

# A time for action on climate change and a time for change in economics

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## **A time for action on climate change and a time for change in economics**

**Nicholas Stern**

**London School of Economics**

**October 2021<sup>1</sup>**

### **1. Purpose and plan**

The address was, and this paper is, about the analysis of policy towards immense risks, the management of which necessitates rapid and fundamental change in our economies. The focus is on action with urgency and at scale, and the logic of that action. If we are to harness our subject effectively, with relevance, and in real time, we must understand and articulate the problem defined by the science and then marshal, develop and apply our economics around the issues and challenges that are at the core of the problem. In so doing, we must avoid trying to force a huge and non-standard challenge into a narrow and standard framework, however convenient it might appear to be to try to use familiar “workhorses”.

Accordingly, this analysis begins with the urgency and scale of the climate crisis. Then the paper examines the twin crises of climate and COVID, together with the difficulties of the decades leading up to COVID, and explains why we must tackle these crises together. It will be innovative investment that can drive us out of the COVID-related economic disruption and on to a much better and sustainable growth path. The case for such investments, and how they can be fostered, forms the subject matter of

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<sup>1</sup> This paper is based on my Past President's address to the Royal Economic Society, delivered in April 2021 at the Royal Economic Society 2021 Virtual Annual Conference. I would like to thank my successors at the Royal Economic Society, Rachel Griffiths, Carol Propper, Tim Besley, and my predecessors Andrew Cheshier and Peter Neary, for the pleasure of working with them. Very sadly, Peter Neary passed away in June 2021. And thank you to all at the Royal Economic Society and Queens University, Belfast involved in the organisation of the Royal Economic Society 2021 Annual Conference. I am very grateful to Charlotte Taylor for her help in preparing the lecture and paper. My ideas on these issues have, over the years, benefited from discussions and collaborations with Philippe Aghion, Tony Atkinson, Amar Bhattacharya, Tim Besley, Alex Bowen, Peter Diamond, Partha Dasgupta, Simon Dietz, Ottmar Edenhofer, Sam Fankhauser, Claude Henry, Cameron Hepburn, Chris Hope, Brian Hoskins, Hans Peter Lankes, James Mirrlees, Jeremy Oppenheim, Naomi Oreskes, James Rydge, John Schellnhuber, Joseph Stiglitz, Josué Tanaka, Adair Turner, Julia Turner, Anna Valero, Bob Ward, Martin Weitzman, Chunping Xie, Dimitri Zenghelis, to whom I am indebted.

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Part I. I will also reflect on what we have learned since the *Stern Review* of 2006 and why the lessons strengthen the case for the action proposed.

I shall also argue that these new investments and innovations present a great opportunity, with many benefits beyond the fundamental rewards associated with reducing the risks from climate change. But strong action to foster and finance these investments will be crucial if they are to come through, and the radical nature of the changes will inevitably involve dislocation, the management of which is central to equitable and successful action.

The case for action with urgency and at scale rests, in large measure, on the immense magnitude of climate risk and the very rapid emissions reductions which are necessary to create an acceptable chance of avoiding the worst of the risks. Tackling the problem in a coherent and effective way requires providing an analysis that identifies: the investments and innovations we need and the policies and finance that can draw through and support these investments and innovations. I will argue that these investments and innovations can deliver a new and attractive form of sustainable, resilient and inclusive growth. That argument can play a critical role in policy discussion and decision-making.

It is surely clear that such analysis must be based on a dynamic approach to the economics of public policy, set in a complex and uncertain world. Policies focussed on change are of the essence; and the analysis must be grounded in and reflect a world where there are many market imperfections, where there are increasing returns to scale, where risk is central, and where the distribution of income and welfare is a crucial issue. This is an economics of public policy which is rather different from the bulk of work in economics in this area, but it is, in my view, an economics forced by the logic of the problem.

In Part II of the paper, I will argue that the economics of climate change, and further, economics more broadly, must change to respond to this challenge of how to foster rapid transformation. There is nothing more important or exciting than this problem. It requires and opens up a tremendous amount of economics. There is so much in the richness of our subject that we can and must put to work. But there is more that we must create. The task requires expertise ranging across the entirety of our subject and, indeed, collaboration with other disciplines. And an engagement by our profession in a way beyond what we have seen so far. It is time for economics and economists to step up.

## Part I

### 2. Urgency, scale and opportunity

#### *2.1 The science of climate change and the role of targets*

We must start with the science<sup>2</sup>. The Intergovernmental Panel on Climate Change (IPCC) has been in existence since 1988 and has produced a series of assessment reports, published every few years, about the current state of knowledge on climate change. Each one of those assessments has been more worrying than the last. The first one, published in 1990, was extremely worrying, but the outlook has only worsened as the evidence has become ever stronger of effects coming through more quickly and with greater intensity than we expected. The latest report (the sixth Assessment Review) published in August 2021 has demonstrated even more clearly and unanimously that we are under intense time pressure if we are to be able to hold temperatures at levels which manage the most extreme risks (IPCC, 2021).

Global mean surface temperature is already 1.1°C above that of the end of the 19th century, our usual benchmark. This puts us on the edge of the temperature of the Holocene epoch; the benign period starting 10,000-12,000 years ago, during which our current civilisations emerged, following the end of the last ice age. It was during this period of fairly stable climate and temperature that many human cultures transitioned to a lifestyle based on sedentary agriculture. This is when we turned grasses into grains and stayed in one place as we nurtured crops until harvests; we built villages; we generated surpluses and used storage, thus creating opportunities for activities and services outside agriculture. With 1.1°C of temperature rise, we are now on the edge of the temperatures of that period and we are already seeing very intense effects: fires associated with heat and drought; severe flooding; hurricanes and typhoons; storm surges; sea level rises; local temperatures at levels dangerous to human life, and so on. In the summer of 2021, northern California and western Canada experienced temperatures close to 50°C, unprecedented and causing extensive loss of life and severe wildfires. And flooding, on a scale never previously experienced, occurred from Germany to China. There could be much worse to come. Our current emissions pathway implies that we are headed for temperature increases of more than 3°C

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<sup>2</sup> I am very grateful to scientist friends, particularly Brian Hoskins and John Schellnhuber, for discussions of the science over the last two decades. Any misunderstandings are my own responsibility.

(UNEP, 2020). The science is clear that such temperatures could carry grave risks to humankind and the planet as a whole. As a world, we have not seen 3°C or more for around 3 million years, and at that time sea levels were 10 to 20 metres higher than now. Those kinds of temperatures would radically change lives and livelihoods across the globe. Many parts of the world could become uninhabitable. Under a business-as-usual scenario, one of the most densely populated regions in the world, the North China Plain, would likely experience deadly heatwaves later this century with “wet-bulb” temperature exceeding the threshold defining what people can tolerate while working outdoors (Kang and Eltahir, 2018). Similar heatwaves could also occur in other densely populated parts of the world, such as North India. Hundreds of millions, possibly billions, would have to move<sup>3</sup>, likely resulting in severe and extended conflict. It is quite possible on current paths that we could see 4 or 5°C of temperature rise 150 years or so from now; temperatures which the world has not seen for tens of millions of years. That would be absolutely devastating. The stakes we are playing for are immense.

