region were caused by air pollution in 2010. The economic costs in terms of willingness to pay to avoid these risks, and the costs of associated illness, are estimated at about 10 per cent of EU GDP in 2013.[12] Since many developing countries have much worse pollution, their true costs may be substantially higher.

However, these estimates are based on what is usually considered the most harmful pollutant, fine particles with a diameter of less than 2.5mm ($PM_{2.5}$), which can penetrate lung tissue, and are produced by combustion. Recently, an independent role for nitrogen dioxide (NO_2), also mainly produced by fossil fuels, has been

established, which may substantially raise estimates of mortality and morbidity from pollution, but is difficult to quantify since both pollutants occur together. More detail on co-benefits is provided in the comprehensive account by Alison Smith, whose 2013 book *The Climate Bonus* shows how decarbonizing the economy could generate huge health and well-being benefits in the medium term.[13]

In contrast to the neglect of this rapidly growing research area by climate economists, Smith shows that the results of happiness economics strengthen the case for a low-carbon economy. Thus, pollution has *direct* negative impacts on life satisfaction, as well as indirect effects through higher morbidity and mortality, which are the only effects normally considered by economists. Though never cited by Stern, Smith, who is a scientist and not an economist by training, shows much more clearly just how beneficial the transition to renewable energy and sustainable agriculture could be for most people in advanced and in developing economies. However, systematic education to promote environmentally friendly behavioural change, provide broad support for other necessary government intervention and overcome fossil fuel lobbying is clearly needed. Unfortunately, media bias and political ignorance and corruption, due in no small measure to this very same lobbying, have hitherto blocked dissemination of unbiased information about all these issues in most developed and developing countries.

The wealthy Northern nations might enjoy milder winters and longer growing seasons in a rapidly warming climate. But they would hardly be able to avoid the resulting chaos and conflict unscathed in an extensively nuclear, chemically or biologically armed world, as not just millions but billions of the poorest inhabitants starved. Refugee and international security problems on an unprecedented and unimaginable scale are likely to dwarf the much-vaunted benefits of technological progress in the advanced economies. Reducing such threats – as well as large-scale loss of future lives in the poorest countries – to a percentage of average global GDP has no ethical or economic justification.

Stern deserves credit for being one of the first economists to highlight economic costs of climate change under continued 'business as usual', as well as the importance of mitigation, though environmentalists and scientists had already warned of greater dangers from climate change, and their pioneering work is ignored in his writings. In spite of serious problems with the IAM methodology in the *Stern Review* (which have been largely ignored by economist critics), the publicity received by the first official review of the costs of climate change has helped to ensure that the threat is now widely acknowledged, at least in developed countries. Stern also emphasizes the urgency of serious carbon pricing and other, complementary mitigation measures, and the huge costs of delay just to wait for new evidence or technology. It is thus all the more surprising that his latest, 2015 recommendations still imply a 50 per cent chance of exceeding the 'disaster scenario' of a 2°C threshold, while using outdated IPCC estimates of climate sensitivity, which neglect slow feedbacks. Though Stern rightly castigates the grossly inadequate emission-reduction targets of the EU and other bodies, his own policy suggestions are only slightly better and still imply very high risk.

Cost–benefit analysis (CBA) of WWS

A much more prudent and technically feasible policy for climate and energy security had already been developed in detail by Jacobson and Delucchi (JD) in 2011 (but very surprisingly is not cited by Stern, Nordhaus or Weitzman).[14] They showed that energy saving combined with *then existing* wind, water and solar (WWS) technology could enable a global transition to 100 per cent renewable energy in two decades, though political and social obstacles would likely extend this to mid-century. The longer time horizon would of course delay reaching the 'safe' target of 350ppm CO_2, and increase the risks of irreversible feedbacks. Since then, the cost of solar power in particular has fallen dramatically and continues to decline, so such a programme would now be even more cost effective, as well as becoming more urgent with each passing year of increasing emissions.

The IMF has estimated that *local* health costs of fossil fuel pollution already amount to about 3 per cent of global GDP, a likely underestimate, and in any case a gigantic implicit subsidy for pollution in the absence of adequate carbon pricing, in addition to substantial direct subsidies of about $500 billion globally.[15] In a detailed new report on energy futures, by the think tank group Citi GPS, *average* annual (undiscounted) expenditure on fossil fuels (including investment) over the next 25 years is estimated at about $5 trillion, assuming current low prices continue, and with little expenditure on renewables or efficiency in a 'market-driven' scenario denoted '*Inaction*'.[16]

Greenpeace and the German Aerospace Centre (DLR) have recently published *Energy Revolution 2015*, a detailed scenario for transition to a zero-carbon world by 2050, which claims that fuel savings could fund all the renewable investment required. This seems optimistic in that they do not explicitly allow for the major investment in smart grid and other infrastructure needed to complement renewable generation in optimal locations, and contribute to energy efficiency. However, they neglect the huge health cost savings from declining local pollution, and from reduced fossil fuel investment, as well as the multiplier effect of expanded renewable investment. They anticipate a much larger share of geothermal, but otherwise there are many overlaps with our simplified scenario.[17]

In contrast, under the JD transition to an almost zero-carbon economy by 2035, we assume that half the projected fossil fuel expenditure (including investment) over this period can be avoided, yielding an *average* annual (undiscounted) saving of about $2.5 trillion, in addition to the growing health cost savings from eliminating most local pollution. *After* the transition, of course, there would be little more fossil fuel expenditure, but ongoing maintenance and capital replacement costs for the oldest WWS installations – the International Energy Authority (IEA) estimates a total (undiscounted) fossil fuel investment of $40 trillion by 2035, which by coincidence is roughly our estimate for JD's wind and solar investment plan, detailed below, to supply most power needs by 2035.

We assume current (best practice) costs, though continuing declines in solar and wind costs are expected. Then almost complete transition to WWS power could be achieved by investing on average around $2 trillion annually or, equivalently,

an *average* of about 2 per cent of growing global GDP annually for two decades (from currently $80 trillion), with a plausible additional 2 per cent for grid and other infrastructure, transmission losses[18] and energy saving. The total investment, averaging about $4 trillion annually, would be partly offset by average annual savings on fossil fuels of about $2.5 trillion, leaving an extra annual cost of about $1.5 trillion, or an average of 1.5 per cent of global GDP over the period, which is in the middle of the range quoted by Stern and others. This would also be roughly equivalent to the *average* annual health cost savings, assuming the IMF's estimated health costs of local pollution (3 per cent of global GDP) decline linearly over the 20 years of transition. Of course, the health costs of pollution and climate change will rise dramatically without rapid mitigation.

It is often forgotten that this investment, as part of a green fiscal policy, would more than pay for itself through the multiplier effect of increased employment and growth in currently depressed economies. The co-benefits include all the gains in health and happiness already discussed, worth at least twice the extra expenditure (ultimately saving more than 7 million lives of potential pollution victims annually and almost all expenditure on fossil fuels after the transition – and, above all, providing comprehensive insurance against climate catastrophe). While the latter is priceless, just the other components already represent the ultimate global bargain, and continuing inaction must be the greatest political failure ever.

JD argued that the total global end-use energy capacity needed by 2030 could be reduced from a projected 17 Terawatts (TW) to 12TW by increased energy efficiency and savings. This total includes all power generation, adjusted for utilization, and all other uses of energy (12.5TW was estimated capacity in 2008, of which only about one sixth was for electricity generation). Technologies for efficiency and alternative energy have since greatly improved, and costs have declined dramatically, so we follow their scenario – but now we turn to the two decades to 2035, to give a very rough idea of radical mitigation costs based on 2015 technology and trends.

JD assume that half of the 2035 capacity or 6TW could be (mainly onshore) wind power, which would require 4 million 5MW wind turbines, or a smaller number of more efficient, newer 7MW or larger units (to allow for an average utilization or capacity factor of about 30 per cent in good locations, and most existing, older turbines would eventually be upgraded). However, the newest turbines on higher towers in optimal locations offer much higher than historical capacity factors, up to 45 per cent, with near-future technology going even higher.[19] Thus, about 14TW of optimally installed capacity should provide an average output of about 6TW.

In terms of a constant capacity growth rate, the 2015 global wind capacity of about 400GW would need to grow at about 20 per cent annually for 20 years to attain the target of 14TW, similar to historical growth rates. However, there would then be excess manufacturing capacity after the target date, so a more cost-effective transition path would entail a higher growth rate initially, say for the first 10–15 years, and a constant output thereafter. The final manufacturing capacity (and output) would then be smaller, but appropriate for continuous upgrading

or renewal of the oldest turbines *after* reaching the final 14TW capacity, though of course this could increase further as poor countries developed. Current capital costs of installed wind power vary widely, and are lowest in India and China, often below $1.5 per watt, and somewhat higher, but very variable, elsewhere. Technical progress and mass production would likely reduce costs over time even in such a mature industry. Roughly $1 trillion annually thus seems to be a plausible *average* expenditure for this policy scenario, though, realistically, expenditure would rise over time.

If global GDP continues to grow at 2–3 per cent annually from about $80 trillion in 2015, this would require an *average* (but probably rising) expenditure of around 1 per cent of global GDP for the 20-year period. The other half of total power capacity could be provided mainly by solar, costs of which have been converging rapidly to those of lowest-cost wind in sunny locations. We present a similar, illustrative calculation for solar photovoltaic (PV) below, which should also cost about 1 per cent of global GDP annually over the 20-year period.

Small hydro, geothermal, biogas and wave and tidal sources also have potential for development as alternatives for baseload supply in appropriate locations. Additional investment in 'smart grid', long-distance, high-voltage, direct current (DC) connections would also be needed, since the best wind and solar locations are often far from main areas of end-use demand, and each other. Smart grid and metering technology can themselves generate substantial savings in required capacity by shifting less-urgent demand from peak to off-peak periods, and DC transmission is much more efficient over long distances that currently use alternating current (AC).

Energy saving would also make a major contribution to reducing projected growth rates of end-use energy demand, partly through retrofitting efficient insulation and heating, including ground or air source heat pumps in the built sector, and partly through the general replacement of internal combustion by much more efficient electric motors in the transport sector and elsewhere. As we explain in Chapter 10, labour-intensive green fiscal policy, including publicly funded expenditure on energy saving, could add several percentage points to rich countries' GDP, with their economies approaching full employment in place of the 10–20 per cent rates of un- and under-employment still widespread after years of post-crash austerity. Due to the multiplier effect of fiscal policy in recession, this investment would more than pay for itself in three ways: reducing expenditure on welfare needed to support workers unable to find jobs, cutting outlays on fossil fuels, and raising tax receipts. Much energy-saving investment would actually be *privately* profitable if undertaken, but remains neglected due to various market failures discussed in Chapter 10. By boosting depressed construction sectors that have suffered most in the Great Recession and its aftermath, this investment would probably generate the largest multiplier effect on employment and growth, and so should have priority in JD's radical mitigation plan.

As noted above, transformation to an almost completely renewable energy supply would save an increasing proportion of fossil fuel expenditure over 20 years, and almost all of it thereafter. Just these direct savings could fund a major part of the

investment in WWS and infrastructure. Appropriately rising carbon taxation could maintain the incentives for investment in both efficiency and renewable supply. Of course, a major war in the Middle East could rapidly push up oil prices to previous highs or beyond at any time, so this policy might generate much larger savings, *and* provide energy security to countries otherwise dependent on imported energy, including most of the EU.

While the IMF treats the potential revenue from carbon taxes as fiscal receipts, such taxes are more likely to gain acceptance in the form of what James Hansen calls a 'fee and dividend' policy, in which all receipts are directly returned as *equal shares* to all citizens. This would be progressive, since the rich generally spend much more on fuel than poor people, and so the policy would benefit a substantial majority of populations in countries with highly unequal income distributions.

To summarize, we assume 2 per cent of global GDP for building the new smart grid and other infrastructure, as well as reserve capacity and energy saving, so about 4 per cent of (growing) global GDP should fund a 20-year transition to almost 100 per cent renewable (WWS) energy, with solar in southern regions complementing wind elsewhere, and largely solving the intermittency problem with the help of large-scale, smart grid connection, as is discussed in detail by JD. Some combination of baseload generation and additional back-up or reserve capacity, powered at least in part by biogas, and various forms of energy storage, would be required. Some of this reserve could simply be surviving gas-generation capacity that is maintained in a state of readiness for emergency use, together with appropriate stocks of natural- or biogas.

The 4 per cent of global GDP and our other numbers are of course just a rough guide in a very simplified scenario. This figure is just above the range discussed by Stern,[20] but, as noted, could be largely funded by reduced expenditure on fossil fuels, and is similar to the global health costs of current local pollution, though much less than the 5–12 per cent of GDP due to even greater health costs in the main emitting countries. Clearly, this target would require much higher investment from the rich countries and more aid to the poor ones, but part of this would quickly pay for itself through fossil fuel savings (and more gradually through health improvements). Part of the investment would simply replace ageing and obsolete fossil fuel generation and equipment, as well as investment in new fossil fuel production, and so is not really an 'additional' investment cost of the transition to zero carbon. Much of the outlay would be funded just by running down fossil fuel consumption and investment, not to mention a major stimulus from green fiscal policy. Finally, we emphasize that extending the transition to 25 or even 35 years would still represent an enormous improvement over Stern's high-risk policy, let alone official targets, particularly when combined with transformation to sustainable agriculture discussed in Chapter 3 and summarized below.

While Stern sees an important role for nuclear power and carbon capture and storage (CCS) in future mitigation, most experts follow JD in recognizing that these are now the most expensive low-carbon technologies, after the costs of wind and especially solar have fallen so dramatically, and hence require the greatest subsidies.

In addition, nuclear has potential for major accidents or sabotage, very long lead times to completion, and major unresolved issues of waste disposal and decommissioning. Despite the low probabilities for such disasters, wind, solar and most other renewables all involve *zero* risk *and* much lower expected cost with existing technologies. While a new generation of nuclear reactors, perhaps with molten salt cooling, might be superior in various dimensions, these are many years from commercial development. China currently has the world's largest nuclear power programme, but there is little reliable information on cost or safety issues, and plenty of evidence from other technologies to raise serious concerns about the latter.

An absurd but recurring objection to complete decarbonization is that WWS generation would require more than the whole land area of the UK or similar countries! Most recently, a prominent energy expert, Vaclav Smil, has made this claim, apparently unaware that such claims had already been thoroughly debunked by JD in 2011. They find that the global footprint of wind turbine towers needed to produce half the world's future energy, 6TW, is only 48km^2 (this is just the area of the tower bases – space *between* towers can be utilized for agriculture, forestry or whatever, and existing access roads or tracks are commonly used). Non-rooftop, utility scale solar to supply much of the other half would have a larger footprint, about 0.3 per cent of the global land area, but most of this would be in desert or unused arid areas with the most solar irradiance. It makes little sense to assume that the UK would produce half its energy from solar, as Smil does, when Scotland has a comparative advantage in wind energy, and a Europe-wide grid could supply southern solar more efficiently.

However, Smil's most implausible projection is to forego the huge efficiency gains from complete electrification of the whole economy, and assume a large liquid biofuel sector for transport, still dependent on highly inefficient internal combustion engines, and biomass for heating and baseload power. Since these fuels have very low 'power densities', they require a large area of (usually agricultural) land per unit of energy produced. To replace all current consumption of petrol and diesel with bioethanol and biodiesel from grain and beet would require several times the UK's entire agricultural area! It is unclear why Smil discusses such an absurd scenario, when the feasibility and multiple benefits of electrifying most transport and heating with WWS have been repeatedly presented by well-known authors such as JD, Lester Brown, Alison Smith and many others.[21] In the few cases where liquid fuels would still be essential, liquid hydrogen produced by electrolysis in fuel cells could be developed with existing technology, while third-generation biofuels from algae represent a potential additional possibility, currently under development in various forms.

Agriculture and climate change

As already discussed in Chapter 3, global agriculture and deforestation may contribute about a third of total carbon emissions, and the conversion to sustainable or eco-agriculture, and lower meat consumption, could transform the agricultural

sector into a major, global carbon *sink*. The capital investment requirements for this transition are relatively small, and cost savings from reduced fossil fuel-based inputs will follow rapidly, so this sector could also make a massive contribution to mitigation, reducing net emissions by nearly half, and accomplishing this much more rapidly than the two decades or so needed to achieve complete WWS energy supply. A rapid switch to sustainable agriculture could probably be implemented with a small fraction of the 200–300 billion dollars of subsidies currently going annually to the richest farmers in Europe and North America, to support destructive industrial agriculture, as well as subsidizing exports to developing countries that undermine the viability of local agriculture.