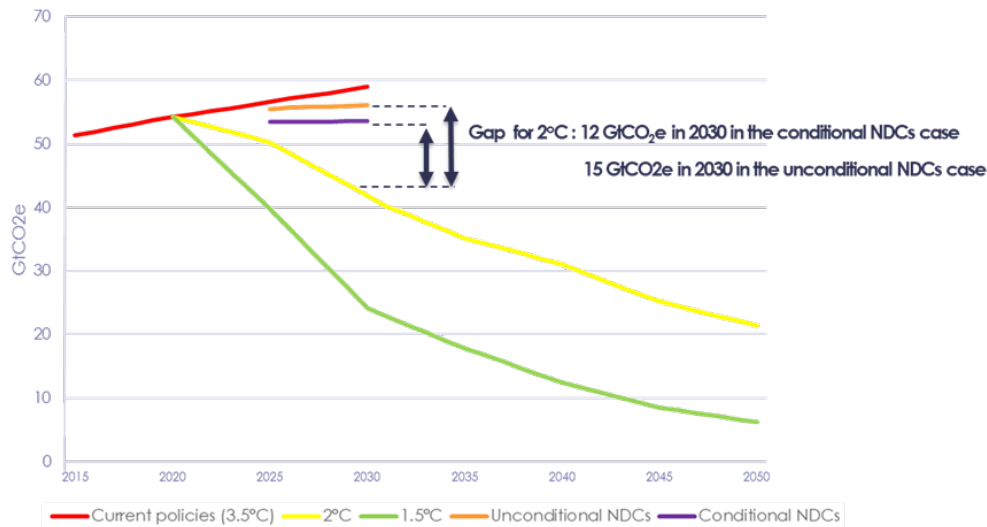
So, what do we have to do? To stabilise temperatures, we have to stabilise the concentrations of greenhouse gases in the atmosphere<sup>4</sup>. To stabilise the concentrations of greenhouse gases, the flow of greenhouse gases into the atmosphere must be net-zero. The earlier we stabilise the concentrations of greenhouse gases in the atmosphere, that is, the earlier we go to net-zero, the lower the temperature at which we stabilise. One can fine tune the climate science but that is the underlying, basic physics and the logic of the net-zero target. If we want to stabilise at 1.5°C (see below), we have to go to net-zero CO<sub>2</sub> by mid-century. Figure 1 shows the emissions pathways we need to follow if we are to stabilise at 1.5 or 2°C of temperature increase.

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<sup>3</sup> Empirical estimates range substantially, from 50 million to 1 billion migrants associated with the effects of climate change during this century (Ferris, 2020). We should remember that we have been forced consistently over the last few decades to bring forward in time our estimates of when serious impacts can occur and revise estimates of their magnitudes upwards. And most models do not embody the tipping points that we think may occur at higher temperature which could generate dangerous feed-back loops (e.g. collapse of Amazon forest, thawing of permafrost, melting of polar ice sheets. Thus the numbers having to move could be badly underestimated in these analyses.

<sup>4</sup> Greenhouse gases are those whose molecules oscillate at a frequency that interferes with the infra-red energy reflected from the earth's surface, thus preventing its escape and causing warming. CO<sub>2</sub> is the most important and is long-lived.

**Figure 1: Stylised emissions pathways for 1.5°C and 2°C and the gap to emissions trajectories based on current NDCs.**



Source: Trajectories based on UNEP (2020). The vertical axis represents emissions in CO<sub>2</sub>e, that is CO<sub>2</sub> plus the effects of other greenhouse gases.

NB: The NDC scenarios (unconditional and conditional) shown in figure 1 estimate the levels of GHG emissions projected as a result of the implementation of the mitigation actions pledged by countries in their Nationally Determined Contributions (NDCs) (UNEP, 2020). Most countries offer targets or “NDCs”, to 2030.

The differences between 1.5°C and 2°C are major. For example, the percentage of the global population exposed to severe heat at least once every 5 years would be 14% with 1.5°C of temperature rise, but 37% with 2°C of temperature rise (Dosio et al., 2018). That is, the risk of being exposed to extreme heat every 5 years would be more than double for 2°C versus 1.5°C. Thus, when we consider the risks in a consequentialist way, the 2°C which we had earlier seen as dangerous to exceed, now itself seems very dangerous. That was the key lesson of the powerful and important IPCC report on 1.5°C of 2018, showing that the risks and dangers are still more serious than estimated previously. An examination of the risks in terms of potential consequences for humans and the planet as a whole suggests that it makes a lot of sense to try to hold the temperature rise down to 1.5°C. And it is an achievable goal if we move strongly and quickly. Further, we will argue that such a path can carry many “co-benefits” beyond the reduced risks from climate change. It can be a much more attractive form of development.

We can think of setting a temperature target as a “guard-rail” approach to extreme risk. It is a standard, indeed widely and understandably regarded as sensible, approach to great risks, particularly around

human life. It is clearly a consequentialist approach, although not necessarily one arising from simple, indeed simplistic, optimisation of some standard welfare function from an underlying model. In my view, the risks, including the possibility of the loss of life of billions, extended and severe conflict, destroyed biodiversity, and profound loss of quality of life, livelihoods and well-being, are not well-captured in narrow utility-based approaches. Neither the standard objective functions in economics, nor indeed the underlying models, capture the challenges at issue. Here, the governments and the people of the world, after thinking it through, came to the targets in the Paris agreement at COP21 of the UNFCCC in December 2015, of holding temperature increases “well below 2°C”, with best efforts to 1.5°C. The IPCC report of 2018 on 1.5°C further underlined the importance of that target.

We should see the 1.5°C target as a balanced and consequentialist approach to immense risk. We can, of course, rig up expected utility models that give that conclusion but, in my view, they do not add significantly to the argument, particularly since such models are so sensitive to specification of structure, functional forms and parameters. Fairly modest model tweaks can give rather different results.

We risk loss of life in the hundreds of millions or billions; because we do not know what the “carrying capacity” of a world of 4 or 5°C might be. It could be much lower than the 9-10 billion or so expected towards the end of the century. It is hard to understand or put numbers on the potential devastation and agony around the process of loss of life that could be involved. It is difficult, in particular, to argue that an expected utility approach captures the issues at stake in a plausible way. In my view, a direct risk-assessment looking across possible consequences and a guard-rail approach is more thoughtful, reasoned, broad-ranging and robust. And it is clearly seen as a reasonable and rational approach by the body-politic.

We know what kind of emissions paths we have to follow to get there, i.e. holding to 1.5°C. But emissions are currently way off track for such paths. Global greenhouse gas emissions rose in 2019 for the third consecutive year, reaching a record high of 59.1 GtCO<sub>2</sub>e (including land-use change) (UNEP, 2020). Although annual emissions decreased sharply in 2020 due to the global response to the COVID pandemic, December 2020 global CO<sub>2</sub> emissions had already rebounded to above December 2019 levels (IEA, 2021a). Returning to Figure 1, we can see that world emissions must start turning down now and continue to drop sharply. To get from current levels of close to 60 GtCO<sub>2</sub>e a year, down to net-



zero by mid-century, we have to change fundamentally the way we do things. And we have to do that everywhere, across all sectors, across all countries. We cannot be confident that there will be net-negatives in large quantities<sup>5</sup>, so we must strive for net-zero across the board.