Nordhaus has a whole chapter (number 7) on agriculture, in his newest book *The Climate Casino*, that seems to be written about another planet, with no awareness of any of the problems discussed in our Chapter 3, nor of the potential for mitigation through sustainable agriculture. First, he claims large positive effects of CO_2 fertilization on crop yields, which are clearly rejected by the latest science. He ignores the evidence that higher temperatures during the growing season in already hot areas reduce yields, and he makes no mention of the major problems of soil erosion and degradation under industrial agriculture in many of the most important agricultural regions, problems that are exacerbated by rapidly falling water tables, rising temperatures and declining precipitation. Finally, he makes the extraordinary claim that, because agriculture now accounts for a very small share of GDP in advanced economies, it follows that impacts of climate change will also be minor, particularly in a future when most of the world will be similarly industrialized.

The flaws in this argument should be obvious. Agriculture is not just one of many sectors producing consumer goods, but essential for survival, as Nordhaus does mention but then seems to forget. With only weak mitigation policies, climate change will generate increasingly frequent and severe droughts, floods and heatwaves in a trend that has already begun, and which will devastate food production in many of the most populous and most vulnerable areas without major mitigation policies, long before slowly rising sea levels inundate the world's coastal cities and regions. Adaptation to adverse conditions has limits, and even the most sustainable agriculture would be ultimately overwhelmed by high enough temperatures, declining water supply and prolonged droughts in critical areas.

Even relatively minor shortfalls have triggered dramatic price rises for wheat and other grains in the past. Severe, long-lasting droughts in already threatened areas with diminishing ground water, say in Northern China, which produces most of the country's grain, and in the grain and corn belts of North America, would soon exhaust global stocks and send grain prices skyrocketing as rich countries and wealthy individuals everywhere bought up all the surplus. Particularly the urban poor with no access to land for subsistence would starve in developing counties without national resources for large-scale purchase of emergency food supplies.

Even in rich countries, for example, a tenfold increase in essential food prices would exhaust the budgets of middle-income and poorer consumers, so that aggregate demand for other goods would collapse without massive government

intervention in the economy. Many people would have to spend most of their time searching for – and trying to grow – basic foods for survival. Even if food waste, meat consumption and overeating by the rich were all drastically reduced in a world where few would be able to afford meat, a disaster of this magnitude, probably inevitable after a few more decades of rising emissions, progressive soil erosion and worsening water shortages, would almost certainly condemn the poorest inhabitants of the poorest countries to mass starvation on a scale never seen before.

It is important to emphasize that this scenario does not depend on unlikely, extreme warming outcomes in a distant future. Agricultural productivity in much of the world is already unsustainable with current methods, as 'water mining' steadily lowers water tables in most irrigated areas. If warming continues unabated, climate models predict that water shortages will gradually worsen, accelerating soil erosion, and leaving farmers in arid regions increasingly vulnerable to ever more frequent droughts and other extreme weather events.

Those who claim that drastic mitigation measures to avoid high risk of future disaster would incur huge economic costs in the short run, simply ignore all the evidence reviewed here. Switching vast existing subsidies from industrial agriculture and fossil fuels to conservation agriculture, reforestation and combined energy saving with renewable energy supply would generate massive cost *reductions* from reduced consumption of fossil fuels, in addition to all the health-related co-benefits, and of course climate 'insurance' against future disaster, a priceless and immeasurable 'payoff'.

Discounting, growth and the value of life

Much of the discussion of climate change economics since the *Stern Review* has focused on how much 'weight' to give to the welfare of richer future generations, who are invariably assumed to have enjoyed uninterrupted material growth. Stern follows ethical philosophers such as John Broome[22] in refusing to 'discount' the welfare of future generations simply because of their date of birth. By contrast, many economists still believe that costs of climate change in the distant future will be small percentages of a much greater GDP, and should be discounted to even smaller present values using market interest rates, because conventional investment (which 'competes' with mitigation) would raise future GDP and could even compensate for climate damage, at least to some extent. A modest but slowly rising carbon tax, such as the initial $25 per tonne of carbon proposed by Nordhaus, is then the only policy required for the main emitting countries.

The common obsession with GDP growth as the ultimate goal and measure of progress or damage has obscured the ultimate threat of climate change, which could render much of the planet uninhabitable and cause large-scale loss of life or extinction. Belated recognition of this possibility by Stern and Wagner and

Weitzman (2015)[23] comes long after the relevant scientific warnings, though these were still being ignored by Nordhaus (2013), who claims that a 3°C average temperature rise would be 'safe', and only reduce a 10 times larger global GDP a century later by 5 per cent.

Although he has a chapter on 'Tipping Points', Nordhaus seems to be unaware that even a 2°C increase would most likely trigger irreversible carbon and albedo feedbacks, which would eventually lead to much higher temperatures and catastrophic loss of human life, prospective 'costs' that never intrude into his main concern with future GDP. The question of discounting and evaluating future damage in (present value) monetary terms still preoccupies economists and philosophers writing about climate change. However, this question becomes largely irrelevant when the overriding priority to stop dangerous climate change *as soon as possible* is recognized – this is the *precautionary principle*, which we discuss in the next section.

Stern does acknowledge that ethical concern for all (much richer) future generations, and not just for our own direct descendants, should also imply a major and complementary commitment to improving the lives of billions of people in extreme poverty today. As economist Eric Neumayer has pointed out, mitigation policy by the most developed countries today is not only about protecting the consumption of our (even richer) descendants tomorrow. More fundamentally, our investment in mitigation today is also a form of deferred foreign aid, for the benefit of the poorest countries and populations that will suffer most from future climate catastrophe.[24] In contrast, Nordhaus has no mention of poverty or inequality.

Faced with the possibility of large-scale loss of life and an end to modern civilization with unmitigated climate change, estimates of discounted costs in terms of GDP become meaningless exercises. Not only is the *precise* sequence and magnitude of future climate impacts essentially unpredictable, but monetary evaluation only makes sense for *low-probability* risks to life and corresponding insurance investment. The precautionary and cost-effective JD strategy for *avoiding* high-risk climate change altogether, introduced above and further developed below, has no need of these futile evaluation and discounting attempts, and is furthermore much less financially and technically (though not socially and politically) demanding than the US mobilization effort in the run-up to WW2.

Most economists agree that willingness to pay (WTP) for investment to reduce a small risk of fatality can be interpreted as a measure of the 'value of a statistical life' (VSL), provided that full and transparent information is available to all affected parties. Thus, suppose a community of 10,000 people suffers two random fatalities from an environmental hazard on average every year. A partial clean-up could reduce the risk to one annual fatality, thus saving one statistical life every year, at the cost of an additional tax of $500 to be paid by each individual annually. Realistically, eliminating the hazard entirely would be much more costly, and require an extra tax burden of, say, $2,000 annually. Assuming similar incomes and preferences in the community, a 'reasonable' result of democratic voting

might be the decision to save one (statistical) life per year, at a total cost of $5 million ($500 \times 10{,}000$), rather than spending $20 million to save two lives. Our community is thus valuing one statistical life at more than $5 million, but less than $10 million (while remembering that the risk faced is very small, comparable to the risk of, say, a traffic fatality – but in contrast to the latter case, we assume a hazard that is not avoidable by individual action).

This decision is reasonable because it roughly accords with examples of local, democratic decision making, common in Switzerland, and with results from detailed questionnaires that ask people about their WTP to reduce small risks in hypothetical but plausible situations. These results, of course, depend on income, and in poor countries most people simply cannot afford to spend much on life-saving investments, even to reduce very high levels of risk to life and health, or to ensure such basics as cleaner air and potable water. It follows that the 'value' (in this sense) of their statistical lives is much smaller than in rich countries.

Although it is widely recognized by all ethical systems that human survival chances should *not* depend on income, this principle is almost universally violated by the strong positive relationship between relative income and survival chances in all countries and at all ages. Thus, in developed countries with the most unequal distribution of income, such as the UK or the US, average life expectancy varies by 10–15 years or more between the most deprived and the most affluent areas, with large differences in infant mortality and opportunities for young people. As the income gap between rich and poor in these (and many other) countries has grown in recent decades, under the combined impact of neoliberal policies and globalization, so also has the discrepancy in health, life expectancy and educational outcomes between the deprived and the privileged increased.[25]

As discussed in earlier chapters, some (though still insufficient) attention has been paid to the plight of the poorest nations, where most of the world's nearly 3 billion poorest people live on less than 2 dollars per day, and suffer high rates of mortality and debilitating disease. Economists such as Jeffrey Sachs have explained that a relatively modest aid effort by the rich nations could remove the worst poverty, and drastically reduce mortality rates.[26] Yet neoliberals oppose aid for the poorest countries and populations, many voters appear to be indifferent to their fate, and Western governments have failed to raise aid for developing countries to meaningful levels.

This indifference has no more ethical justification than overt racism, but it still remains the dominant attitude to the fate of the world's poorest inhabitants and their descendants under unabated global warming. Part of this indifference is undoubtedly due to widespread lack of knowledge about the dire consequences of climate change, for Southern Hemisphere agriculture in particular. However, current poverty in the developing world has been given extensive publicity, but it has met with little enduring response. Altruism and empathy have evolved as essential for social cooperation, but largely in the context of communities that share ethnic or linguistic heritage – as 'tribal morality', which is an inadequate basis for social justice in our global society, as we discuss in more detail in Chapter 6.

Climate catastrophe, the precautionary principle, and policy

Continued business-as-usual emissions of GHGs (and other activities) threaten the survival chances of billions of the most vulnerable members of present and future generations, and violate the most basic principles of justice and human rights. Rawlsian justice, as discussed in Chapter 6, implies that the *welfare* of the poorest (which obviously includes ensuring their survival) should be maximized. This is, of course, a long-term goal, which appears to be unattainably utopian under current lack of concern in the rich countries, and resulting political constraints. Economics can help to minimize the costs of achieving this goal, but cannot replace the ethical judgements required. IAMs based on *average* income per head make little or no adjustments for the huge and growing inequalities in income and welfare, both within and across countries. In general, such models ignore the crucial distributional issues of life-saving aid for the most vulnerable, both currently and in the future.

The ethics of priority for life saving cannot say precisely how much of our consumption we should sacrifice today, in order to alleviate current poverty, and to reduce emissions to protect future lives. The answer depends on how much 'weight' we give to the welfare and the lives of the poor, compared to our own consumption, and on how we evaluate their future survival chances; this is always a rather difficult, subjective decision. The social context is also highly relevant. Collective action is obviously much more effective than anything that a few individuals can achieve in the short run. However, political commitment and consensus, on originally controversial issues, is usually built upon the pioneering efforts and initiatives of individual campaigners, who are brave enough to defy majority prejudice and, frequently, defamation. The ethical ideal of offering equal opportunities to the currently most deprived and most vulnerable is obviously constrained in practice by political feasibility and personal commitments, habits and perceptions.

The argument for reducing emissions much more rapidly than suggested by most economists or current government targets is strongly supported by enlightened self-interest in the least threatened nations. Runaway warming poses less well-defined dangers to the rich North than to the poor South, but to expect continuing growth, peace and prosperity while the world's poorest people starve, failing states proliferate and world order collapses, is a dangerous delusion. The potential for destructive and ultimately even global conflict inherent in climate change, is now being increasingly emphasized by international organizations such as the United Nations Environment Programme.[27]

Currently poor populations and their descendants face the greatest threats from climate change (and lack resources for mitigation), though ultimately most or all of humanity would be threatened. The only prudent and ethical response to such a prospect is to minimize the chances of disaster by the kind of major mitigation effort sketched out above, following JD, where the barriers and constraints are primarily political and social, not technical. This is often described as the *precautionary principle*. The overriding policy priority should be to *eliminate* catastrophic risk altogether,

which is entirely feasible with current technology, but does require substantial government involvement and changes in behaviour by most individuals.

Traditional cost–benefit analysis does not help to justify priority for radical mitigation to *remove* the threat of catastrophe altogether, at least as far as is humanly possible (but of course is invaluable in the design of efficient implementation). Thus, trying to put a money value on the lives of large numbers of mainly poor people in present and future generations (who cannot all participate in these decisions), and then trying to calculate their present value in monetary terms, in order to decide how much to spend (or not to spend) on saving their lives, is both nonsensical and thoroughly unethical.[28]

As discussed above, the financial burden of a radical mitigation strategy to supply all energy from renewables by 2035 is still surprisingly modest, probably in the region of 4 per cent of global GDP, which is much less than the cost of WW2 mobilization in the US, and less than just the *local* pollution costs of fossil fuels in the main emitting countries. The green fiscal policy explained in the next chapter could further reduce cost and increase current welfare by generating high employment in a world of otherwise increasingly precarious jobs, chronic under-employment and looming secular stagnation. While carbon taxes are also essential to radical mitigation, without additional major government investment, regulation and further involvement, they would take too long to achieve zero emissions. Private sector adaptation to large tax or other changes is a slow process, as people need to learn about (and adopt) new technologies, but appropriate regulation with additional incentives or 'nudges' can greatly facilitate and shorten this process.

Substantial energy saving in the short run is also possible by using existing equipment more efficiently, or with modest investment, for example in energy-saving appliances and house insulation, that yields a very high private return. Energy savings that would be *privately* profitable in the long run, are usually estimated to be in the range of 20–40 per cent in advanced economies, and of course depend on the future prices of fossil fuels. These prices would eventually fall under any adequate global mitigation policy, so a steadily rising carbon tax would be needed to further discourage waste and promote alternatives.

However, many existing and profitable opportunities for energy saving are neglected simply through ignorance or powerful, psychological force of habit, or financial budget and liquidity constraints. Poor or already over-indebted households may simply have inadequate cash flows for such investment that would be privately profitable under full-information, present-value calculations. Such households often also lack access to (additional) credit (particularly in recession). Government funding, appropriate regulation and standards for energy efficiency thus all have very important roles to play, in addition to carbon taxes. Given that the rate of return to renewable technologies depends on fossil fuel prices, carbon taxes should be used as a flexible, stabilizing mechanism that will keep green energy competitive (particularly in times when fossil fuel prices decline sharply, as happened both in 2008 and 2015, when the price of oil more than halved on both occasions).[29]

The financial collapse and beginning global recession of 2008 offered a rare opportunity for 'green fiscal policy', or public investment to *combine* energy saving and job creation, at a time when both employment and prices were falling steeply. The construction sector was particularly hard hit everywhere, with consequences for climate and the real economy, given that retrofitting inefficient buildings for energy efficiency is much more labour intensive than similar investment in new fossil generation, saves more energy than would be produced and of course reduces emissions. This opportunity was largely missed, as governments rescued the banks that caused the crash with 'quantitative easing', but no adequate new regulation. At the same time, credit and funding for alternative energy projects and small business in general has been dramatically curtailed by banks lacking the confidence to lend, neoliberal austerity policies, and weak commitment to climate goals by most governments.

All of the mitigation measures discussed so far would impose little *net* financial cost on the global economy. The direct health and welfare co-benefits from these policies in the medium term, in addition to fossil fuel savings, are likely to add up to several per cent of GDP in many developing and advanced economies. The policy costs – or obstacles to implementation – result from political resistance to the necessary redistribution that is involved in these measures, as well as from ingrained cultural attitudes and habits. In spite of net efficiency gains, a carbon tax or the reallocation of existing subsidies still creates winners and losers, as do all the other policies considered. While the costs, or just the change of habits required, are clearly visible and immediate for well-defined groups, gains such as reduced pollution, mortality and morbidity have less obvious individual impacts on a large population over a long period of time. Opposition to change from those with most to lose is thus focused and often vehement, even though general benefits may be recognized by all in the long run.

While these political costs are indeed major barriers to abatement policy (and in fact may well block such policy until it is too late), it is important to emphasize that public education and stakeholder involvement in the process of planning and implementation can reduce the opposition and gain converts to sound policies. Such community involvement in Denmark has largely eliminated opposition to wind power, which now supplies more than 40 per cent of the country's electricity, planned to reach 84 per cent by 2035. However, government conviction and initiative, rather than acquiescence to fossil fuel lobby pressure, is required. Special incentives may also be required to encourage initial change of habit in a hostile environment.