## ***2.2 Urgency***

The next decade is critical. Choices made on infrastructure and capital now will either lock us in to high emissions, or set us on a low-carbon growth path which can be sustainable and inclusive. In the next 15-20 years infrastructure will roughly double; in the next 20-25 years the world economy will probably double; and in the next 40 years the urban population will likely double. If that new infrastructure, the new world economy, or the towns and cities we build look anything like the old, we will have no hope of meeting the objectives of the Paris Agreement. The infrastructure we build in the next 15- 20 years will be decided in the next few years. That is why we have to act quickly. A sense of urgency is absolutely critical in our decision making.

## ***2.3 A new form of growth***

The necessary rapid change across the whole system, just described, can be a story of growth, indeed the only sustainable story of growth. In the shorter term, the necessary investments can boost demand in a world where planned savings exceed planned investments (with sluggish demand and low real interest rates). In the short and medium term it is full of innovation, investment, discovery, and new ways of doing things. It can be more efficient; and much cleaner. It can create cities where we can move and breathe, and ecosystems which are robust and fruitful. It is potentially a very attractive, different way of doing things, relative to past dirty models, with so many gains across the different dimensions of well-being. But that does not mean that it is easy. It does mean that it is sensible, it does mean that it is attractive, and it is within our grasp. We have to change radically and, particularly, invest and innovate strongly to get there. That is the challenge. But there can be a real payoff in terms of a much better form of growth. We must also remember that there is unlikely to be a long-run growth story that

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<sup>5</sup> We can and should create negative emissions by building our natural capital, e.g. restoring degraded land and expanding our forests. And we should work intensively on possibilities for “air capture” to bring down costs, and to examine potential for scale.

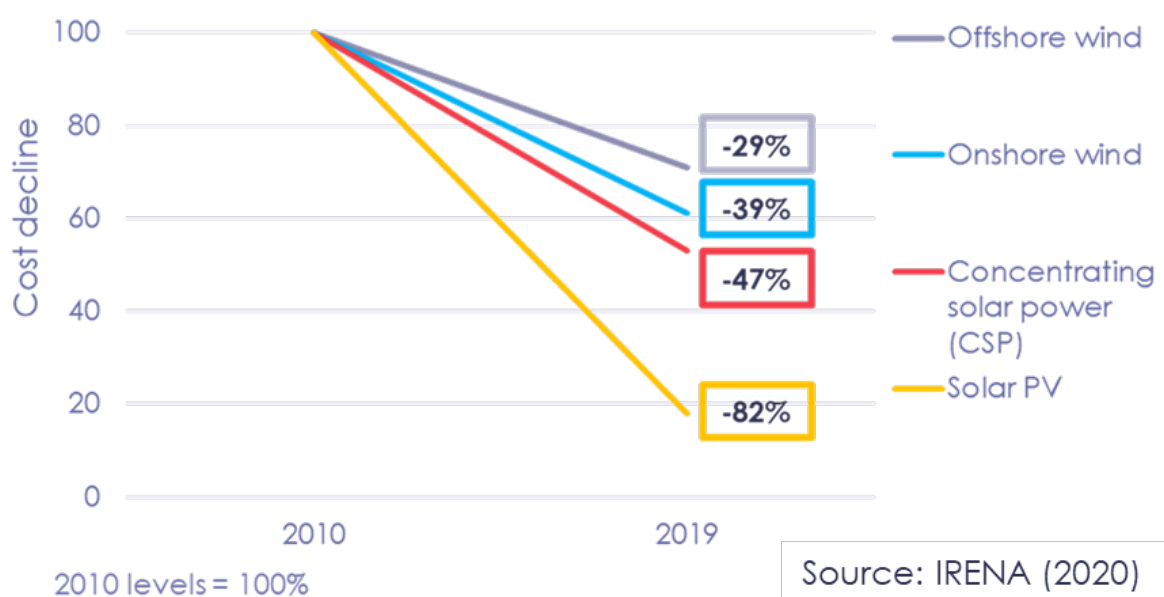
is high carbon; it would likely create, the IPCC reports show, a physical environment so hostile as to derail growth and undermine living standards across the board.

Can it be done? The answer is 'yes' and in particular there are four forces at this current moment which are particularly favourable to moving quickly and on scale: low interest rates, rapid technological change (see section 2.4), international understandings coming together (including the UNFCCC, COP21, the Paris agreement of 2015 and more than 100 countries covering 61% of emissions committing to net-zero by mid-century (Black, et al., 2021)), and pressure from the young people of the world to change (for example, Fridays for the Future and strong activity in the universities of the world).

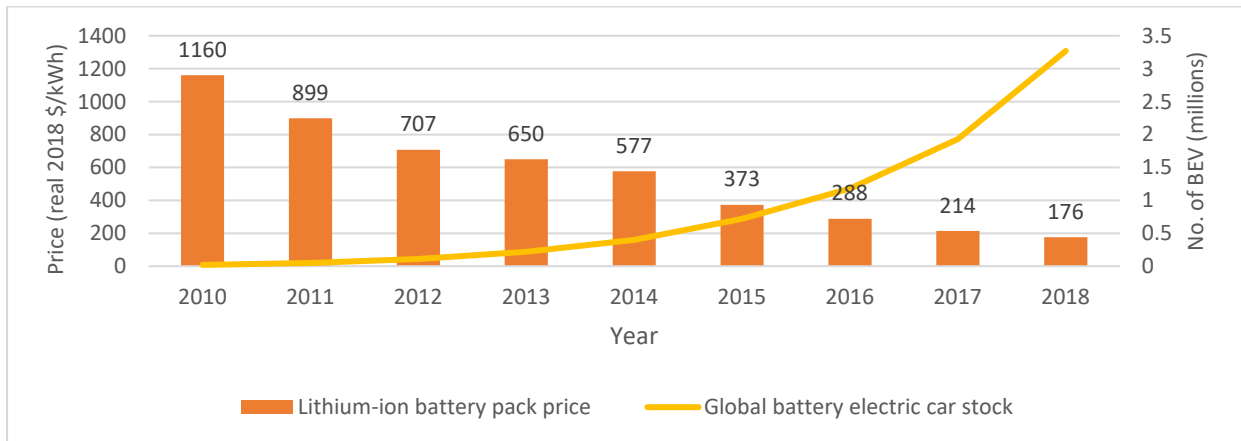
## 2.4 Rapid technological change

Technology has changed very rapidly over the last 15 years or so. A whole range of low-emission technologies, that are already competitive with fossil-fuel based technologies without subsidy or a carbon price, have emerged. Capital costs for renewable electricity continue to fall much faster than those for conventional technologies and many electric vehicle technologies are now close to cost-competitive with their fossil-fuel counterparts (see Figures 2 and 3).