In summary, most current emissions could be cut in the next two decades, in combination with major carbon sequestration through sustainable agriculture and reforestation, with co-benefits greater than financial costs in the medium term. If existing natural carbon sinks do not deteriorate, *net* emissions could be negative by 2035, and reduce atmospheric CO_2 to perhaps close to 350ppm by mid-century, with the prospect of further rapid decline to offset the expected loss of aerosol cooling. All this of course depends on political leadership and worldwide mobilization for energy saving, conservation agriculture, tropical forest protection and

afforestation, and gradual replacement of economically obsolete capital equipment by cleaner technology – helped by rising carbon taxes.

'Optimal' carbon taxes have been extensively discussed by economists, such as Nordhaus and many others, and are supposed to reflect the 'marginal social cost' of carbon, both in causing local pollution and long-run climate change. We have argued that attempting to calculate a monetary cost for the latter seriously misunderstands and underestimates the ultimate threat of catastrophic climate change. Carbon taxes are essential complements to other policies for achieving the precautionary goal of minimizing the probability of catastrophic climate change. But all the decisions involved depend on moral and political values, which vary among individuals. Clearly these should contribute to the political process, which in turn defines what is *politically* feasible at any time (which has been generally too little and too late!).

Economic analysis of the effects of taxes and other measures can obviously help in the formation of considered judgements, but these will always depend on the ethics of current sacrifice for the future lives and well-being of usually unknown individuals. In view of the real and often substantial costs of adjustment and huge political obstacles to any new taxes, even a 'carbon tax (or fee) and dividend' scheme where all proceeds are returned as equal shares to all citizens, would have to start at a relatively modest level and be increased gradually according to observed reactions and political acceptance, a dynamic process with little resemblance to optimal tax calculations.

Philosopher John Broome and economist Duncan Foley[30] have argued for 'Pareto improvement', or a policy that benefits everyone, to overcome political resistance from the fossil fuel sector to serious mitigation policies. In this approach, those who have most to lose initially from climate change (mainly younger people and the poor populations of vulnerable developing countries) should simply acquire or purchase controlling majorities of all fossil fuel producers and gradually close them down, thus essentially compensating fossil fuel owners for their losses, so that everyone can gain with most fossil reserves then left prudently in the ground.

Apart from the infeasibility of hostile takeovers of state-owned or -controlled, major fossil fuel producers under authoritarian regimes such as in Russia, Iran or Saudi Arabia, the 'value' of global fossil reserves has been estimated as 20 to 30 trillion dollars, far beyond the budget of the global poor. A transfer of this magnitude (to a generally wealthy class of fossil fuel owners) could hardly be funded without an almost equally large inherited debt burden for the descendants of today's poor.

Compensation for producers to cease their destruction of the environment appears even more unacceptable – and indeed perverse – in the light of leaked internal documents, published as *The Climate Deception Dossiers* in 2015 by the Union of Concerned Scientists (a body of independent experts working on environmental issues). They show: 'For nearly three decades, many of the world's largest fossil fuel companies have knowingly worked to deceive the public about the realities and risks of climate change.'[31] This extensive evidence that these companies were

well informed about the dangers of climate change while promoting deception, similarly to tobacco companies in the past, suggests to some commentators that they should be held liable for damages and legally required to *pay* compensation for fraud or racketeering, to those already suffering from – or threatened in the future by – climate change and pollution.

More co-benefits, costs and waste

The transport sector produces around 15 per cent of the carbon emissions in modern economies. Most urban trips are less than 5km and would be easy to cycle, if segregated cycle lanes were provided and motorized traffic restricted with large-scale pedestrian areas. Congestion charging, as in London, has reduced traffic by only about 20 per cent, and is thus an inadequate alternative to the extensive pedestrian areas and switch from cars to bicycles, which has transformed cities such as Amsterdam, Copenhagen, Florence and Freiburg in Europe. Cycle rickshaws have been spreading from Asia to Western capitals, and growing rapidly in popularity (even in still-crowded London, despite the congestion charge). Together with the cheap, street-based cycle-rental facilities that are expanding in many European cities, these modes could replace motorized traffic for most short trips. Plug-in hybrid and electric vehicles with batteries that could be charged overnight from alternative or 'clean' generating capacity, which is underutilized during such off-peak periods, could provide further, emission-free urban transport, as well as cheap storage of excess power from night-time wind generation.

However, the *single* car user who switches to cycling on crowded and polluted roads still incurs all the costs of pollution and accident risks caused by existing traffic. Only when a *majority* of motorists have followed, will there be a serious improvement in the environment so that all cyclists can safely enjoy the health benefits from more exercise and less pollution, as in the European cities mentioned above. Thus a major change of this kind requires strong regulation such as banning traffic from central areas, in the face of a powerful motor lobby, before major welfare improvements can be attained. In this, as in many other cases, purely individual financial incentives like carbon taxes may be very slow to generate large-scale response, and direct regulation such as restrictions on motorized traffic, priority lanes for cycles and extended public transport will be needed.

A remarkable example of long-term transport and urban planning is the Brazilian city of Curitiba, with a population now approaching 2 million. Facilities for public transport, cycling and pedestrians, as well as extensive green spaces throughout the metropolitan area have been systematically developed as in the European examples above since the late 1960s, but on a much larger scale, and yet with comparable success. Traffic congestion and pollution are much lower, while average income and 'quality of life' ratings are higher than in any other big city in Brazil. In 2010, Curitiba received the Global Sustainable City Award, and is described as one of the world's most sustainable cities in numerous case studies.

In spite of all this well-publicized success, car lobbies and corrupt or incompetent politicians have blocked the implementation of similar policies in almost all the world's major cities.

In addition to substantial energy savings and less pollution, a large-scale shift from cars to cycling and walking would have major and direct health benefits, at a time when increasing lack of exercise has damaging health effects similar to – or worse than – smoking (lack of exercise *interacts* with excessive consumption of sugar and processed food, and inherited or acquired predispositions, to contribute to modern epidemics of obesity, type-2 diabetes, and allergic and immune-related conditions).[32]

As well as the direct health benefits from more exercise, a drastic reduction of urban traffic would alleviate much of the local air pollution, which is a major cause of mortality and morbidity. The World Health Organization (WHO) estimates that small particulates ($PM_{2.5}$) cause about 30,000 premature deaths in the UK, 600,000 in the EU, and more than 7 million worldwide. However, the lethal effects of nitrogen dioxide (NO_2) have been neglected and are likely to raise the death toll significantly.[33] Furthermore, higher temperatures in the summer interacting with vehicle emissions will increase ozone formation and exacerbate these health problems, as well as reduce crop yields close to densely populated and motorized areas.

Using the conventional value of a statistical life discussed above, the willingness to pay to avoid these fatalities, and also extensive morbidity, might amount to several per cent of GDP if people were well informed about the risks, though the health effects of urban air pollution are systematically downplayed by media, car lobbies and governments. Aviation is one of the fastest-growing sources of emissions, encouraged by massive subsidies, including tax-free aviation fuel worldwide. Switching these subsidies to improved rail services, for instance, would have a significant impact on slowing the growth of emissions.

In addition to fossil fuel subsidies, a prime example of waste on a gigantic scale (at least from a global perspective) is military expenditure amounting to 2.5 per cent of global GDP, almost half of which is the US military budget. If even a small proportion of this expenditure were diverted to supporting alternative energy development, the mitigation effect would be enormous, with no net cost to the world economy. Nuclear energy has been the largest civilian recipient of public R&D funding for the last 50 years (largely due to its early connection with nuclear weapons programmes in most countries, and all other aspects of nuclear power have also been heavily subsidized), but the costs of new nuclear power stations have been rising, rather than declining, in striking contrast to wind and solar in recent years. Commercial construction still requires major government involvement in funding, guarantees, disaster insurance, security and waste disposal. Most nuclear waste is still stored in poorly protected, provisional sites, in the absence of any agreement on permanent disposal. Major cost overruns and delays have plagued the few new reactor projects in the West.

The growing environmental and health costs of pollution in China (probably over 12 per cent of GDP) and other developing countries (much of it from coal burning),

are likely to accelerate already rapid alternative energy expansion, including large-scale nuclear power development. In spite of this, China's latest (June 2015) target is for only 20 per cent of energy from renewables by 2030, with emissions peaking but not yet declining by then, a plan increasing the likelihood that even the 2°C threshold will eventually be breached.

In the meantime, existing technology for 'scrubbing' or removing sulphates, particulates and other emissions, but *not* carbon dioxide, from coal-burning power stations (and car exhausts), offers a relatively cheap and tempting interim solution for polluted cities. Since the WHO estimates more than 3 million premature deaths annually from outdoor air pollution, this would yield substantial *local* health and welfare gains for urban populations in the most polluted cities of China, India and indeed most developing countries, but at the same time it would *accelerate* global warming by reducing aerosol pollution and its cooling effect (and continuing carbon emissions).

While a drastic reduction of biomass and coal burning would have the biggest impact on global emissions, this would of course also remove much of the smoke and aerosol pollution from the atmosphere. In addition to the huge health benefits from this 'clean-up' (and some local cooling from less soot in the air), there would also be a substantial overall warming effect, as more incoming solar radiation reached the Earth's surface. The existing aerosol cooling effect is probably equivalent to about 50–70ppm of carbon dioxide in the atmosphere (with considerable uncertainty). Aerosols survive for only about 10 days in the atmosphere before they are washed out by rain, so there is an initial *warming* effect when biomass and coal burning is reduced. Thus additional reduction of carbon emissions would be required to compensate for the loss of the aerosol cooling effect, a point that is never mentioned by Stern.[34]

It follows that stabilizing total GHGs in the atmosphere at around current levels while also eliminating most of the aerosol pollution would be equivalent to *adding* 50–70ppm of carbon dioxide, enough to ensure that the 2°C threshold would almost certainly be exceeded. Depending on how quickly natural sinks lose their effectiveness, and how the fast-growing developing countries respond, much more drastic policies by the developed countries responsible for most of the existing GHGs in the atmosphere may be required. These more advanced economies will probably have to reduce their emissions by at least 90 per cent by about 2035, in order to keep global emissions low enough for the stock of atmospheric GHGs to *decline* over time, and compensate for the loss of aerosol cooling.

More on technologies for mitigation

Carbon capture and storage (CCS) is a much-discussed response to expanding use of coal, a technology that in principle could be retrofitted to existing coal-burning power plants, and remove carbon dioxide from emissions, for storage in exhausted oil fields or elsewhere. While the basic science is well understood,

commercial-scale projects mainly rely on selling extracted CO_2 to nearby oil companies for enhanced oil recovery, which hardly reduces overall emissions. Large-scale commercial deployment with the infrastructure for long-term carbon storage has not yet been developed, and would require much more coal to produce the same amount of energy, due to the high energy cost of extraction and pumping. Remaining emissions include methane from the increasingly prevalent open-cast mining, which also has a devastating effect on the local environment, and from the energy used in transport of coal and CO_2, while capital costs are also greater.

JD's conclusion still stands: coal with CCS and nuclear power are the two *least* cost-effective low-carbon alternatives, while the latest onshore wind turbines in good locations continue to provide the cheapest essentially carbon-free energy, which is competitive with most fossil fuels, now closely followed by solar PV in sunny areas.[35] In spite of all this, the UK Conservative government elected in 2015 (by just 24 per cent of registered voters, thanks to the 'first-past-the-post' electoral system) supports large-scale CCS projects and provides huge subsidies for new nuclear power and expensive offshore wind farms while drastically cutting all the most effective green programmes, including subsidies for onshore wind and solar energy, home insulation, and higher standards for new buildings.

The dramatic decline in the price of natural gas with the widespread use of fracking in the US has encouraged the replacement of coal by gas, which has only about half the carbon content of coal. However, methane leaks may offset much of this advantage, and there are problems with pollution caused by the toxic chemicals used in fracking.[36] Gas-powered generators are easy to stop and start, and gas storage is relatively cheap, so there might be a case for retaining some gas-powered capacity as a reserve or back-up for exceptional weather conditions with little wind over even a very large grid-connected area, such as a future 'zero-carbon' Europe. However, biogas from bio-waste would be a preferable alternative, as it is carbon neutral in the long run, as discussed below.

Although alternative energy has attracted relatively little government subsidy in comparison with nuclear, fossil and first-generation biofuels, costs, particularly for solar PV, have fallen dramatically with technical progress and mass production in China, while global demand for wind and solar has grown at around 20–30 per cent per year (albeit from a very small base, and with interruptions due to recession and production bottlenecks). Maintaining such growth rates for the next two decades to attain the 'safe' JD targets would of course require massive new investment in production capacity in many producing countries, and resulting economies of scale should lead to further declining prices.

Wind and solar power are often criticized for their intermittent supply, and optimal sites that may be far removed from centres of demand. However, major advances in the technology of high voltage, direct current (DC) transmission mean that long distances between generators and electricity users add only moderate cost. The second, and related, crucial point is that winds are very variable across regions, so that national or international (such as European) grid connections will be required to smooth supply. However, building the required large-scale, smart

grids will be impossible without major government involvement and international cooperation. Developing technologies such as geothermal, tidal, wave and more efficient heat pumps could provide baseload capacity, in addition to biogas, with extra gas generating capacity in reserve.

Clearly the variability of wind and other alternatives (as well as the demand for electricity) can be 'smoothed' by energy storage. Most technologies are still expensive, though with potential for development. In appropriate hilly terrain, water can be pumped into high-level reservoirs when excess power is available, and then used for hydroelectric generation to meet excess demand. By far the cheapest form of energy storage, albeit a short-lived one, is the old fashioned 'storage heater'. This decidedly low-tech device was marketed before central heating became popular in the UK and elsewhere, in order to utilize cheaper, off-peak or night-time electricity for domestic heating. The storage unit was heated overnight, when there was widespread excess generating capacity, and gradually released warmth throughout the day.

With a large enough wind-generating capacity to exceed night-time demand, the surplus could thus be used to provide cheap and carbon-free heating during day-time hours of peak demand. A related application is to charge the batteries of electric or plug-in hybrid vehicles overnight, to provide cheap and pollution-free motorized transport. Smart metering devices can also switch off non-essential appliances when demand peaks, and lead to better utilization of a smaller generating capacity, thus reducing capital costs.

Occasionally, the wind can drop over an extended region under a large area of high pressure, for a number of days. If wind produced more than about 10 per cent of total electricity throughout Europe, even an extended grid connection might not be able to avert shortages in such freak weather conditions, unless there was sufficient storage, complementary solar power, or flexible reserve capacity powered by biogas or natural gas. In the long run, solar power (particularly from the southern periphery), the cost of which is falling rapidly, should be developed to complement wind, and could itself provide most of Europe's daytime energy, as we discuss in more detail below.

An interesting and long-neglected alternative in some regions is geothermal power. Rapid advances in the technology of drilling deep wells for oil in recent years have opened up an exciting new potential for extracting geothermal heat from depths of several thousand metres. Engineered geothermal systems (EGS) pump cold water through hot, deep rock formations, and use the resulting steam to power conventional turbines and generators. Pilot plants have been developed in several countries, but government support for large-scale, commercial systems has hitherto been minimal, although the EGS potential for continuous and relatively cheap power, particularly around the Pacific Rim, is enormous. This technology seems far more promising than nuclear power or CCS, and merits a major, publicly funded development programme. Geothermal energy can also be used directly for heating purposes, as is the case in Iceland, where more than 90 per cent of all households rely on the technology.

Hydroelectric power is still by far the most important alternative energy source, though the local environmental consequences of large dams such as the Aswan or the Three Gorges in China have been disastrous. Because most of the best sites have already been exploited, there is only limited potential for further development of large hydropower, particularly when external costs are considered. Nevertheless, there is considerable scope for the development of small-scale hydropower, as well as tidal and wave power in suitable coastal locations.

Nuclear energy, however, is increasingly becoming a much less popular solution to the energy security and climate change problems. For many years, the emphasis was on the problems associated with the storage and transportation of radioactive waste, the risk of proliferation of nuclear weapons and the environmental harm from uranium mining. The 2011 nuclear disaster in Fukushima showed that the possibility of accidents is another critical factor that had been seriously underestimated. The magnitude 9 earthquake and 15-metre tsunami that hit Japan's north-east coast on 11 May 2011 disabled the power system and cooling of three nuclear reactors – contaminated water leaked for days and more than 300,000 people were evacuated in the vicinity of the power plant.

As we emphasize in several parts of the book, individuals, firms and politicians are more likely to adopt radical changes in behaviour and policy, once they realize that the threat of climate change is not an extremely unlikely scenario – this is exactly what happened with nuclear energy and the Fukushima disaster. It is rather unfortunate that it took another major nuclear incident, after the 1986 accident in Chernobyl, to remind the world that the risk of a nuclear accident was not negligible. Since then, public and government support for nuclear energy has fallen substantially in most parts of the world (but not everywhere), and the International Energy Agency has now halved its estimate of additional nuclear-generating capacity to be built by 2035.

In Germany, the hitherto pro-nuclear government of Angela Merkel saw the accident and growing public opposition as an imperative to phase-out all nuclear energy by 2022 (with nuclear energy providing more than 20 per cent of all electricity supply until the Fukushima disaster!). Unfortunately, nuclear power is being replaced in part by new power stations using domestic lignite (brown coal, the most polluting kind of coal), and the Merkel government under industry pressure recently rejected a proposed tax on older lignite power stations. Yet 40 per cent of German emissions come from coal, the largest share in the G7, and the new policy casts doubt on the country's long-term climate goals.[37]

Biofuels

The most expensive and destructive attempt to produce alternative energy, has, ironically, received extensive support in the US, and is still heavily subsidized in the EU. The energy-intensive, industrial agriculture on which ethanol is based, and the inefficiency of the whole production process, probably *increases* total

GHG emissions, partly from the chemical fertilizers and energy used (discussed below).[38]

This dismal balance contrasts in some – but not all – respects with the situation in Brazil, the other major producer of ethanol. Here, in tropical or sub-tropical conditions, the production of ethanol from sugar cane is much more efficient, and appears to generate a net reduction in carbon emissions, while supplying about 40 per cent of Brazil's transport fuel. However, large-scale sugar cane monoculture has devastating effects on the local environment and economy. Furthermore, intensive cultivation of newly cleared (savannah or forest) land for biofuels releases large amounts of carbon for many years, which more than compensates for the direct reduction of fossil fuel use. Cultivation of biofuel crops on existing farmland displaces food production onto new land with similar effects.[39]

In addition, demand for biofuels to meet EU targets for renewable energy is encouraging the destruction of tropical rainforest. This problem is particularly acute in Malaysia and Indonesia, driven by growing demand for high-yielding palm oil plantation to produce relatively cheap biodiesel, demand that takes no account of the environmental destruction and loss of rainforest resources. The entire remaining habitats of the Orangutan in Borneo and Sumatra are under serious threat from rainforest destruction for palm oil monoculture, to supply biodiesel for the EU. Requirements for 'sustainable' biofuel sources without destroying rain forest will simply displace food crops from existing farmland to newly deforested areas.

Biodiesel is produced mainly in Europe, where the EU has set perversely unqualified targets for 'renewable' shares in total energy use, rising to 20 per cent by 2020, with no accounting for the total environmental impact. Again, high-cost production is heavily subsidized with ultimately destructive environmental effects, while the main raw materials – rapeseed and soybean oil – compete directly with food production. Nobel prize-winning climatologist Paul Crutzen has argued that the nitrogen fertilizers used to grow feedstock for biofuels generate so much of the powerful GHG nitrous oxide, that the fossil fuel emissions that are saved may actually be exceeded by emissions from biofuel production.[40]

A far more promising biofuel is biogas (or syngas) made from non-food, or waste biomass, that would otherwise be incinerated, deposited in landfill sites, or simply left to decay and pollute the environment. Biogas is produced by anaerobic fermentation of bio-waste, and consists mainly of methane and carbon dioxide that can be separated and sequestered, though at additional cost. Thus, refined biogas is similar to natural gas, and can also be used to power road vehicles after slight modification, which greatly reduces local pollution. Small-scale bio-reactors and bio-digesters are working successfully in many countries, and costs should fall as experience is gained and units can be mass produced. A further advantage of biogas production is that the residue left after fermentation is a valuable, nitrogen-rich organic fertilizer (called *bio-slurry*), which can replace energy-intensive chemical fertilizers that damage the environment and soil biota. This is a much more environmentally friendly use of bio-waste than simply burning it as an alternative to fossil fuels, which is only carbon neutral in the very long run.[41]

As discussed in Chapter 3, there is a further refinement of biofuel production that goes beyond merely reducing emissions or even carbon neutrality, to actually achieving a negative carbon balance, and in fact offers a potentially cheaper method of carbon sequestration than CCS for coal power. In the process of low-temperature *pyrolysis*, bio-waste is heated without oxygen to produce hydrogen and methane biogas and liquid biofuel, leaving perhaps half of the original carbon content as a residue in the form of active charcoal called *biochar*. This residue, containing the mineral contents and trace elements of the original bio-waste, is likely to have beneficial effects on soil fertility.[42] In the 'terra preta' or fertile, dark soils found in parts of the Amazon basin, biochar seems to have remained stable for thousands of years, though eventually it will oxidize to carbon dioxide. Only a small proportion of the energy or biogas produced is required to heat the bio-waste, so this process provides both energy and fertilizer, while effectively removing carbon from the natural cycle.

Lester Brown and many others have proposed large-scale planting of trees on marginal or waste-land, to absorb atmospheric carbon dioxide. There are around 1 billion hectares of currently unused but reclaimable wasteland – former agricultural- or grass-land that could potentially be reforested, with an appropriate carbon tax or reward for carbon sequestration. Sustainable mixed forest, agro-forestry or small-scale tree planting yield many additional environmental benefits, as well as biofuel or timber harvest. Much of this potential is in developing countries, so international aid and policies to reverse current deforestation for short-term profit will be needed. Some marginal land is used for common grazing by poor farmers, so commercial reclamation should be accompanied by adequate compensation for any loss of traditional rights, in contrast to the theft and eviction that is still all too common in many developing regions.[43]

Fast-growing perennial grasses to produce biogas and/or biochar can rival or exceed the sustainable 'productivity' of forest, in terms of carbon sequestration and co-benefits. These perennials do not require high-quality land or chemical fertilizers, so their opportunity costs in terms of foregone food production, and GHG emissions, are very low. Their deep root systems mean that even newly reclaimed and planted soils in abandoned agricultural areas are likely to accumulate rather than lose carbon as under conventional cultivation.

Thus, there appears to be a huge potential for carbon sequestration combined with timber and biofuel production, that enhances rather than reduces food production through the environmental benefits of sustainable reforestation and agro-forestry instead of deforestation. Estimates of available land suggest that billions of tonnes of carbon could be captured annually over decades of growth. International mobilization for halting deforestation and for really large-scale reforestation is needed, policies that could help to reduce atmospheric carbon to safe levels in the next decades, while fossil fuels are phased out. Current wasteful subsidies for destructive bioethanol and biodiesel should be switched to the much more promising developments outlined here, that allow sustainable biofuel production without the diversion or degradation of potential agricultural land. 'Agricultural

crimes against humanity' (and biodiversity) are the result of current subsidies for inefficient bioethanol and biodiesel, motivated by dependency on imported oil and gas and agribusiness lobbying rather than climate concerns.

Second-generation or advanced biofuels include cellulosic ethanol, which also uses bio-waste rather than food products as feedstock, and is coming into small-scale production in a number of countries. However, it remains to be seen whether mass production will reduce high capital and other costs sufficiently to attain competitiveness with the other alternative energy sources discussed here. A future prospect with a big potential is the use of algae to produce liquid fuel, but this seems to be some years from commercial development.

Solar energy

Solar PV power is the fastest-growing alternative energy, with capacity increasing by around 25 per cent annually in spite of persisting low fossil fuel prices. Global PV capacity will reach about 200GW in 2015. The average installed price of solar PV declined by half from 2011 to 2014, and has reached grid parity in many sunny regions, though solar still only supplies about 1 per cent of global energy. For off-grid, distributed use, particularly important in developing countries, solar PV is usually by far the cheapest alternative.

Continued annual growth of 25 per cent for the next 20 years could create a capacity of about 17TW by 2035, though, as with wind power discussed above, this would yield excess manufacturing capacity at the end of the transition period, which could be avoided by initially faster growth followed by constant output. This would be needed to regularly replace the oldest installations after target-generating capacity was reached, so total manufacturing capacity should be maintained (or expanded if needed). Utilization or capacity factors for solar PV vary widely, with much historically installed capacity in suboptimal areas such as Northern Europe. As with wind, the complementary, long-distance DC grid would facilitate optimal location of new solar installations in the sunniest regions, allowing for about 30 per cent utilization or an effective capacity of nearly 6TW, or somewhat less if other renewables were developed to make up the difference.

Large-scale concentrated solar power (CSP) could replace some solar PV if its cost also falls commensurately, and other alternatives such as hydro, geothermal, biogas, and perhaps wave and tidal all have potential. The exact proportions will obviously depend on how the respective technologies develop. The dramatic decline in the cost of solar PV, with further progress in the pipeline, and its convenience as a decentralized source of energy, suggests that it might take a larger share of a zero-carbon economy than envisaged in earlier projections.

The lowest capital cost per watt of installed solar PV is converging to $1 per watt, less than wind, and the technology continues to improve rapidly. Thus, the cost of this solar scenario should be below an *average* annual cost of $1 trillion. As noted above, this adds up to around 4 per cent of global GDP to complete the

transformation to zero carbon in 20 years, including energy-saving investment, the associated grid infrastructure, allowance for transmission losses, and necessary baseload and reserve capacity.[44] If all this seems optimistic, recall that we are not relying on future technical progress, though this will surely continue, if not at the dramatic pace experienced by solar PV in recent years. In any case, extending the completion date by a few years, or slightly raising the rate of investment could still achieve near-zero carbon well before mid-century, with the same enormous co-benefits, and so would be much less problematic than a similar postponement of the *starting* date of radical mitigation, which unfortunately is the depressingly likely scenario.

We have not separately considered the (lower) costs of solar thermal, which could actually replace some of the PV, and energy-saving investment, but simply included them with grid and other infrastructure, which also contribute to energy saving. Much saving expenditure is privately profitable, especially at current low rates of interest. As part of the green fiscal policy discussed in Chapter 10, these investments would raise depressed employment and output by several per cent through the multiplier effect, and thus quickly pay for themselves. As explained above, total savings from efficiency gains and WWS provide an *average* annual financial return on the investment of about 2.5 per cent of GDP (a return that of course also depends on the future path of fossil fuel prices, and whatever carbon taxes are introduced). This return *adds* to the medium-term health care, morbidity and mortality cost reductions of about 3 per cent of global GDP due to reduced pollution, which we have already emphasized.

The southern periphery of Europe is obviously a much better location for solar energy than the northern countries, which had installed most capacity by 2015, and could ultimately feed half or more of daytime power requirements into an EU-wide grid (the sunniest areas, including North Africa and the Middle East, provide about twice the solar radiation of northern regions, more than enough to offset relatively modest transmission losses). Southern winter cloud cover is generally local and short lived, and usually accompanied by windy conditions in the North – hence, a fairly steady electricity supply could be maintained from the solar–wind combination, with additional hydro, geothermal, biogas and perhaps tidal energy, together with storage, and distributed with the appropriate international grid connections. As explained above, surplus night-time generation from wind (and long-term baseload capacity) could then be used for charging electric (or hybrid) vehicle batteries to provide clean motorized transport, as well as storage heaters.

Just how much pure reserve-generating capacity (probably gas turbines with stored natural and/or biogas) would be required depends on baseload capacity, the composition and other properties of the international network, and the probabilities of freak weather and its effects on aggregate power output. Extending the grid to North Africa would improve reliability of the solar power component if political obstacles could be overcome. In the long run, existing storage technologies, including batteries, offer much potential for further development, possibly including the large-scale use of hydrogen produced by solar or wind energy.

Since peak power generation from wind and solar is much greater than average utilization, efficient long-term storage in some form or other could substantially reduce the need for reserve capacity. Storage and reserve capacity are obviously substitutes for ensuring reliability under extreme conditions, with the economics of the trade-offs depending on future development of the relevant technologies.

Implementing this final component of cost-effective mitigation in the EU will clearly require extensive international cooperation rather than the uncoordinated – and often inconsistent – national policies that are only just beginning to be set up. The European political framework should at least facilitate a coordinated energy policy when a sufficiently strong sense of urgency emerges. National rivalries or hostilities across borders in Africa and Asia provide a less favourable environment for effective mitigation.

The other main solar application, solar thermal or water heating, is much cheaper and with other uses – such as solar cooking and water disinfection – is also expanding rapidly as costs continue to fall. Again, a little more government support, and diverting subsidies from fossil fuels and nuclear energy, could dramatically accelerate the rate of expansion of solar energy use. The huge environmental benefits from substituting solar energy for biomass burning in developing countries have already been emphasized.

In contrast to the practical solutions discussed here, there has also been some discussion of 'geo-engineering' to sequester carbon by fertilizing plankton in southern oceans, or producing sulphate aerosols to reflect solar radiation. These yet-to-be-developed technologies are fraught with potential dangers, while diverting attention from the political obstacles to cost-effective mitigation and carbon sequestration through sustainable eco-agriculture and development of bio-char.

Conclusions

Our emphasis here on the co-benefits of mitigation suggests that the real, long-run net costs (in narrow economic terms) of even a drastic, worldwide reduction of emissions would be very modest. The short-run, *perceived costs* of changing habits and customs and the necessary redistribution are, of course, much greater, and form the main psychological, social and political barriers to change, as JD had already emphasized in 2011. If natural sinks have not declined too much by around 2035, and positive feedbacks not progressed too far, the total stock of carbon in the atmosphere could then be declining if mitigation on the scale outlined here (sustainable eco-agriculture plus the JD energy transition) was soon started. The world would then be heading for the relatively safe target of 350ppm CO_2, and could remain well below the dangerous 2°C threshold. As already mentioned, extending the energy transition by 5 or even 10 years would still be better than official targets, provided that the parallel transition to sustainable eco-agriculture still proceeded rapidly.

The developed countries will probably have to implement the largest reductions in any international framework that succeeds Kyoto. One of the major

political uncertainties most relevant for climate change is the question, when will progressive environmental degradation and worsening water shortages in China and India in particular, lead to serious remedial action?

Finally, it cannot be sufficiently strongly emphasized that this relatively 'optimistic' assessment depends fundamentally on a *rapid* reduction of GHG emissions. As many writers (including Stern) have pointed out, further delay in implementing serious abatement measures will necessitate much more drastic policies later. Already, at present concentrations of GHGs, and with the likely reduction of aerosol pollution under any serious mitigation effort, it will be necessary to *remove* large amounts of carbon from the atmosphere to avoid the risks of runaway warming. Again, as we have shown, this is feasible and cost effective with already existing technology, by using conservation agriculture, and extensive reforestation to sequester large amounts of carbon (but without very costly CCS), while switching to low-carbon WWS energy. However, as argued above, the immediate *perceived* costs and political barriers (in spite of net co-benefits) are likely to remain substantial, until serious impacts of warming become so obvious after a dangerously long period of further business as usual, that public perceptions change and political resistance also collapses.

The overwhelming majority of economists who have considered the costs of climate change have failed to incorporate the latest evidence from climate science on the high probability of accelerating feedbacks and runaway warming when mitigation is too little and too late, as under all official targets. Instead they still assume catastrophic events to be extremely unlikely, and essentially reduce the risks to relatively small reductions of much higher future average income. Historical high rates of material economic growth, which have depended on ruthless and growing exploitation of non-renewable resources, are simply projected or assumed to continue for centuries to come. The future distribution of income and poverty (under the impact of climate change) receives even less attention than these issues do today.

The assumption of everlasting material growth, whatever happens to climate and environment, is based on blind faith in technical progress – a science fiction scenario in defiance of all the evidence from climate and environmental science. Ironically, this ideology is shared by neoliberal economists with the Chinese Communist Party. Both have favoured growth at the cost of the environment and sustainability, and the apparent success of China in terms of growth rates has even elicited increasing admiration from the other end of the traditional political spectrum.