**Figure 2: Renewable power technologies: cost decreases since 2010.**



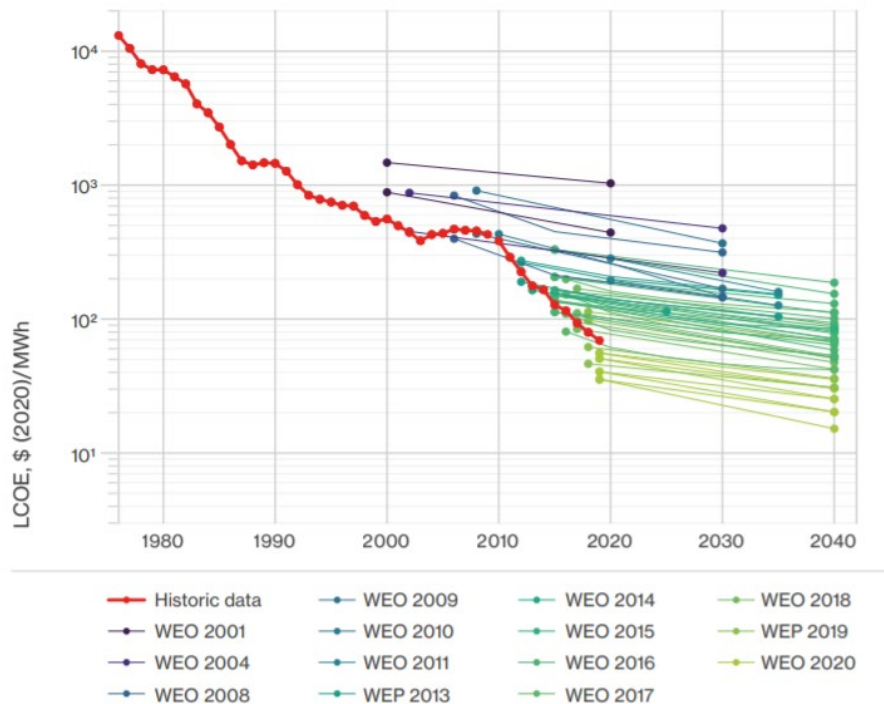
**Figure 3: Lithium-ion battery pack price reduction and global battery electric vehicle stock**



Sources: BNEF (2019), IEA (2020)

The pace of these advances in technology and reductions in cost has been much faster than expected. For example, since 2001, the International Energy Agency (IEA) has consistently underestimated the rate at which the cost of solar Photo Voltaic (PV) would subsequently fall, in its World Energy Output (WEO) reports (Ives et al., 2021) – see Figure 4. These costs of the new cleaner technologies are falling rapidly and will likely continue to do so.

**Figure 4: Actual versus IEA projected LCOE of solar PV**



Source: Ives et al. (2021).

With falling costs of clean technologies, estimates of the ‘cost’ of the transition to net-zero have been consistently reduced. The UK’s Climate Change Committee (CCC) has been producing estimates of the investments, costs and resource savings associated with the UK’s pathway to net-zero. Their 2020 analysis suggests that the annualised resource cost<sup>6</sup> of reducing GHG emissions to net-zero would be approximately 0.5% of GDP in 2050 (CCC, 2020). This is lower than the estimate the CCC produced in 2019, which put the annual cost of meeting the net-zero by 2050 target at 1-2% of GDP in 2050. Further, the estimate they produced in 2008 put the annual cost of meeting a much weaker target, reducing emissions by 80% by 2050 (relative to 1990), at a similar 1-2% of GDP in 2050 (CCC, 2019).

At the time of the Stern Review (2006) we estimated costs of 1-2% GDP per annum for reducing emissions (globally) by 80% (comparing 1990 and 2050). It has been argued that the last few percent would be particularly costly (that is embodied in the modelling of many Integrated Assessment Models).

<sup>6</sup> Annualised resource costs are estimated by adding up costs and savings from carbon abatement measures and comparing them to resources costs in an alternative scenario of no-further-climate-action (CCC, 2020).

Now we have estimates (in the case of the UK) below 1% of GDP for going to **net-zero** emissions by 2050. The changes in estimates reflect real changes in costs and fairly modest assumptions (in relation to experience) of future cost changes - technical progress continues rapidly. There are strong economies of scale in production and discovery, which with clarity in policy direction, will drive change.

Low-carbon technologies are already competitive with fossil-fuel based alternatives in the power sector. In 2020, solar/wind was the cheapest form of new power generation<sup>7</sup> in countries representing over 70% of GDP (Systemiq, 2020). And renewable energy technologies are expected to continue to decline in cost. Reductions in upfront capital costs will be driven by innovations around efficiency and new methods, more competitive global supply chains and economies of scale, while reductions in total levelised cost of electricity (LCOE) generation will be driven by increasing capacity factors and declining operational and financing costs (ETC, 2021). By 2030, low-carbon technologies and business models could be competitive in sectors representing over 70% of global emissions (today 25%) (Systemiq, 2020), without carbon tax or subsidy. In addition to the adoption of low-carbon technologies, the IEA's global pathway to net-zero emissions by 2050 projects that around 8% of emissions reductions will need to be achieved from behavioural changes and materials efficiency. The absence of behavioural changes to reduce energy demand in transport, buildings and industry, would increase the costs and difficulty of achieving net-zero by 2050 substantially (IEA, 2021b).

Further, there are immense benefits beyond the fundamental contribution of radically reducing the risks of climate change. As we have noted, these include cities where we can move and breathe and be more productive, and ecosystems which are robust and fruitful. We can find, and are finding, great advances in resource (including energy) efficiency. And, crucially, we can strongly reduce deaths and damage to health from air and other pollution – around 15% of world deaths in 2018 were linked to air pollution associated with the burning of fossil fuels (Vohra et al., 2021).

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<sup>7</sup> Based on the levelised cost of electricity (LCOE). LCOE is the average offtake price needed across a project lifetime for a developer to meet its equity hurdle rate of return (BloombergNEF, 2020).

In summary, in this section I have explained why we have to change, the degree to which we have to change, why it is feasible, and the very attractive new form of growth and development that this change could bring.

### **3. The first decades of this century, the COVID crisis, and the climate crisis**

We are at a very special moment in history, facing two crises: the COVID crisis that we are experiencing right now (summer of 2021)- we hope shorter-term, although that itself depends on strong global action - and the climate crisis, which is going to stay with us for a long time. The climate crisis embodies risks and challenges that are bigger, deeper and longer-lasting even than the tragic COVID crisis. There are powerful arguments that we have to tackle these crises in a similar way; with strong, innovative investment, to drive a recovery and create a new form of development and growth. But in assessing ways forward we must begin with the first two decades of this century and paths of investment and growth.

#### ***3.1 The decades before COVID***

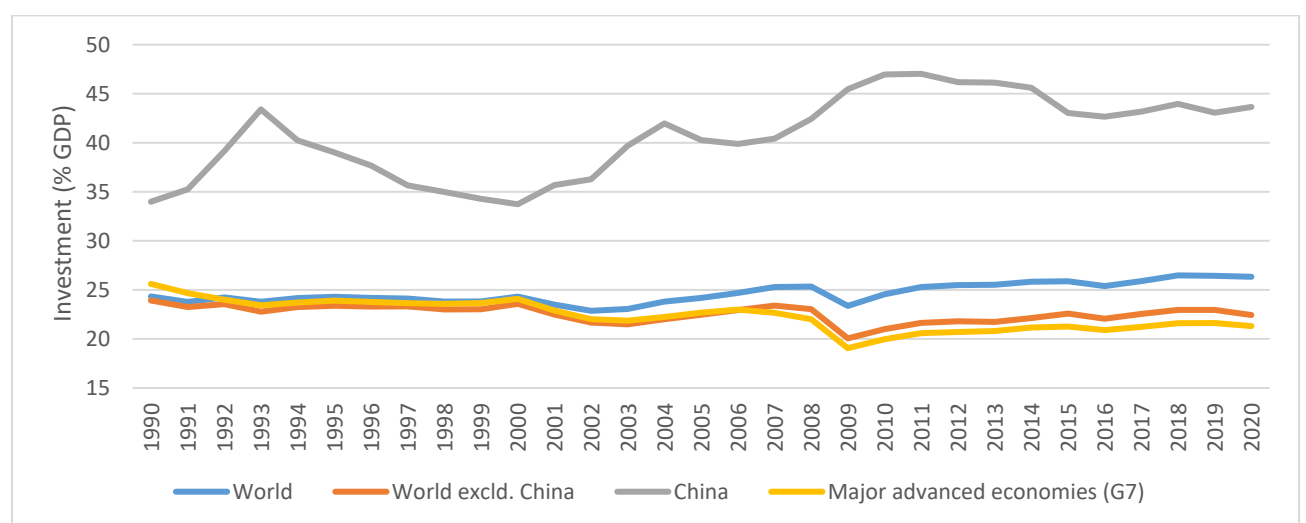
The first decade of this century saw fairly steady growth paths and rates of investment (as a proportion of output) for the world as a whole, see Figures 5 and 6. But this average conceals falling rates in 67 countries and rising rates for China (and a few other emerging market countries), where investment rates moved up strongly. For China it was a decade where output more than doubled and territorial emissions rose by 132% (WRI, 2021).