Belief in everlasting material growth may also be influenced by wishful thinking and the mistaken idea that consumption growth always increases subjective well-being, though average life satisfaction has declined in China, and failed to increase in many developed countries. This evidence has been completely ignored in the conventional consensus on material growth as the universal priority for economic policy. Slower but more sustainable growth (that does less damage to the environment and social capital, and raises the survival chances of our descendants)

is thus perceived to be a welfare cost, rather than a net benefit, in the perverse 'cost–benefit' analysis still widely applied to climate change, and indeed to many other economic issues.

Almost all discussion of the economics of climate change has been hamstrung by a misplaced focus on growing *average* consumption of a non-declining world population. Most economists in developed countries have little interest in agriculture, perhaps because this sector is now so small a part of advanced economies. Thus, there is little awareness of just how great is the threat to food supply in the developing world from further warming and progressive water shortages under current policies. The second result of this neglect is that the huge potential of conservation agriculture and reforestation (for combining mitigation with short-term, economic co-benefits) has been missed.

The rational collective response by humanity should be precautionary: to do whatever it takes to avert the *possibility* of catastrophe, and to ensure our survival, without wasting time trying to calculate the (unknowable) 'optimal' mitigation path. Persuading individuals and nations to abandon free-riding, and support collective survival strategies, remains the fundamental political challenge.[45] However, we have to admit that all this still looks unlikely after the December 2015 Paris climate agreement, and that climate-related disasters will have to become much more frequent and severe before public opinion in the major emitting countries supports the necessary scale and pace of investment in mitigation.

Notes

1 Nordhaus, W. (2013) *The Climate Casino*, Yale University Press, New Haven, CT, 145.
2 See Nordhaus (2013), and Stern, N. (2007) *The Economics of Climate Change: The Stern Review*, Cambridge University Press, Cambridge, UK, which popularized IAM estimates and generated much critique and discussion. For a summary of the science that has since become still more pessimistic, by one of the world's pioneering and most influential climate scientists, see Hansen, J. (2009) *Storms of my Grandchildren*, Bloomsbury, London, UK. The seminal (but by no means the first) 'early-warning' paper that was ignored by almost all economists was Hansen, J., Johnson, D., Lacis, A., Lebedeff, S., Lee, P., Rind, D. and Russell, G. (1981) 'Climate impact of increasing atmospheric carbon dioxide', *Science*, vol 213, no 4511, 957–966. For an early and appropriately scathing critique of IAMs by a prominent climate scientist, still ignored by economists such as Nordhaus, see Schneider, S. H. (1997) 'Integrated assessment modeling of global climate change: Transparent rational tool for policy making or opaque screen for hiding value-laden assumptions', *Environmental Modelling and Assessment*, vol 2, no 1, 229–249.
3 Stern, N. (2015) *Why Are We Waiting?*, MIT Press, Cambridge, MA, 146.
4 See Stern (2015). We presented a similar critique of the IAM results used in the *Stern Review* in the first, 2010 edition of this book, and many climate scientists and environmentalists had emphasized far greater dangers from climate change, long before relatively trivial damages were simply *assumed* in the IAMs by Nordhaus and the *Stern Review*.
5 Kolbert, E. (2015) 'A new climate-change danger zone?', *The New Yorker*, 23 July, available at www.newyorker.com/news/daily-comment/a-new-climate-change-danger-zone.
6 Hansen (2009), 142.
7 McKibben, B. (1989) *The End of Nature*, Anchor, New York, NY.
8 Stern (2015).

9 Brown, L. R. (2003) *Plan B*, Norton, London, UK.
10 See Brown (2003). These ideas are further developed in Brown (2012).
11 Stern (2015), 19.
12 World Health Organization (2015) 'Economic cost of the health impact of air pollution in Europe: Clean air, health and wealth', available at http://www.euro.who.int/en/media-centre/events/events/2015/04/ehp-mid-term-review/publications/economic-cost-of-the-health-impact-of-air-pollution-in-europe.
13 See Smith, A. (2013) *Climate Bonus: Co-benefits of Climate Policy*, Routledge, London, UK.
14 Jacobson, M. Z. and Delucchi, M. A. (2011) 'Providing all global energy with wind, water, and solar power, Part I', *Energy Policy*, vol 39, no 3, 1154–1169, and Jacobson, M. Z. and Delucchi, M. A. (2011) 'Providing all global energy with wind, water, and solar power, Part II', *Energy Policy*, vol 39, no 3, 1170–1190. Recently, these authors and others have provided very detailed 'roadmaps' for 50 US states to achieve wind, water and solar (WWS) economies by 2015: Jacobson, M., Delucchi, M., Bazouin, G., Bauer, Z., Heavey, C., Fisher, E., Sean, M., Diniana, M., Piekutowski, D., Vencilla, T. and Yeskoo, T. (2015) '100% clean and renewable wind, water and sunlight (WWS) all-sector energy roadmaps for the 50 United States', *Energy and Environmental Science*, vol 8, 2093–2117.
15 International Monetary Fund (2015) 'How large are global energy subsidies?', Working Paper No 15/105, International Monetary Fund, Washington DC, available at https://www.imf.org/external/pubs/cat/longres.aspx?sk=42940.0.
16 Citi GPS (2015) 'Energy Darwinism II: Why a low carbon future doesn't have to cost the earth', August, available at www.citivelocity.com/citigps/ReportSeries.action; 'Inaction' is compared with an 'Action' scenario, which includes major investment in energy efficiency to reduce fossil fuel use (but still only modest spending on renewables). It costs less but allows fossil fuels to remain the largest energy provider, and does no better than Stern's very risky 50 per cent chance of exceeding the 2°C threshold. The report is also flawed by adopting the absurdly low, few-percent-of-much-greater-GDP climate damage estimates produced by most economists using unrealistic IAMs.
17 Greenpeace (2015) 'Energy revolution 2015', 21 September, available at: www.greenpeace.org/international/en/publications/Campaign-reports/Climate-Reports/Energy-Revolution-2015.
18 With high-voltage DC transmission, losses are usually quoted at around 3.5 per cent per 1,000 km, so our target power capacity might have to be raised, say by another year or two of expansion beyond the 20 years projected.
19 US Department of Energy (2015) 'Potential wind capacity', http://apps2.eere.energy.gov/wind/windexchange/windmaps/resource_potential.asp.
20 Stern (2015).
21 See Smil, V. (2015) *Power Density*, MIT Press, Cambridge, MA, and Wynn, G. (2015) 'Why a 100% renewable energy future must be electric', *Energy and Carbon Blog*, 5 August, available at http://energyandcarbon.com, for a critique of Smil.
22 Broome (2012).
23 Stern (2015), and Wagner, G. and Weitzman, M. (2015) *Climate Shock*, Princeton University Press, Princeton, NJ.
24 See Neumayer (2007).
25 Many authors have documented the debilitating effects of rising inequality since the 1980s: Wilkinson and Pickett (2009); Barry, B. (2005) *Why Social Justice Matters*, Polity Press, Cambridge, UK; Irvin, G. (2008) *Super Rich: The Rise of Inequality in Britain and the United States*, Polity, London, UK; Stiglitz, J. E. (2013b) *The Price of Inequality*, W.W. Norton & Company, London, UK; Atkinson, A. B. (2015) *Inequality*, Harvard University Press, Cambridge, MA. A striking example of inequality in the UK comes from the traditionally deprived Calton ward in central Glasgow, where male life expectancy has been estimated at 54 years, less than in many very poor countries.

In the nearby, prosperous small town of Lenzie, male life expectancy is 82 years, no less than 28 years more! Population movement means that there is some uncertainty around these numbers, but the broad picture is inescapable.

26 See Sachs, J. (2008) *Common Wealth: Economics for a Crowded Planet*, Penguin, London, UK and (2011) *The Price of Civilization*, Bodley Head, London, UK. These problems are discussed in much more detail in Chapter 5.

27 See Campbell, K. M., Gulledge, J., McNeill, J. R., Podesta, J., Ogden, P., Fuerth, L., Woolsey, R. J., Lennon, A. T. J., Smith, J., Weitz, R. and Mix, D. (2007) 'The age of consequences: The foreign policy and national security implications of global climate change', Center for Strategic and International Studies, Washington DC. In their executive summary (page 7), the authors note: 'The *catastrophic* scenario, with average global temperatures increasing by 5.6°C by 2100, finds strong and surprising intersections between the two great security threats of the day – global climate change and international terrorism waged by Islamist extremists. This catastrophic scenario would pose almost inconceivable challenges as human society struggled to adapt.'

28 The precautionary principle is considered by Wagner and Weitzman (2015). They emphasize that disastrous impacts may be impossible to quantify as in conventional CBA and IAMs, and conclude that mitigation as a form of insurance should ensure that disastrous climate change just does not happen. However, they do not discuss how cost effective existing alternative energy actually is and how extensive the co-benefits are. One of the first economists to offer more sensible policy alternatives based on the precautionary principle, discussed below, was Ackerman, F. (2008) *Can we Afford the Future?*, Zed Books, London, UK.

29 On many occasions economists and financial analysts have failed to forecast accurately future changes in fossil fuel prices (especially oil). Speculation, unpredicted changes in supply and demand, and geopolitical uncertainty have all contributed to unforeseen fluctuations in oil prices in the past. There used to be a general consensus that the global oil production would peak between 2010 and 2030 (this is often referred to as the timing of *peak oil*), which could lead to rapid increases in oil prices in the absence of readily available alternatives (particularly for transportation). The recent increases in unconventional oil reserves (e.g. oil sands, oil shale), and the prospects of more oil and gas under the receding Arctic ice-shelf, might render fossil fuels even cheaper in the near future, unless carbon taxes ensure that their prices reflect their true value that includes environmental damage. For a recent discussion on peak oil issues, see Chapman, I. (2014) 'The end of peak oil? Why this topic is still relevant despite recent denials', *Energy Policy*, vol 64, no 1, 93–101.

30 Foley, D. (2007) 'The economic fundamentals of global warming', Working Paper No 07-12-044, Santa Fe, NM.

31 Mulvey, K. and Shulman, S. (2015) *The Climate Deception Dossiers*, Union of Concerned Scientists, Washington DC, available at http://www.ucsusa.org/sites/default/files/attach/2015/07/The-Climate-Deception-Dossiers.pdf.

32 See Spector, T. (2015) *The Diet Myth*, Weidenfeld & Nicolson, London, UK.

33 For example, see Chen, R., Samoli, E., Wong, C.-M., Huang, W., Wang, Z., Chen, B. and Haidong, K. (2012) 'Associations between short-term exposure to nitrogen dioxide and mortality in 17 Chinese cities: The China air pollution and health effects study (CAPES)', *Environment International*, vol 45, no 7, 32–38, as well as Boseley, S. (2015) 'Air pollution may cause more UK deaths than previously thought, say scientists', *The Guardian*, 2 April, available at http://www.theguardian.com/environment/2015/apr/02/air-pollution-may-cause-more-uk-deaths-than-previously-thought-say-scientists.

34 Stern (2015).

35 See Brown, L. (2015) *The Great Transition*, Norton, London, UK, for a survey of alternative energies discussed below, and their dramatic growth in spite of relatively weak government support in most countries, and declining fossil fuel prices.

36 Kovats, S., Depledge, M., Haines, A., Fleming, L. A., Wilkinson, P., Shonkoff, S. B. and Scovronick, N. (2014) 'The health implications of fracking', *The Lancet*, vol 383, no 9919, 757–758.

37 See Hayashi, M. and Hughe, L. (2013) 'The Fukushima nuclear accident and its effect on global energy', *Energy Policy*, vol 59, no 1, 102–111, and Srinivasan, T. and Rethinaraj, T. (2013) 'Fukushima and thereafter: Reassessment of risks of nuclear power', *Energy Policy*, vol 52, no 4, 726–736. On German emissions, see Evans, S. (2015) 'German coal compromise leaves doubts over climate goal', *The Carbon Brief*, London, UK, 2 July, available at www.carbonbrief.org/german-coal-compromise-leaves-doubts-over-climate-goal.

38 Fargione, J., Hill, J., Tilman, D., Polasky, S. and Hawthorne, P. (2008) 'Land clearing and the biofuel carbon debt', *Science*, vol 319, no 5867, 1235–1238.

39 Chen, X. and Khanna, M. (2013) 'Food vs. fuel: The effect of biofuel policies', *American Journal of Agricultural Economics*, vol 95, no 2, 289–295.

40 Crutzen, P. J., Mosier, A. R., Smith, K. A. and Winiwarter, W. (2007) 'N_2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels', *Atmospheric Chemistry and Physics Discussions*, vol 7, 11191–11205.

41 There are currently several projects in the developing world supporting biogas production in rural areas, that combine clean energy supply with the benefits of organic, cheap fertilizers. An additional side benefit is the reduction in indoor air pollution (and associated health costs) by relying on biogas rather than charcoal, wood or dung for cooking. See Cheng, S., Zifu, L., Mang, H. P., Huba, E. M., Gao, R. and Wang, X. (2014) 'Development and application of prefabricated biogas digesters in developing countries', *Renewable and Sustainable Energy Reviews*, vol 34, no 2, 387–400.

42 There is extensive research ongoing to better understand the properties of biochar, their dependence on the type of feedstock used, and on the details of the pyrolysis process. See Lehmann J. and Joseph, S. (eds) (2015) *Biochar for Environmental Management*, 2nd edn, Earthscan, London, UK.

43 Dressler, W., McDermott, M., Smith, W. and Pulhin, J. (2012) 'REDD policy impacts on indigenous property rights regimes on Palawan Island, the Philippines', *Human Ecology*, vol 40, no 2, 679–691.

44 For a very detailed survey of renewable costs see International Renewable Energy Agency (IRENA) (2015) 'Renewable power generation costs in 2014', January, Abu Dhabi, United Arab Emirates, available at www.irena.org/DocumentDownloads/Publications/IRENA_RE_Power_Costs_2014_report.pdf.

45 See Ostrom, E. (1990) *Governing the Commons: The Evolution of Institutions for Collective Action*, Cambridge University Press, Cambridge, UK, and Ostrom, E. (2014) 'A polycentric approach for coping with climate change', *Annals of Economics and Finance*, vol 15, no 1, 71–108.

10

GREEN FISCAL POLICY

From austerity to full employment in a low-carbon economy

Introduction

Policymakers in many countries have forgotten the logic and success of Keynesian countercyclical policy. The dominant deficit hawks follow the neoliberal agenda and prefer smaller government, less welfare for the poor and lower taxes for the rich, in spite of enduringly high unemployment and even the prospect of secular stagnation, without any recognition of lessons from failed policies and predictions in the past. At the same time, woefully weak targets for emissions reduction and continued opposition to carbon taxes in the face of ever more urgent warnings by climate scientists are defended by fossil fuel lobbyists and complicit media and politicians. This in turn requires that they systematically ignore and suppress the huge external costs of pollution, in terms of both local mortality and morbidity today, and the survival of future generations at the global level.

This concluding chapter draws on our earlier policy recommendations throughout the book to advocate for a Keynesian fiscal policy that can tackle the major current economic problem of high and persistent unemployment in many developed economies. This can be implemented through large-scale investment in a 'low-carbon future', which is urgently needed to avoid dangerous and irreversible climate change – the overriding long-term threat to future prosperity, and even civilization. The separate effects of the natural *common* solution to two of the biggest global problems have long been well known, but they are rarely analysed together for reasons that will be outlined below. There were exceptions at the start of the Great Recession, such as Tim Jackson's pioneering *Prosperity without Growth*, and various reports by the Green New Deal Group culminating with *A National Plan for the UK* in 2013, which clearly predicted the failure of austerity and advocated green fiscal policy for attaining full employment, rather than just focusing on growth. Eminent environmentalists and economists have also long proposed 'green investment' for sustainable economic growth, though ecologists often disagree on the feasibility of 'sustainable growth'.[1]

However, these ideas are all anathema to the prevailing neoliberal ideology of a smaller state with lower taxes for the rich, less welfare for the poor and more economic growth, whatever the social cost, combined with climate science

denial by conservatives (mainly in the US, but also by some in the UK). Instead, the preferred response has been to rely on traditional monetary policy of large-scale asset purchases by central banks, QE or 'quantitative easing', to maintain low interest rates and restore economic growth. Before the financial crisis in 2008, government debt and budget deficits were at historically quite low levels in most countries, but they rose sharply as tax revenues plummeted with rapidly declining economic activity, while expenditure on welfare and unemployment benefits, the 'automatic stabilizers' triggered by recession, increased.

There were some additional but seriously inadequate fiscal measures, particularly in the US, but, by 2010, 'deficit hawks' had begun to dominate political discussion, led by conservatives in the US, the UK and Germany. Policymakers then began to react as they had at the start of the Great Depression in the 1930s – by cutting government expenditure and public sector employment 'to reduce the deficit', but of course the result was to *delay* recovery, *maintain* high unemployment, *reduce* tax revenues and thus to *raise* deficits.

The lessons of the 1930s – and basic textbook Keynesian economics – have been systematically ignored in the ongoing obsession of policymakers with debt and austerity, the 'deficit fetishism' that was euphemistically called 'fiscal consolidation' throughout the developed economies. In spite of the obvious potential for environmental and other investment in recession, weak economic recovery and growing worries about deflation and even secular stagnation were deflecting public attention from climate change policy. Short-term issues dominated policy discussion among bankers and politicians who appeared to be mired in pre-Keynesian economic illiteracy, but were also probably just following the neoliberal agenda of 'smaller government', for which the current crisis offers superficially plausible, though economically nonsensical, populist justification. Many prominent economists have explained the absurdity and destructiveness of austerity in detail.[2]

It is true that QE in the US and UK, with the help of some modest, initial expansionary fiscal policy, probably prevented the Great Recession turning into a second Great Depression in these two countries with the most dominant and least regulated financial sectors, which in the US was mainly responsible for the crash in 2007/8. However, as deficit hawks and austerity generally prevailed after 2010, the pace of recovery slowed down, and the costs of continued, and perversely *pro-cyclical* austerity have been immense, particularly in the eurozone. Monetary policy has kept interest rates close to the zero lower bound (ZLB), or even negative in the advanced economies, but unemployment was around 11.5 per cent in the Euro area in 2015 (remaining persistently high and above 10 per cent for the fifth consecutive year), and is still more than twice as high for young people, and for all in the southern periphery – at Great Depression levels.

Most of the benefits of generally anaemic growth have been captured by the top 1 per cent of the income distribution, whose shares of total income in several countries are now approaching levels last seen in the 1920s. Their share is nearly 25 per cent in the US, having doubled since the 1970s, though the real median wage for men has stagnated since then, while most wages have *declined* since 2008

in the UK. In the UK and the US, headline unemployment has fallen, but the new jobs are mainly part-time, low-wage, insecure or self-employed with inadequate income.[3] Above all, QE and stagnant wages have triggered booms in stock markets, corporate profits, cash-hoarding and share buy-backs around the world, as well as renewed house price inflation in many big cities. Meanwhile, the net investment (both in public infrastructure and by the private sector) that is needed to drive recovery and ensure future prosperity, has been *declining* since the 1980s in most industrial countries, in a little discussed but all the more alarming trend.[4]

At the same time as the economic crisis has deflected attention away from ever more urgent warnings by climate scientists, fossil fuel interests, led by the Koch brothers in the US, who have overtaken ExxonMobil, continue lavishly funded campaigns to denigrate and deny climate science, and attack prominent climate scientists, aided by complicit media and prevailing neoliberal ideology. As pointed out in Chapter 2, these campaigns have been documented in detail by many authors. Environmentalist Naomi Klein provides an eloquent recent review and draws depressing parallels with earlier industry campaigns to cast doubt on the science that exposed the enormous health hazards of tobacco and leaded petrol.[5]

The result of these intensive campaigns of climate science denial has been a declining public perception of the risks from continued reliance on fossil fuels, just as the scientific findings reveal ever-greater dangers from postponement of far-reaching mitigation measures. This in turn makes it more difficult to introduce the carbon taxes, which most economists agree are an essential part of action on climate change, and easier to reduce support for low-carbon investment in the name of austerity.

By contrast, the large expansionary effect, or 'fiscal multiplier', from additional government expenditure in a 'liquidity trap' or ZLB situation is now increasingly accepted by economists, even at the IMF, that former bastion of the neoliberal 'Washington Consensus' which inflicted so much austerity and harm on developing countries in previous decades.[6] The IMF's *World Economic Outlook* (2014) has finally recognized that declining public investment in advanced economies for the last three decades has allowed gradual deterioration of essential infrastructure, particularly roads, bridges and many public buildings, such as schools and hospitals. Furthermore, the IMF provides extensive analysis that confirms the basic Keynesian insight – with underutilized resources at the ZLB, debt-financed public infrastructure investment will more than pay for itself through the multiplier effect, the high returns on improving urgently needed infrastructure, and subsequently higher tax receipts – the ultimate 'free lunch' that is still so often denied by conservative economists.

However, the IMF, and indeed many Keynesian economists, still fail to recognize that the ultimate in deteriorating global 'infrastructure' is really our climate, which in its hitherto benign, interglacial phase over the last 10,000 years has enabled the rise of agriculture and civilization. One prominent exception is economist Jeffrey Sachs, who has repeatedly emphasized the urgent need for massive investment for a low-carbon future, in addition to other infrastructure, to generate sustainable growth. This will yield not only the incalculable benefits of survival and

potential prosperity for the especially vulnerable, poor populations most threatened by climate change, but also *two* economically quantifiable, short- to medium-term returns that would far exceed the direct outlays in the advanced (but currently underperforming) economies. The first is just the multiplier effect already discussed, which could bring advanced economies closer to their potential output with full employment, and a gain of several percentage points of GDP from currently depressed activity that, in the views of several prominent economists, may well be heading towards a new era of secular stagnation.[7]

The second co-benefit of reducing emissions follows from the huge health costs of fossil fuel pollution, particularly in developing countries, of which coal is the major source, which were reviewed previously in Chapter 9. The most cost-effective way of initially reducing emissions is investment in improving the energy efficiency of existing buildings, which would also, of course, reduce fuel costs. By neglecting these co-benefits, many economists (who are not climate change deniers, and do support moderate carbon taxation) have also unwittingly fuelled opposition to climate policy by seriously *overestimating* the total costs of transition to a low-carbon economy. In addition, most economists and politicians who do recognize the reality of climate change continue to ignore the danger of really catastrophic climate impacts, far beyond modest declines in GDP, if serious mitigation efforts are delayed too long.

Green investment, in contrast to quantitative easing, is labour-intensive rather than asset-price boosting, and would have a substantial *direct* impact on employment. Construction sectors have generally suffered most in the ongoing Great Recession, and would also benefit most from major investment in energy efficiency in the built sector. Public investment can be funded at near-zero interest rates, or directly by monetary expansion with an even larger multiplier effect, and *without* any danger of inflation in current depressed, ZLB conditions with looming deflation.[8] Such investment reduces future fuel and climate change costs, and also the health hazards of local pollution, as well as cutting unemployment and government deficits through the multiplier.

Largely ignored in current discussion, even by observers who emphasize the need to restore economic growth, are the strongly negative effects on subjective or self-assessed well-being (SWB, life satisfaction or happiness) caused by declining social capital and real wages for many, and growing inequality and unemployment, which offset the benefits of intermittent GDP growth. We discussed these issues in detail in Chapter 4, but to reiterate a key result, life satisfaction in the EU15 has remained flat over the last three decades of growth, which doubled average per capita real GDP, a finding that confirms Easterlin's famous 'paradox' of 1974, and stands in striking contrast to continuing emphasis on the benefits of economic growth in material consumption as the ultimate policy goal.

Finally, and scandalously neglected in most policy discussion (by non-scientists), long-term projections of future climate change, under continuing business as usual with *growing emissions*, are becoming increasingly pessimistic, as we reviewed in detail in previous chapters. There is little time left for major mitigation investment

to ensure that most of the existing proved reserves of fossil fuels stay in the ground to limit the risks of climate change that may otherwise become irreversible, and ultimately generate catastrophic conditions in much of the world.

The employment and poverty crisis since 2008

The global financial crisis that started in late 2007 caught the world by surprise and raised fears of a second Great Depression. In the end, propped up by massive government spending to rescue failing banks in the financial crisis of 2008–2009, GDP fell only by 5–7 per cent in the main economies. This was a much smaller decline than in the Great Depression, when US and German GDP declined by more than a quarter between 1929 and 1933 as government expenditure was drastically cut, in the most striking historical examples of the failure of austerity. However, this failure was followed by expansionary public expenditure, as part of President Roosevelt's New Deal in the US, and mainly for rearmament in Germany, policies that generated rapid recovery and actually preceded the publication of Keynes's *General Theory* in 1936, which only then provided the theoretical justification and analysis of such *countercyclical*, expansionary fiscal policy.[9]

Nevertheless, history and theory have since been overridden by neoliberal ideology, and recovery since 2009 has been *slower* in Europe than in the 1930s, thanks to *pro-cyclical* austerity policies in defiance of standard Keynesian macroeconomics after 2010. The US has performed better in terms of GDP growth and official unemployment rates, with somewhat less austerity, but still remains far below economic potential, with major problems of growing inequality and underemployment. In Germany, extensive work-sharing agreements with the unions, in cooperative rather than confrontational collective bargaining and co-determination, spread the cost of recession and kept unemployment relatively low, while an absence of the austerity cuts that Germany and the EU imposed on the southern periphery, together with a continued export boom, helped to maintain modest GDP growth.

The German technology-based export boom has been helped by a favourable euro exchange rate (held down by the weaker southern economies), which made German exports cheaper for foreign buyers than under the strong Deutschmark, and by vigorous neoliberal policies to reduce welfare and restrain wages of less-skilled workers (real incomes of the poorest 30 per cent have been declining since the mid-1990s). Germany's current account surplus, at over 7 per cent of GDP, is twice China's share, and reduces aggregate demand and employment in the deficit nations, hampering their recovery. Even former Federal Reserve Chair Ben Bernanke (2015) has called for wage hikes in Germany, rather than sole reliance on further wage depression in deficit states, to rebalance the eurozone.[10]

In the UK, some work-sharing combined with substantial wage cuts and weak productivity growth helped to keep official unemployment below eurozone levels, even after drastic spending cuts were introduced by the Conservative–Liberal

coalition in 2010. Austerity was relaxed (unofficially, and of course with no admission that two years of spending cuts and stagnation had been a big mistake) by Conservative Chancellor George Osborne in 2012, so that modest employment growth returned in time for the election in 2015, together with promises of further drastic cuts by all the major parties. These were needed, according to the myths of what Simon Wren-Lewis, in his Mainly Macro blog, calls 'mediamacro' or populist deficit hysteria propagated by conservatives on both sides of the Atlantic, and uncritically disseminated by complicit media, to reduce the still-growing deficit.

In the meantime, poverty, deprivation and under-employment have been increasing over the longest period of declining real wages in the UK for most workers since the 1870s. Young people have been hardest hit – median real earnings for employees in their twenties have fallen by 15 per cent during the Great Recession – and recovery has been slower than in the 1930s, and indeed the slowest for any major recession since the South Sea Bubble of 1720! Low- and medium-skilled workers' real earnings have fallen by nearly 14 per cent from 2008 to 2014, more than the 10 per cent drop in skilled earnings, and faster than in any other EU economy except Greece. GDP per capita was still 5 per cent lower in 2014 than in 2007, a worse performance than in any but the hardest-hit, southern EU economies.[11]

In these countries, Portugal, Italy, Greece and Spain (often referred to by the rather derogatory term 'PIGS', or 'PIIGS' when also hard-hit Ireland is included), the Great Recession has indeed become the second Great Depression, with youth unemployment ranging from 35 per cent in Portugal, and nearly 50 per cent in Italy, to nearly 60 per cent in Spain and Greece. These two countries still had average unemployment rates of nearly 25 per cent in 2015, a slight drop from their peaks three years earlier, which was trumpeted as a sign of success of EU austerity policy! These numbers are in spite of unprecedented emigration of many of the most qualified young people, leaving the remainder to be likely scarred for the rest of their lives by lack of work experience, psychological trauma and lack of any prospects for rapid improvement. Europe's young, skilled but nevertheless jobless generation is also becoming increasingly disillusioned with the EU and its policies – most young Europeans feel that the recipient of the 2012 Nobel Peace Prize (for its contribution to 'peace and reconciliation, democracy and human rights in Europe') has let them down with repeated broken promises of a better future.

In the EU28, prime age (25–49) adult unemployment increased by 53 per cent between 2007 and 2014, while youth (15–24) unemployment increased by 41 per cent over the same period, with a growing share of long-term unemployed. Average youth unemployment is still around 20 per cent in Europe, while the most disadvantaged, NEET (not in employment, education or training) share of youth remains at about 12 per cent. This group has virtually no long-term prospect of stable and legitimate employment.[12]

Average unemployment in the PIGS is also at depression levels of around 25 per cent, leading to extreme poverty and deprivation for the most vulnerable sections of the population in countries with weak social security. The smaller

economies of Ireland and the Baltic states have also suffered substantial declines in output and employment, though official unemployment has been mitigated by the highest proportional rates of emigration, as usual by young and well-qualified workers.

It is well known that unemployment is a major cause of ill-health and unhappiness, and prominent public health experts David Stuckler and Sanjay Basu document the devastating effects of recent austerity on health, particularly among the poorest, in several countries. In the most severely affected, Greece, austerity led to a 40 per cent cut in the health budget, and an equal rise in infant mortality from 2008 to 2010 and in the number of people reporting that they have been unable to access essential medical care, as well as epidemics of HIV, malaria and TB, and rising rates of depression, mortality and suicide. Worldwide, 1 in 5 suicides are associated with unemployment, and the number increased by more than 10 per cent from 2007 to 2011.[13]

The macroeconomic failures of prolonged austerity are well known: *rising* levels of debt, unemployment and underemployment occurred in most affected economies, while real GDP per head was 25 per cent lower in Greece in early 2015 than in 2007, with substantial declines in the other PIGS. As Paul Krugman notes, the effect of austerity on Greece has been similar to the effect of defeat in total war on Imperial Germany, which suffered a similar decline in GDP from 1913 to 1920.[14] Real wages have fallen by 25 per cent in Greece, but this increase in 'competitiveness' has failed to boost exports, because the needed investment in export sectors has been blocked by austerity, which of course has also reduced demand for Greece as a tourist destination in other affected countries. In contrast with the familiar and depressing macroeconomic headlines, however, the even more devastating distributive consequences of austerity programmes consisting mainly of wage and welfare cuts, and of the QE that benefited mostly banks and the rich, have received less emphasis, but are now also beginning to attract more attention.

Thus, in the US, the most unequal among the advanced economies, average wealth declined dramatically (by 44 per cent from 2007 to 2010, mainly due to the collapse of the housing bubble), and then failed to rise after 2010 (in spite of the rebound in asset prices), leaving the poorest half of the population with negative net wealth (due to debt) on average, and the poorest 60 per cent of households owning less than the 94 richest individuals.[15] Most of the benefits of growth, not only since recovery from the financial crisis of 2008, but actually since the late 1970s in the US, have been captured by the top 1 per cent of the income distribution. Their share of national income has more than doubled since 1980, while the share of the top 0.1 per cent has quadrupled. Real hourly wages for most male workers have *declined* in the US over this period, while aggregate productivity doubled – real household income for the bottom quintile *fell* by no less than 12 per cent, while real income for the top quintile rose by 50 per cent (from 1979 to 2012, US Census Bureau).

In the UK and the US, the recent decline in official unemployment rates has deflected attention away from other, more worrying trends, including the rise in

long-term unemployment, as well as low-paid and part-time employment, falling real wages for most workers, declining labour-force participation, and the growth of self-employment with low earnings. In these two countries, the share of low-paid employees is the highest in the OECD. Only 1 in 40 of the new jobs created in the UK from 2009 to 2014 provided full-time employment.