Growth rates and investment rates plunged across the world during the global financial crisis (2007-2009) and, for the most part, had not, in the second decade of this century up to COVID, recovered the levels of 2000. China was the exception where investment rates have been fairly steady in the second decade, up to the COVID crisis, although China's growth rate was substantially lower in the second, relative to the first, decade.

The experiences in the richer (G7) countries over the last few decades have led to a revival of the idea of secular stagnation (Summers, 2013, 2021), first raised by Hansen in 1938 (Hansen, 1938). This pattern of lower investment rates (see Figure 5) and lower growth (see Figure 6) was important

background to the challenges of social cohesion and populism (Tabellini, 2019) which emerged during the second decade. There was also some faltering, particularly under President Trump<sup>8</sup>, of internationalism. This was in addition to rising emissions and severe loss of biodiversity (Dasgupta, 2021). It was a decade, following the global financial crisis, of increasing problems. Broadly speaking, the economic and social conditions across the world during the decades before the COVID crisis, were troubling.

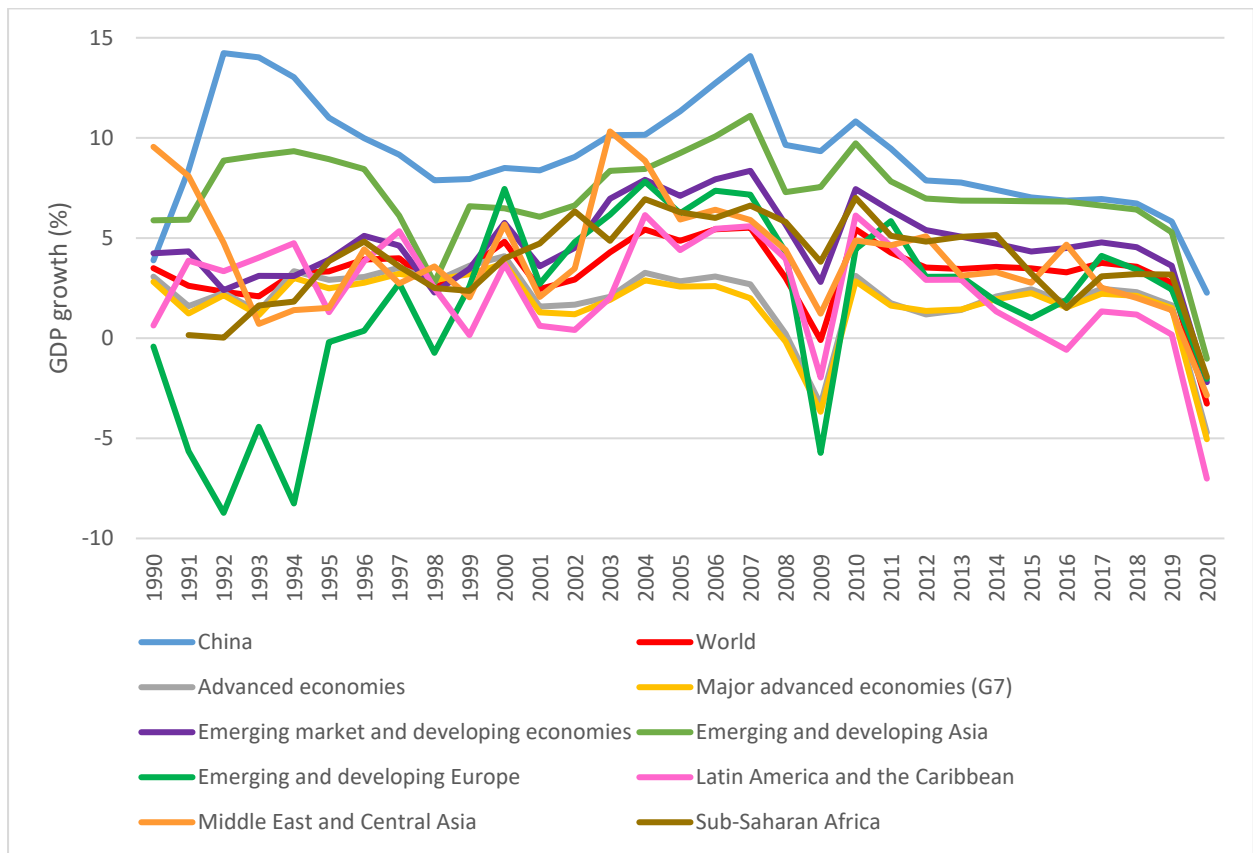
**Figure 5: Investment rates in the decades before COVID**



Source: IMF (2021).

<sup>8</sup> Under the Trump administration, the United States left the Paris Agreement on climate change, pulled out of the Iran nuclear deal, withdrew its membership in UNESCO, set in motion a process of exiting the World Health Organization, blocked the appointment of the new Director-General for the World Trade Organization and undermined confidence in NATO.

**Figure 6: GDP growth in the decades before COVID**



Source: IMF (2021).

However, in the decade prior to COVID, the response to climate change was building. The Paris Climate Agreement of 2015 was a major advance in international commitment and agreement; further, 2015 was also the year of the adoption of the Sustainable Development Goals (SDGs) which encapsulated a broader and deeper perspective on development (and provided relevant indicators), than the Millennium Development Goals which had come before. We were also beginning to see and understand a new approach to development and to growth that could be more efficient and better environmentally, and constitute a very attractive, inclusive and resilient growth story, if we got it right (Stern, 2015; NCE, 2018; OECD, 2018).

In the last few years, private firm after private firm has committed to net-zero emissions (Black et al., 2021). The Central Banks have been working together via the Network on Greening the Financial System, which has over 90 members (May 2021). In the budget of this year (2021), the UK Chancellor



of the Exchequer enhanced the remit of the Monetary Policy Committee (MPC) to include climate change. There is a Coalition of Finance Ministers on Climate Action, which is building momentum.

All this is being reflected in investment. For example, global annual renewable power capacity expansion exceeded non-renewable capacity expansion every year from 2015-2019 (IRENA, 2020). Thus, in international agreements, in the private sector, in central banks, in finance ministries and in real investment, fundamental change is building.

But now, with COVID, we are in a deep crisis; of health, of employment, of investment and increasingly of finance and debt in many countries. The costs in terms of human life are tragic, the risks of an extended slowing of growth, or depression, are real, and the developing world is facing the danger of a lost decade of development.

### ***3.2 Tackling the twin crises and creating a new internationalism***

Tackling the two crises requires a new and shared understanding of how to reconstruct our economies and societies and the meaning of “build back better”. That understanding should be based on a recognition of the nature and origins of the fragilities and difficulties that had been growing before the COVID crisis broke over us. Rebuilding in a different way will involve substantial investment and innovation, and the global nature of the challenges demands international collaboration.

There have always been arguments for internationalism; in our current circumstances they are extraordinarily powerful. The twin crises and multi-polar world, including the continuing rise of Asia, are changing both the challenges and structures of internationalism. Our ways of collaborating will need to develop. However, a shared understanding of the great returns to collaboration associated with the current challenges and context could help both build internationalism and spur change.

The returns to collaboration in current circumstances can be expressed in terms of four wins. The first is that we face high unemployment in many countries of the world and we need to expand demand<sup>9</sup>. Expanding demand in countries simultaneously has a much more powerful effect than expanding

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<sup>9</sup> In some countries supply has been curtailed along with demand.

demand in just one country, because increasing demand in one country spills over to boost employment in others. Second, we have to reset expectations, not only for growth but also for a different kind of growth. If we reset those expectations together, then investors will know that the investments they are considering are of a kind that are going to be in harmony with the movement of demand around the world. A third win is that if there is a shared understanding of the direction of new technologies then we will create increasing returns to scale in production and discovery. We have already seen (see Section 2) that very powerfully in the way in which costs of solar and wind power have been driven down; the same is happening now with batteries; and electric vehicle costs are going to fall very quickly. The overall scale of technology deployment, achieved by acting together, can generate big returns. The fourth win comes from climate and biodiversity being global public goods. If we emit less greenhouse gases in one country, then all other countries gain from that drop in emissions: similarly protecting and regenerating biodiversity benefits us all.

Working together is, therefore, of fundamental importance, perhaps now more than any time in history. Some of this should play through via international mechanisms such as the UN, OECD, G20, G7. Many players will be involved in creating responses to the immense issues of COVID and climate; the private sector, the multilateral development banks and international financial institutions, and the ministries of finance and the central banks all have central roles.

## **4. Realising investment for a strong and sustainable recovery**

### ***4.1 Investment***

In section 3, I explained why strong, internationally coordinated investment should be at centre stage, right through from recovery from the COVID pandemic to transformational growth and the drive to a net-zero economy. What kind of orders of magnitude of investment do we need to make? To bring through the new ways of doing things and the new technologies required to make that happen, we have to increase investment by around 2-3 percentage points of GDP across the world, relative to the previous decade - more in some places, less in others – as well as change the composition of investment (in China, however, it is not a question of raising investment rates but changing the composition of investment). Many of these new technologies involve pulling capital increases forward, along with investing in different ways. Renewable electricity, for example, requires upfront investment

whereas fuel cost savings are realised once the renewable technologies are operational. Importantly, these investments should not be seen narrowly in terms of extra costs from going “clean”; many of them have tremendous returns in terms of greater efficiency, cleaner air, better health and more. But an increase in the investment rate by 2-3 percentage points of GDP is needed to realise these gains, to recover sustainability and to put us on a new path.

This estimate of the magnitude of the necessary boost to global investment can be arrived at from a number of different perspectives. First, for the world excluding China, it would take us back to the level of investment seen three or so decades ago (Figure 5 and IMF, 2021), and help to restore growth rates and productivity improvements. Second, there has been a persistent gap in infrastructure spending in both developed and developing economies, in terms of what is necessary to support growth and development, that has been estimated at 2 - 3% of global GDP (New Climate Economy, 2016; Bhattacharya et al., 2019). Third, we can examine the specifics of the needs and significant opportunities for scaling up the sustainable investments necessary to accelerate the transition to a low-carbon and climate-resilient economy, and restore natural capital. These investments are examined and quantified in a number of recent reports (ETC, 2021; IEA, 2021b; Stern, 2021). These three approaches are not additive, they are different ways of looking at the issue, but they all point to numbers in a similar range.

At the country level, the necessary increase in investment will vary according to level of development and circumstances. For the G7 countries, a 2 percentage-point step-up in investment, relative to the past decade, would partly reverse earlier declines driven in part by cuts in public investment. For many Emerging Market and Developing Countries (EMDEs), these necessary magnitudes will likely be higher than 2 percentage points, given the range of investments, particularly around infrastructure, required to meet development goals. For China, as noted, the main challenge will be to change the composition rather than the level of investment .

Such an investment programme could overcome the secular stagnation that has been experienced around the world over the last decade or so. From a basic Keynesian macro perspective, this was associated with planned investment being too small in relation to planned saving. The obvious solution, then, is to increase planned investment, in the light of the urgent requests we have described. From

this perspective, we can overcome secular stagnation by investing in new, and environmentally necessary, ways of doing things, thereby not only restoring demand but also charting a much more attractive form of growth.

## ***4.2 Policy***

These increases in investment, will require strong policy and a positive investment climate, including the functioning of relevant governmental institutions. Further, the many relevant market failures (see section 7b) and the urgency of change indicate the necessity of a whole range of policy instruments. Carbon pricing will be important, but alone it will not be enough. Complementary policies, including city design, regulation and standards, and investments in R&D, will also be needed.

Investment seeks returns over the medium and long term and requires clear and credible signals. However, circumstances change and learning occurs, and that means policy will be revised; but it should occur in ways that are “predictably flexible”. Thus, policy revisions, as lessons are learned, systems change and technologies advance, must be carried through in ways that people understand, and which can be anticipated. For example, it can be announced that an emerging technology will be supported initially but as it moves out, or “diffuses”, into the productive world, or as the cost of the new technology falls, its supporting subsidy will be reduced. Predictable flexibility has been a principle of monetary policy for some time, but it should be applied across the board; otherwise confidence in policy is undermined, policy risk is seen as pervasive, and investment is discouraged. Government-induced policy risk is one of the major deterrents to investment worldwide, particularly around infrastructure (World Bank, 2004; WEF, 2014; Baker et al., 2015; OECD, 2015; World Bank, 2020; World Bank, 2021).

## ***4.3 Finance***

Investment and innovation inevitably involve a certain amount of risk. Strong and rapid increases in investment might be seen as particularly risky, especially around infrastructure where early stage risk can be severe and the reliability of long-term revenue streams can be problematic. The necessary investment can be realised only with the right kind of finance, in the right place, at the right time, which can help reduce, share and manage the risk. Across the world there are great investment potential and

strong savings. But there are important difficulties in turning opportunities into real investment programmes; good policies and social institutions have a powerful role to play.

Further, getting the right kind of finance, in the right place, at the right time is not easy. Mobilising private sector finance, at scale, will be critical. But there will also be a need for development finance and concessional finance to support the activities that do not quickly generate strong revenue streams or have high risks. The international financial institutions, especially the multilateral development banks, and including the IMF, have a crucial role to play. This is a moment - with the crises of COVID and climate, the criticality of raising investment, the centrality of rapid change, and the importance of internationalism - to expand and strengthen our international financial institutions. In doing so, we should expect them to ramp up their support for developing investment programmes, expand their finance for investment, and expect them to ramp up and reorient their activities towards sustainability. It would be a “grand bargain” with great potential rewards for the world<sup>10</sup>.