Even in Germany, the EU's leading economy, average real income of the bottom 90 per cent has remained flat since 1980, while the higher earners in the top 10 per cent of the distribution enjoy most of the benefits of growth that doubled real output over the period. Thus, the lowest earners and jobless have also suffered substantial *declines* in real incomes in Germany, as low-wage and precarious employment has expanded, in spite of less austerity than most of the EU, and slower growth of the share of the top 1 per cent than in the UK.[16]

While some people obviously do prefer part-time work in order to cope with family responsibilities, particularly when another member of their household is in full-time work, many are currently in part-time employment because they cannot find full-time work, although they need the extra income. These latter include those employed on the notorious and proliferating zero-hour contracts, which provide no assurance of any paid hours in any given period. Similarly, many of the newly self-employed have been unable to find adequately paid, full-time work, and remain under-employed on low earnings. According to the comprehensive new deprivation measure developed by Lansley and Mack, poverty in the UK more than doubled from less than 15 per cent in 1983 to 30 per cent in 2012. QE in the UK has also reignited the house-price boom, so that rapidly rising housing costs for renters, who include most low-income households, have further depressed their already declining 'real' wages, which are thus overestimated by the traditional RPI (retail price index) deflator used to calculate real wages.[17]

Persistent and extensive un- and under-employment is a major legacy of the financial crash of 2008, with devastating consequences for welfare, which is everywhere seriously underestimated by official (International Labour Organization or ILO) unemployment rates, and is predicted to increase further in the medium-term future. Globally, according to the ILO, 'more than 61 million jobs have been lost since the start of the global crisis in 2008 and . . . projections show that unemployment will continue to rise until the end of the decade'.[18]

Meanwhile, austerity policies reduce government payrolls, delay vital investment in infrastructure, stifle growth, and actually generate rising levels of government debt, contrary to claimed objectives. More discouraged workers with low skills leave the labour force in recession when chances of finding regular work decline. Finally, those with some disability and little formal qualification who would nevertheless like to work are increasingly disadvantaged. Eurostat lists discouraged workers and the underemployed under 'supplementary indicators' for the EU28, and finds these categories each amounted to about half the average 10 per cent official ILO unemployment rate in mid-2015, or 11 per cent in the eurozone.

Why austerity in the Great Recession?

Since Keynes, it has been well known to most economists that purely monetary policy is ineffective in depressed conditions when nominal interest rates are close to zero, and cannot fall further to discourage excess savings and stimulate aggregate demand (the ZLB, or liquidity trap). Moderate inflation would help by generating effectively negative real interest rates, but is anathema to conservative European central bankers and policymakers, particularly in Germany, obsessed with folk memories of 1920s hyperinflation, and stagflation following the OPEC oil-price shocks in the 1970s. Instead, these policymakers point to Germany, with its huge trade surplus, as the most successful economy in Europe, and the example that the deficit-plagued rest of the eurozone should emulate by becoming more 'competitive'!

Apart from the simple arithmetical problem that one country's surplus has to be matched by others' deficits, this view obscures the origins of Europe's current woes. German and other banks were all too eager to finance the excess spending of the less competitive member-states right up until the crash in 2008, or as international economist Paul De Grauwe puts it, 'for every reckless debtor there must be a reckless creditor'. Rising national debt levels at the start of the Great Recession were mainly due to the costs incurred by governments in rescuing the reckless creditor banks, instead of letting their shareholders and creditors bear the losses for which they were ultimately responsible, and if necessary nationalizing the banks. Instead, the guiding principle behind neoliberal austerity remains that taxpayers in the poorer, debtor countries should ultimately pay for the losses incurred by the reckless creditors – while, in many cases, the managers of these troubled, bailed-out banks continued to be rewarded with excessive bonuses.[19]

Under the single currency of the eurozone, the traditional response of exchange rate adjustment or devaluation was no longer available to countries with current account or trade deficits, so the costly alternative of internal devaluation or deflation was enforced by massive cuts in government expenditure and employment. Predictably, these measures generated depression levels of unemployment, and Greece and Spain, the countries making the largest proportional cuts, suffered the biggest declines in output and employment. Due to the multiplier effect, tax revenues from shrinking economies then declined faster than government expenditure cuts, so government deficits and debt actually *increased* rapidly as a direct result of misguided, pro-cyclical austerity policies throughout the Great Recession. While Spain is held up as a model of 'successful' austerity by German and EU politicians, unemployment was still 22 per cent in 2015, and per capita GDP had only reached the 2003 level by 2014.

Real wages and unit labour costs have declined steeply in the southern periphery as a consequence, but there has been *no* corresponding rise in labour cost and imports in Germany and most of the northern, creditor nations, as part of the symmetric adjustment that is needed to resolve the imbalance of Germany's huge and still-growing trade surplus. Imports in the debtor economies have fallen dramatically, but exports have shown little improvement in Greece (and only small

improvements in others), due both to lack of domestic investment in the most promising sectors and lack of a demand stimulus from the creditor countries. In the latter, excess savings and absence of sufficient stimulus from the ECB and their own fiscal policies have generated eurozone interest rates close to or below zero, so that planned QE is unlikely to stimulate employment. Helped by falling oil prices, inflation in the EU turned negative in late 2014, raising fears of 'secular stagnation' or deflation, as in the last two decades in Japan, with a generally falling price level encouraging people to delay non-essential purchases in the hope of lower prices, and hence slowing growth.

As many economists have emphasized, none of this hardship is necessary. When resources are underutilized, there really is a 'free lunch' – additional government spending on labour-intensive projects can directly put people back to work and increase total output and tax revenues, *without* generating harmful inflation or currency crises, *and* also reducing deficits in the longer term (of course, the EU creditors and particularly Germany actually *should* generate modest inflation with fiscal expansion, and thus raise their unit labour costs, restore trade balance and aid recovery in the South, as explained below). In addition, the benefits from government investment in urgently needed but long-neglected public goods will continue to provide long-term benefits, both pecuniary and non-pecuniary, and in the case of climate change mitigation, benefits of survival and sustainable growth instead of catastrophic collapse.

The mechanisms involved are actually simple and basic macroeconomics as taught in most first-year courses, and frequently emphasized by leading Keynesians such as Nobel prize-winning economist and *New York Times* columnist Paul Krugman, and Simon Wren-Lewis in the UK. As formerly unemployed workers are re-employed and begin earning, they spend more, in turn generating further increased demand and still more employment, a process called the 'fiscal multiplier', which is substantially greater than one in depression conditions. This means that extra output will be much greater than the initial stimulus, while spending on welfare can fall as more people work and earn. This explains why debt tends to increase under austerity in recession, and fall with expansionary policy.[20]

In view of this, as well as extensive historical evidence, the continued obsession of the deficit hawks who dominate policy in countries with moderate debt-to-GDP ratios (as in the UK and US), becomes all the harder to understand. However, as Joseph Stiglitz puts it in the US context, 'that the deficit hawks ignore these realities suggests that they have another agenda: downsizing government and increasing the regressivity of our tax and expenditure system'.[21] Stiglitz and other critics have also pointed out that investment in education and vital infrastructure that is blocked by current austerity typically has much higher rates of return than private investment (which also depends on these investments for its own competitiveness and viability). Thus, the shortfall will continue to impoverish affected economies long after the as-yet uncertain end of this destructive neglect, exacerbated by the long-term decline in public investment driven by neoliberal ideology.

Similarly in the UK, the Conservatives have made no secret of their intentions to make further drastic cuts to welfare for the poor, who are increasingly stigmatized by politics and the media, in order to reduce the deficit. At the same time, tax-collection resources have also been drastically cut, without any attempt at seriously restricting the numerous legal loopholes for tax avoidance by the rich, which successive governments have actively helped to create.[22]

The long-term consequences of this short-sighted policy of redistribution from the poor to the rich are further emphasized by De Grauwe:

> The prevailing view in many countries is that governments should not increase their debt levels lest they put a burden on future generations. The truth is that future generations inherit not only the liabilities but also the assets that have been created by the government. Future generations will not understand why these governments did not invest in productive assets that improve these generations' welfare, while present-day governments could do so at historically low financing costs.[23]

Even the IMF has performed something of a U-turn, and shown that fiscal policy in advanced economies has been much more contractionary during the current Great Recession than in previous recessions, though not in emerging economies, thus contributing to the greater duration and depth of the current downturn in many advanced economies.[24]

Krugman summarizes: 'The main economic studies that supposedly justified the austerian position have imploded; inflation has stayed low; the bond vigilantes have failed to make an appearance; the actual economic effects of austerity have tracked almost exactly what Keynesians predicted.'[25] Furthermore, De Grauwe and Ji have shown not only that these policies were driven by financial market panic reactions with no relationship to fundamentals, but also that the strongest austerity measures led to the biggest GDP declines: 'the sharp austerity measures that were imposed by market and policymakers' panic not only produced deep recessions in the countries that were exposed to the medicine, but also . . . up to now this medicine did not work. In fact it led to even higher debt-to-GDP ratios, and undermined the capacity of these countries to continue to service the debt.'[26]

The preferred response to the crisis in the UK and US, with their own currencies, has been the policy of 'quantitative easing' or purchase of government bonds by their central banks. This has generated stock-market booms and a renewed surge in property prices, thus benefiting mainly the rich, but it has had little effect on employment, while real wages for most workers (and labour's share of GDP) have been declining, and employment recovery has been weak. The European Central Bank (ECB)'s massive new programme of QE in 2015 is likely to have similar effects, though the falling exchange rate of the euro may also boost exports.

The much more effective alternatives of directly distributing newly created, central bank money to poorer households who are most likely to spend it (called 'helicopter money' or people's QE), and of course, simply funding much-needed

public investment, are taboo for central banks for reasons that are clearly illogical, as recently emphasized by several prominent economists.[27] Public investment will of course benefit all in the long run, and indeed should be accompanied by redistribution to the poor, which will raise aggregate demand in the short run because poor people have a lower propensity to save.

In contrast, the Bank of Japan has monetized some (though not enough of) past and current fiscal deficits to boost growth and investment. Although Japan's ratio of government debt to national income is higher than in most EU countries (but mainly held domestically), and per capita growth has been slow, though positive, for more than two decades, unemployment in Japan at 3.6 per cent is about one third of the level in Europe, a clear testament to the failure of austerity and monetary policy or QE at the ZLB, and the success of countercyclical fiscal policy.[28]

Even Germany's apparent prosperity conceals serious structural problems, in addition to worsening poverty and the growing low-wage sector mentioned above. A low birth rate, an ageing population and restrictive immigration policy have led to a growing shortage of skilled labour, while much public infrastructure, including roads, bridges, schools and the energy grid, has been deteriorating due to insufficient investment for many years. *Net* public investment in Germany has been *negative* for more than a decade; so the national public capital stock is actually being run down, an even worse record than in the UK and US where public investment has declined sharply over the recession. The share of gross public investment in German GDP is the lowest in the EU15, and expenditure on education, which is an especially important form of long-term investment, is also much less than in the UK or Sweden.[29]

New investment and additional employment in all these areas would be appropriate everywhere, and particularly so in Germany. Funded at near-zero interest rates, and on a sufficient scale to generate moderate inflation and wage growth, such a programme would not only have obvious long-term domestic benefits, but would also raise demand in the depressed EU, and help to restore competitive balance. Instead of the gigantic human and economic costs of enforced internal deflation and destitution in the less competitive economies, inflation with faster wage growth to reduce Germany's huge export surplus would have been a feasible alternative at the start of the Great Recession, and should still be an important part of EU-wide fiscal expansion instead of austerity for the South. In the light of all this, it is astonishing that many German economists appear to be unaware of elementary Keynesian ideas, usually taught in first-year undergraduate economics, and still defend the inevitability – and proclaim the success – of austerity (as do most German and EU politicians). Notably, they only refer to financial indices and never mention unemployment, poverty or rising mortality and morbidity.[30]

International credit-rating agencies (such as Standard & Poor's, Moody's, and Fitch) also had an important role to play in exacerbating the global financial crisis, creating panic for foreign investors and irrational responses by policymakers. In the good old (pre-crisis) days, the agencies would offer favourable evaluations of insolvent financial institutions, hence encouraging excessive borrowing. Instead,

their harsh sovereign debt ratings of crisis-hit countries (with their public debt often downgraded to 'junk') raised the cost of borrowing for the governments that needed a fiscal stimulus the most. Several of them (Greece, Cyprus, Ireland and Portugal) were forced into recessionary bailout deals in exchange for austerity – governments in these countries had little choice, as private investors followed almost blindly the advice of these credit-rating agencies, irrespective of how uninformed their evaluations might have been, with little reflection of economic fundamentals.

Turning to historical background, the Weimar hyperinflation, which wiped out the savings of much of the middle class in 1923, is still widely seen as having set the stage for Hitler's accession to power 10 years later, and seems to fuel an irrational fear of inflation among German and EU policymakers, even as concerns over deflation, fuelled by rapidly falling oil prices in 2014, are growing. Small signs of growth in the still-depressed southern economies are interpreted by German and EU politicians and neoliberal economists as vindication of austerity, while ignoring the lessons of their own history and the basic economics of Keynes.

It is thus ironic that the much more relevant German experience of the 1930s has largely been forgotten today. In 1930, capital flows from the US that had been used to pay reparations to European allies were terminated as the US economy slid into depression. Conservative German Chancellor Heinrich Brüning then reacted to the fiscal crisis, under the constraints of the Gold Standard, with the same kind of drastic austerity, but even more disastrous consequences (supported by the Social Democrats in the Reichstag), that conservative German Chancellor Angela Merkel (in coalition with the Social Democrats), and the EU, are currently imposing on Southern Europe.

In fact, the 1930s austerity in Germany, which pushed unemployment up to 30 per cent, at a time when there was little social security to alleviate the resulting large-scale poverty and individual suffering, and which had only been opposed by the Nazis, was a major contributing factor to Hitler's rise to power in 1933. Large-scale rearmament and other public expenditure, which had started after Brüning's resignation in 1932, then generated the fastest recovery from depression in any affected country, attaining essentially full employment by 1936. The better-known but smaller-scale, parallel 'New Deal' associated with President Roosevelt in the US, also restarted economic growth, though more slowly, and both these programmes of fiscal expansion replacing austerity (albeit for different purposes) actually preceded Keynes' *General Theory* of 1936 by several years. However, it was only from 1939 to 1941 that the much greater, debt-funded US expenditure on military build-up increased employment by nearly 20 per cent and finally achieved full employment.

In spite of this historical legacy, there is little awareness of Keynesian economics among German and other northern macroeconomists and policymakers except for a few on the Left. The prevailing view is that profligate Southerners need to be collectively punished by austerity until they repay all the loans that were provided by (reckless) northern banks. After rescuing the mainly German and French banks instead of restructuring them in 2010 (with no penalties imposed),

this debt is now largely held by EU institutions and the IMF, without any support for investment to boost competitiveness in Greece, while the Greek politicians and wealthy tax-avoiders who were both reckless and corrupt have also avoided justice. Instead, the general population, who knew little of what was going on, and in any case had no control over their elites, are now suffering all consequences of the creditors'/policymakers' economic illiteracy, with related stories applying to the other debtor nations.[31]

This morality tale, and also Germany's failure to borrow and invest more even at unprecedentedly low interest rates, may have been subconsciously strengthened by linguistic tradition – German uses essentially the same word for debt, guilt and sin. The historical association of successful Keynesian policy with Hitler's early popularity and rearmament has perhaps also contributed to the psychological motivation for widespread neglect of this alternative to austerity among German economists and policymakers today. There is added historical irony in the often forgotten fact that the victorious allies agreed to write off half of Germany's post-war debt in a London agreement in 1953, providing a major boost to post-war reconstruction under growing Cold War tensions. Today, a growing minority of economists are calling for a similar step to relieve the southern debtors from the crippling burdens of austerity.[32]

Continuous austerity in the southern periphery of the EU has also severely constrained governments' capacity to deal with the current influx of refugees from Syria, Libya and other nearby war-torn and unstable regimes. In 2015, more than a million desperate refugees crossed the Mediterranean into Europe – most of them made the perilous journey in very small, overloaded boats, after having paid thousands of dollars to opportunistic human traffickers (many do not reach their final destination and drown in one of the frequent migrant vessel incidents that have unfortunately received much more attention by the media than have the politicians). The European periphery cannot deal with a humanitarian crisis of such epic dimensions when austerity-driven policies provide no means to support the thousands of displaced refugees who seek a safer haven. This clearly demonstrates the importance of an issue that we have repeatedly discussed in several parts of the book – developed economies are not immune to crises in other parts of the world, which can in a very short time result in large refugee flows, as a result of civil conflict, climate change or their interaction. For example, the worst drought in recent history in Syria from 2007 to 2010 was probably related to climate change and a likely factor in triggering the violent uprising there in 2011.[33]

Why green fiscal policy?