## **5. What we have learned since the Stern Review**

In the light of the policy analyses and arguments set out above, it is interesting to ask how issues and understanding have moved on since the publication of *The Economics of Climate Change: The Stern Review* (Stern, 2006) in October 2006. Fifteen years on, the review’s core finding – that the costs of inaction on climate change are much greater than the costs of action – which was compelling then, in my view, is now still stronger. First, the *science* is ever more worrying. Greenhouse gas emissions have continued to rise. There is evidence that the impacts of climate change are happening faster and with greater intensity than expected. We can see ever more clearly that there are significant risks of major areas, with currently large populations, becoming unliveable; thus the risks of mass migration and conflict look increasingly severe. Each IPCC report over the last three decades has looked more worrying. The IPCC 2018 report showed how much more dangerous 2°C is than 1.5°C. And the Sixth Assessment Report of the IPCC on the physical science, published in August 2021, paints a still more difficult picture; time is running out for strong and decisive action if we are to hold temperature increases to 1.5°C.

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<sup>10</sup> For more on these issues, see Stern (2021) and Bhattacharya et al. (2021).

Second, clean energy *technologies* have been developing at pace, with costs falling further and faster than expected. Any reasonable estimate of the costs of inaction would be still higher, and the costs of action lower than in 2006.

Third, the *politics*, have sometimes moved forward strongly (e.g. UNFCCC, COP21, Paris, 2015) and sometimes backwards (e.g. the election of Presidents Trump and Bolsonaro). The global financial crises of 2008 and 2010 reduced “bandwidth” for climate change. More recently there have been strong positives politically, for example, China’s commitment to carbon neutrality by 2060, the intensification of action in the EU, and in the USA following the election of President Biden. The private sector has started to engage strongly.

Fifth, *analytically* our understanding and focus have moved to emphasise still more strongly the dynamics of change (Acemoglu et al., 2012; Aghion et al., 2016; Van der Meijden and Smulders, 2017; Systemiq, 2020; Ives et al., 2021). We can now point to new and much more attractive models of development than were followed in the past. We can look to a new story of growth, indeed the drive to net-zero can be the sustainable, inclusive and resilient growth story of the 21<sup>st</sup> century. The deeper understanding of the problem, in terms of dynamics of development and of breadth of potential benefits, implies that we have to deepen our economic analysis. This is the subject of Part II of this lecture.

## **Part II**

### **6. How economics must change**

An assessment of what the current situation demands of us, particularly for this decade, was set out in Part I. That requires changing our ways of producing and consuming, rapidly and fundamentally, and creating the investment, innovation, sets of policies, and the finance that could foster and support the change. How can we bring our economics to bear in a way that informs those very real and urgent problems? How can we use economic analysis to tell us as much as it possibly can about why to do this, how to do this, and the methods and policy instruments we should use? In this section I will focus, in terms of broad analytical approaches, on where we are in the economics discipline on climate change and argue that it is time for change in the economics of climate change and, in some respects,

economics generally. In the following section, 7, I will argue that our subject does have much to offer in applying our existing tools and in developing new perspectives and analyses, but we must be innovative and, as a profession, engage much more strongly on this, the biggest issue of our times.

### ***6.1 Some history of the economics of climate change***

A natural starting point is the important set of insights of economists Alfred Marshall and Arthur Pigou. At the end of the 19<sup>th</sup> century, Marshall (Marshall, 1890) drew attention to the potential difference between marginal private cost and marginal social cost. Thirty years later, Pigou (Pigou, 1920) argued for a tax, equal to the difference between the marginal private cost and the marginal social cost, to correct for an externality, where that is the source of the difference<sup>11</sup>.

Around 60 or 70 years ago, Ronald Coase began considering these concepts in a different way, emphasising institutional arrangements (Coase, 1960). He spoke of allocating property rights and establishing markets so that there could be trade in externalities. James Meade - his work 'Trade and Welfare' (Meade, 1955) was a landmark - also wrote very insightfully about the theory of externalities, including integrating externalities into the theory of reform, bringing in distributional issues and looking at general equilibrium in multi-good models. Coming forward further, and looking at applications 30 or so years ago, David Pearce, for example, was writing 'Blueprint for a Green Economy', emphasising how the Pigouvian idea could be implemented (Pearce et al., 1989).

This is all a very important and valuable part of our intellectual history in economics. Then climate change came along with an explicit and very large problem. The Intergovernmental Panel on Climate Change was established, as a result of initiatives from scientists, in 1988, and climate change started to become a more active subject in discussions of policy. There was growing recognition that climate change could be disruptive, but at that time the common belief was that our emissions of greenhouse gases would cause only small perturbations at some point in the future. The modelling of climate change began with Bill Nordhaus' important and admirable paper 'To slow or not to slow?', published in the *Economic Journal* in 1991 (Nordhaus, 1991) and Bill Cline published his book 'The Economics of Global

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<sup>11</sup> There could be other sources, such as monopoly power, missing markets, asymmetric markets, market failures in other markets, and so on.

Warming' in 1992 (Cline, 1992). Nordhaus's question, recognising that there could be potential dangers from climate change and that emissions arose from activities around producing and consuming, was 'should we grow a little less fast than we might have envisaged before we thought about climate change?'. He proceeded in a sensible way, taking an emerging problem and applying the standard tools of economics: first the Pigouvian story of marginal social costs, marginal private costs, and taxing for the externality; second on growth, he used the framework of a standard exogenous growth model and considered the impact of climate change largely in terms of small perturbations around the underlying growth path(s). That was a sensible early contribution for the economics of climate change.

Over the following 10-15 years, it became more and more clear that climate change is not a marginal problem. We are dealing with a challenge involving huge potential disruptions, which requires very radical changes in our production systems and ways of consuming. That simply cannot be picked up by assuming a fairly standard underlying model of exogenous growth and, within that model, portraying climate change in terms of marginal damages of just a few percent of GDP. Nordhaus' DICE model launched a major literature on integrated assessment models (IAMs), and their scope has been expanded. But the basic underlying features of optimisation of explicit, calibrated social welfare functions, underlying exogenous growth and aggregation (usually to one good) impose severe limitation on their ability to illuminate two basic questions. The first is how to approach analytically the challenge of managing immense risk, which could involve loss of life on a massive scale. The second is how to chart and guide a response to this challenge which will involve fundamental structural change across a whole complex economy. These two issues are at the core of economic policy on climate. The basic structure of IAMs, I shall argue, even with the many advances and mutations that have been offered, is not of a form which can tackle these two questions in any satisfactory way.

There is a problem in the profession, which goes beyond the way IAMs are structured and specified, associated with an inability or unwillingness to move much beyond the static Pigouvian or 20<sup>th</sup> century approach to externalities in analysing the challenges of climate change. Many discussions of policy suggest that "economic theory says" that policy should be overwhelmingly about a carbon price. A carbon price should indeed be at centre stage, but we need so much more in terms of policy and perspectives, and understanding of the issues. However, we must be clear that the suggestion that



“theory says” that the carbon price is the most effective route is simply wrong and involves a number of mistakes.