As should now be clear from the above discussion, pro-cyclical austerity has been an unmitigated disaster, with the scale of fiscal tightening being closely correlated with the level of subsequent unemployment, exactly as predicted by standard Keynesian economics. It follows that expansionary fiscal policy in countries with

seriously underutilized resources would yield major employment and growth benefits in the short run. In addition, as Bowen and Stern argued, 'a demand-induced downturn provides a very good opportunity to undertake a necessary step change in the public spending component of environmental policies and to start working through a backlog of public investment to improve the environment'.[34]

While there are many obviously important and, indeed, urgent candidates for infrastructure investment, which have been neglected for far too long, the severity and length of the current economic crisis has critically deflected attention from the quintessentially *long-term* threats of climate change. At the same time, our continued, global 'business as usual' with rising emissions in emerging economies rapidly increases the ultimate cost of limiting warming to a relatively 'safe' level, often claimed to be 2°C above pre-industrial levels, beyond which irreversible and catastrophic climate change quickly becomes much more probable.

However, as discussed in previous chapters, this widely recognized limit is much too high – in fact a 'recipe for disaster' according to the pre-eminent climate scientist James Hansen, due to the slow, albedo and carbon feedbacks, which are not included in standard climate models. There is a growing consensus that the 2015 CO_2 concentration of 400 parts per million (the highest for at least 3 million years) must be *reduced* to around 350ppm to avoid the worst consequences, and to achieve this most of the world's proved fossil fuel reserves must stay in the ground. Although the ultimate threat may seem distant, so distant that it is all too easily overshadowed by pressing current problems of poverty, insecurity and precarious employment for so many, climate change is already associated with increasing frequency of extreme weather events, which are now causing severe problems, particularly for agriculture, in many parts of the world.

A global carbon tax or cap and trade, and abolition of traditional, huge subsidies for fossil fuels in many countries, is widely agreed to be the essential basis of policy to internalize both the local health – and global climate – costs of pollution. The IMF has estimated total, direct and indirect *subsidies* for fossil fuels at around 6 per cent of global GDP, including health costs of local pollution of about 3 per cent of global GDP, though using a very low value for the climate cost of carbon emissions. More realistic estimates of the latter would multiply the total subsidy cost several times over.[35] However, poor populations in many, particularly developing countries would directly suffer from removal of fuel subsidies and imposition of a carbon tax, so income support measures, perhaps in the form of an equal 'dividend' from tax revenues for all citizens, which would benefit a poor majority, and a universal basic income as discussed below, would also be required to ameliorate the distributive effects of these measures. Naturally, carbon taxes would need to (more than) compensate for any major fall in the prices of fossil fuels in international markets (as has happened since mid-2014).

In view of all the real costs of adjustment to rising fossil fuel prices, and to avoid disruptions to national economies such as those caused by the OPEC oil-price hikes of the 1970s, even a revenue-neutral carbon tax could only be raised gradually, after political agreement is reached. Even when the announced path of

increasing future carbon taxes is widely known in advance, appropriate behavioural changes and supporting investment all take time to adopt and implement. Since this market-based process will be much too slow on its own to reduce global emissions fast enough to avoid the danger of triggering irreversible feedback effects, there must be a major role for direct government involvement to accelerate the process. Unfortunately, this has been largely overlooked by most economists, who ignore the risk of catastrophic climate change, and believe that slow adjustment to gradually rising carbon taxes will be sufficient to avoid serious climate damage.

In 2015, with most of the world's major economies still operating far below potential or full employment, green fiscal policy offers a perhaps unique opportunity to start major mitigation programmes with government investment in key areas, which also provide a financial payoff in the short- to medium term. Funded by borrowing at interest rates close to zero, or with newly created money, such investment could end the Great Recession's legacy of excessive unemployment and thus yield rapid economic benefits as well as greater well-being for all those who return to work. Due to the large fiscal multiplier effect in depressed economies, extra expenditure that directly raises employment yields major financial returns in the form of additional tax revenues and reduced welfare spending to support the unemployed. This is in addition to substantial fuel cost savings and improved health from less local pollution, and of course the incalculable benefits of long-term climate mitigation. Currently depressed economies thus allow essentially *negative*-cost mitigation and other infrastructure investment, at least until full employment has been reached.

It is important to start with the 'low hanging fruit' – the energy-saving investment, especially in the built sector, which currently offers the highest total returns, including a much-needed boost for still-depressed construction in many countries. Technological progress is rapidly reducing the cost of solar power (and, though more slowly, of wind power), so there are gains from postponement of building new capacity, but of course also costs of delay, so the right balance needs to be struck. There is general agreement that the built sector everywhere offers multiple high returns to renovation for energy saving, reducing both future fuel costs and emissions. Various informational and market failures limit even privately profitable investment of this kind, and schemes to subsidize energy efficiency that have been enacted in various countries have been too limited and slow to take effect.[36] The additional incentive effects of a carbon tax would also take time to work their way through the economy.

On one estimate,[37] up to 70 per cent of current energy use could be saved eventually with the most efficient buildings and appliances, and drastic reduction of wasteful use of materials, though not all the necessary investment would be cost effective in the short term, and significant behavioural changes would be required (we followed JD's conservative assumption of a smaller savings potential previously in Chapter 9). In view of all these potential benefits, and the urgency of emissions reduction, market-based incentives need to be complemented by adequate regulation and efficiency standards, and enforcement to ensure full compliance, rather than relying on the slower pace of voluntary take-up.

The construction sector has been the hardest hit by recession in most affected economies, and would currently benefit directly from large-scale investment in energy efficiency in buildings (and in renewable energy) – both are particularly labour-intensive activities, and hence very effective in reducing persistent unemployment. Thus Houser and Heilmayr estimated that a green stimulus package in the US could create four times more jobs than an equivalent tax rebate.[38] The contrast with the most favoured policy response to recession – 'quantitative easing', in which central banks buy government bonds to drive up asset prices and mainly benefit the rich, with little 'trickle down' to the poor and the unemployed – could not be more marked.

As discussed previously in Chapter 9, an essential complement to the optimal location of wind and solar energy in areas that are often remote from main centres of demand, is for governments to invest in large-scale, international 'smart grids', which are now technologically feasible. These grid connections can provide additional efficiencies by smoothing both demand and natural variability, and so become more effective as the area covered increases, and this obviously calls for international cooperation in regions such as Europe. High-voltage, direct current (DC) grid connections can transport power over long distances with relatively small losses, and so would be ideal to link the sunny south as a source of complementary solar power (the costs of which are still falling rapidly), with the windy north, and minimize the need for back-up.

An additional combination of other renewables, such as geothermal, tidal and wave, together with easily storable biogas (from bio-waste, and *not* from food crops as currently supported by subsidies in the EU, which typically increase overall emissions), could ensure reliable power supplies even through exceptional weather conditions, without reliance on the uncertain long-term development of cost-effective and safe, fourth-generation nuclear or, probably even more costly, carbon capture and storage.

As discussed in previous chapters, after the failure of international efforts to reduce GHG emissions over the past decades in which the scientific evidence has become ever more alarming, there is now growing agreement among environmentalists that only a rapid and large-scale 'mobilization' for mitigation can avert the risk of irreversible and ultimately disastrous feedbacks spiralling out of control. This effort has been compared with pre-WW2 mobilization in the US, which finally ended the Great Depression, but, as we showed in Chapter 9, an extra investment of only about 1.5 per cent of global GDP could enable transition to an almost zero-carbon economy in about 20 years.

While green fiscal policy on this scale could have an equally dramatic effect on currently high and persistent unemployment in many countries, this investment (in contrast to military build-up) would yield massive financial returns, not only from increasing employment, but also from reducing future fuel costs, in addition to the longer-term health and climate benefits from declining emissions. Of course, the fossil fuel sector will suffer major losses since most of its assets must remain in the ground – hence the continuing campaign by the most unscrupulous industry

lobbyists and associated media to discredit climate science and derail climate policy with ludicrous claims about excessive costs and economic disaster.

As already emphasized, the net financial cost of the first phase of green fiscal policy, when started in depressed economies far from full employment, would actually be *negative* (due to the multiplier effect when interest rates are close to zero and resources are underutilized, and to the positive financial returns from energy saving and efficiency investment). Some of the most prominent environmentalists and economists in favour of radical climate policies are also growth optimists, such as Lester Brown, Jeffrey Sachs and Nicolas Stern, who argue that sufficient government involvement in mitigation, innovation and new technology, could also avert the threat of secular stagnation, with transition to renewable energy and radical recycling providing sustainable consumption and production growth.[39]

More sceptical but perhaps more realistic environmentalists and ecological economists, however, argue that material growth with ever more consumption of 'stuff' always uses up some non-renewable resources, even when largely based on renewable energy and maximum recycling, and so cannot be entirely sustainable. In contrast to material growth, there is evidence that well-being *can* continue to grow with improved quality of life, an idea with classical roots in John Stuart Mill, and more recently popularized as 'steady state' economics by Herman Daly. Well-being could increase with qualitative, greener growth and its many less tangible benefits, instead of stagnating or falling as under traditional and unsustainable, fossil-fuelled material growth.[40]

The optimists weaken their case for the importance of material growth in rich countries by neglecting the numerous results of happiness research. The pessimists, however, argue for more fundamental changes in values, behaviour and regulation to attain not only a zero-carbon economy but also a steady state economy in the long run, and these changes are obviously even more difficult to attain in the current cultural and political climate.

The scale of investment needed to complete the transition to a zero-carbon economy in two or three decades surely means that much *material consumption* growth with major negative externalities (such as overpowered, energy-wasting cars and extravagant houses for ever more people) will have to be reversed rather than continued. These, mainly status symbols of fashion-and-celebrity-driven conspicuous consumption, would in any case become unaffordable for most under appropriate carbon and congestion taxes, which would 'internalize' the external costs. New technology, though, can facilitate qualitative 'growth', such as smaller, quieter non-polluting electric cars, charged overnight by wind power, as well as a shift to urban cycle use, which together could dramatically improve the urban environment and actually make people happier and fitter.

Another point that is often forgotten in the debate, is that a steady state economy is quite compatible with individuals enjoying real income growth over their working life-cycle, though of course young people entering the work force will have to start at the same level again as their parents' generation on average. This will require developed countries to take the lead over the next three decades, since

less developed countries still do urgently need to raise the material living standards of their poorest populations, and need help from the rich world to switch from the currently destructive, fossil-fuelled growth to sustainable green development.

What most observers do agree on is that the growth of knowledge, aided by digital technology and perhaps eventually quantum computing, is essentially unbounded. Nevertheless, this has its downsides for the world of work,[41] and is unlikely to lead to the world of leisure envisaged by the two most influential economists of the industrial age – Marx and Keynes – not least because they had no conception of the need for a far-reaching transformation to a zero-carbon, sustainable global economy, which is now the only alternative to catastrophic climate change. This transformation also offers an alternative to the secular stagnation that neoliberal policies generate, before the full import of climate change is recognized widely enough under their concomitant ideology of denial. As we have argued at length, this transformation will only be possible (at least, in time to avert the risk of catastrophic warming due to irreversible feedbacks) with large-scale government involvement in green fiscal policy, which could also ensure full employment.

With the increasing cost of scarce raw materials, and the simultaneously declining cost of communication and computation, the very nature of consumption and production is changing. New goods, gadgets and services are often so different from their predecessors that it is becoming increasingly difficult to construct meaningful, quantitative measures of aggregate, 'real' consumption and production, and the appropriate price deflators to compare the 'real' value of varying combinations or 'baskets' of quite *different* individual goods and services consumed years – let alone decades – apart. These technologically driven trends could also help to hasten the demise of economists' and policymakers' obsession with their 'great domestic problem', better known as GDP. Helped by globalization, this measure is becoming increasingly disconnected from domestic employment and under-employment, while of course the *trend growth* of GDP per capita has been unrelated to subjective well-being for many decades in rich countries, and more recently in developing countries including China.

Replacing increasingly meaningless GDP growth targets and comparisons with the simple goal of full employment would thus be a natural complement to green fiscal policy. Since globalization and digital technology are likely to increase precarious employment, with all its attendant uncertainty and unavoidable spells of unemployment, a universal and unconditional basic income or UBI for all citizens is also needed, in place of current, complicated, and often conflicting and uncoordinated systems of social welfare. This could provide a comprehensive safety net, and sufficient redistribution, together with higher marginal tax rates for the rich, to reverse the current trend towards ever greater inequality, and insecure or temporary work, with all its negative social consequences.

Surprisingly, perhaps, a basic income for all to maximize aggregate or utilitarian well-being, and the required tax to fund this transfer, would be preferred by a majority to the similarly utilitarian 'optimal' combination of a lower tax and categorical unemployment benefit or transfer only to the poorest and unemployed.

Though this result follows in a simplified model, it does capture the 'poverty trap' or negative-incentive effects of means-tested benefits that are lost when moving into employment, or from part-time to full-time work.[42]

An adequate UBI would remove the compulsion for low-skilled unemployed people to accept the next-worst job offer or risk losing their benefits. Intrinsically unpleasant jobs would have to be rewarded with a genuinely 'compensating differential' or premium pay to attract workers who were not under duress and had meaningful choices. Alternatively, some might forego higher pay for the sake of attractive work and conditions, so employers would face better incentives to design job packages aligned with worker preferences and requirements. Thus, functioning labour markets with more symmetric bargaining power might move from the model world of economics textbooks into the real world of the least qualified and increasingly deprived after the dramatic decline of collective bargaining in most sectors.

An unconditional safety net with UBI would facilitate finding a new job without duress for the unemployed, including part-time or irregular work in accordance with family needs. Badly treated workers could quit to look for better conditions with much less risk and hardship than under current welfare systems. This in turn would reduce employers' monopsony power and encourage them to provide acceptable pay and conditions. The goal of 'full employment' also becomes much more realistic, particularly when extended to include a larger voluntary sector, especially women who would have an independent income to support their caring services, both at home and elsewhere, which become increasingly important in ageing societies. The unavoidably disruptive effects of the major structural changes that are involved in the transition to zero-carbon economies would also be cushioned by a UBI as an extended and automatic stabilizer. Yet, unlike most policies, UBI requires no further government intervention or intrusive surveillance of the kind that is increasingly used to cut the benefits of the most vulnerable welfare claimants who are deemed to have infringed some bureaucratic regulation. With an adequate UBI, minimum wages and wage subsidies would be unnecessary – employers would just have to offer a package of pay and conditions that was sufficient to *attract* workers who no longer lived under the threat of benefit cuts and destitution.

In a similar vein, the American Citizens' Climate Lobby (CCL) campaigns for the carbon fee-and-dividend proposed by James Hansen and other prominent climate scientists, in which the proceeds of a carbon tax would be distributed equally, as a regular 'dividend' to all citizens. The poorest majority would pay less carbon tax than the equal-share dividend because the relatively small number of high-income households have proportionately much bigger carbon footprints than the poor, so the carbon fee-and-dividend is progressive. Surprisingly, CCL has not discussed these distributive effects of the proposal, perhaps to avoid charges of 'class warfare'.

The equal-dividend part of the carbon fee proposal resembles the uniform UBI (which is sometimes called a citizens' income), though of course the proceeds from an initial carbon tax would not be sufficient to replace most means-tested and other welfare benefits. These two policies would be natural partners in support of green

fiscal policy, since the idea of equal distribution of benefits, without the considerable administrative cost of assessing every individual's eligibility for welfare payments and the resulting, inevitable distortion of work incentives, has attracted interest across the political spectrum (as has the carbon tax-and-dividend). While an interventionist state can create sufficient jobs with green fiscal policy to counter the growing tendencies towards secular stagnation, additional redistribution (supported by UBI and genuinely progressive taxes without loopholes for the rich) becomes increasingly important as modern technologies help to generate an ever more skewed distribution of income. However, conservative–neoliberal ideology of cutting taxes on high incomes, and welfare for the poor, while rejecting any carbon tax, continues to dominate media politics and main party policies in the major economies, and continues to be lavishly funded by fossil fuel lobbies. It remains to be seen whether grass-roots campaigning and activism by currently small, green and maverick political groups and associated individuals will be able to gain popular support and break the grip of media misinformation and the ruling ideology, in time to avert catastrophic climate change.

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