The first mistake is that there is a whole collection of market failures and market absences of great relevance beyond the greenhouse gas externality (see section 7). The second is that under the temperature target or guardrail approach (see section 1), the choice of carbon prices is focused on its role, in combination with other policies, in incentivising paths which achieve the overall target (such as net-zero emissions by mid-century to fit with the temperature target) with as much economic advantage as possible. Such prices are not simply the marginal social cost as in Pigou (see discussion of Stern-Stiglitz Commission below, this section). Third, where the risks of moving too slowly are potentially very large and there are increasing returns to scale and fixed costs in key industries, then regulations can help reduce uncertainty and bring down costs (e.g. Weitzman, 1974). Fourth, many consumers, producers, cities, and countries, recognise the obligation to act, and are not blinkered, narrow optimisers with a view of utility focused only on their own consumption. Fifth, much of the challenge of action is how to promote collaboration and act together. This poses a whole set of important questions around institutions and actions for mutual support. This is an immense challenge concerning risk, values, dynamics and collaboration, and the narrow Pigouvian model, useful though it is, is very far from the whole story.

## ***6.2 Some problems with IAMs***

To explain my argument concerning the failures of IAMs in relation to these two questions, I will set out, in broad terms, some of the basic structure and specifications in standard IAMs. There is an underlying one-good growth model where emissions depend on output, accumulated emissions cause temperature increase and climate change, and emissions can be reduced by incurring costs. However, much of this literature, which has dominated so much work on the economics of climate change, has been misleading and biased against strong action, because climate damage specifications are implausibly low and costs of action implausibly high, and subject to diminishing returns. For example, a recent version of the DICE model estimates losses of 8.5% of current GDP at a global temperature rise of 6°C (Nordhaus, 2017). If this were plausible, there would be little cause for concern because 6°C of warming will not be reached, even with bad luck, probably for over 100 years, by which point, with a modest

amount of economic growth, losing less than ten percentage points of GDP would be of minor significance in relation to GDP which had more than doubled (at say an underlying growth rate of 1% p.a.). But a 6°C temperature rise would likely be deeply dangerous, indeed existential for hundreds of millions, or billions, of people. It could be a world that could support a far lower population, and we could see deaths on a huge scale, migration of billions of people, and severe conflicts around the world, as large areas, many densely populated currently, became more or less uninhabitable as a result of submersion, desertification, storm surge and extreme events, or because the heat was so intense for extended periods that humans could not survive outdoors. It is profoundly implausible that numbers around 10% of GDP offer a sensible description of the kind of disruption and catastrophe that 6°C of warming could cause. We cannot be sure of the probabilities of different scales of catastrophe, but it would seem deeply unwise, indeed reckless, to assume that catastrophe of immense proportions would not be associated with temperature increases of this magnitude.

Most standard IAMs also embody diminishing returns to scale and increasing marginal costs of action to reduce emissions, plus modest rates of technical progress (relative to those experienced in the last decade or so). These features are very problematic because we have already seen how important increasing returns to scale and very rapid change in technology are in this context. Costs of solar power and LEDs have plummeted as the world has scaled up investment and innovation in cleaner technologies (as we saw in section 2). The same is happening with batteries and electric vehicles, and is likely to happen with hydrogen. By embodying diminishing returns and modest technical progress, the IAMs systematically overstate the costs of climate action. Further, they distort the theory of policy which is much more complex when we have increasing returns to scale; particularly in the context of risk. Standard optimising policy models which focus on “marginal cost equals marginal benefit” are far more tractable with diminishing returns and increasing marginal costs to action, but by choosing model assumptions primarily for tractability and convenience, we risk severely disturbing the policy discussion at issue.

Some of the flaws and biases described above and embodied in the standard IAMs can be mitigated with different assumptions, and there have been some valuable and relevant contributions in the

literature<sup>12</sup>. But, and this point is crucial, there are deeper problems with the general approach of maximising a social welfare function (for example, based on expected utility) in the presence of extreme risk, which cannot be corrected by adjusting functions and parameters. The stakes we are playing for are absolutely immense. Standard utility or welfare functions at the heart of the IAMs cannot capture adequately the nature and scale of the risks from climate change, and the challenges of immense risk to life itself for many, points towards the need for alternative strategies for building theories and models. Impacts which can involve deaths of billions are not easily captured in the standard social welfare functions, which we used in most IAMs (and more broadly), involving aggregation of individual utility functions. Indeed, as Weitzman argued (Weitzman, 2009, 2012) standard approaches quickly run into problems of utility functions going to minus infinity. There can be arbitrary “fixes”, for example by putting bounds on utility, but it is an indication that the model has lost touch with the problem.

With immense risk, rapidly developing clean technologies, and increasing returns to scale, it can be argued (and see section 2) that the sensible, consequentialist approach to such immense risk is to put in place targets or guardrails (e.g. temperature increase of 1.5°C) and then think about how to keep within them. This was the approach taken within the Paris agreement (UNFCCC, COP21, 2015).

Just as with the social welfare function aspect of IAMs, there is a deeper question on the production side of the modelling. The policy challenge, as we have seen, involves generating rapid and major change in key complex systems, including energy, transport, cities and land, over a very short period. Simple “cost” functions for emissions reductions, even if made more realistic, do not get to grips with the real policy challenges of how to make these changes.

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<sup>12</sup> Dietz & Stern (2016) show that if the DICE model is modified to take more strongly into account three essential elements of the climate problem – the endogeneity of growth, the convexity of damage and climate risk – optimal policy comprises strong controls. Hänsel et al. (2020) show that adjusting the parameters of DICE, to reflect the latest findings on economic damage functions, some of the latest climate science and a broad range of expert recommendations on the pure rate of time preference and the elasticity of marginal utility, as elicited by Drupp et al. (2018), brings the economically ‘optimal’ climate policy path in line with UN climate goals. Schumacher (2018) has demonstrated how equity weighting can lead to significantly higher global damages from climate change than those reported by unmodified IAMs. Moore and Diaz (2015) show that implementing temperature effects on GDP growth rates in DICE results in optimal climate policy that stabilizes global temperature change below 2 °C. Explicit modelling of adaptation in IAMs shows that joint implementation of mitigation and adaptation is welfare improving (de Bruin et al. 2009; Bosello et al. 2010). Work by Carleton and Hsiang (2016), Ciscar et al. (2019) and others feed into better calibration of damage functions. Climate and social tipping points have been incorporated into IAMs (see e.g. Cai et al 2016; Grubler et al. 2018; Yumashev et al. 2019). Completely different approaches to IAMs are under development, e.g. analytical IAMs (Gerlagh and Liski, 2018a; Gerlagh and Liski, 2018b; Golosov et al., 2014; Hassler and Krusell, 2012; Hassler et al., 2018; Iverson and Karp, 2017; Karp, 2017; Rezai and van der Ploeg, 2016; Traeger, 2018) and agent-based IAMs (Czupryna et al., 2020; Lamperti et al., 2018).

The Stern-Stiglitz Commission looked at the implementation of a target-based approach, in that it examined price profiles of carbon that could lead, over time, using markets and a range of government climate interventions, to achievement of the goals of the Paris Agreement. The 2017 report of the Commission suggested CO<sub>2</sub> prices of \$50-100 per tonne, for 2030 (Stern and Stiglitz, 2017)<sup>13</sup>. These are prices which guide production decisions rather than prices based on marginal damages. In simple, perfectly competitive models which are fully optimised, the prices to guide production would be equal to marginal damages. But we are in a world with many market imperfections, with major risks, requiring fundamental systemic change, and where optimisation is difficult to define, let alone achieve. Thus, such equality cannot plausibly be assumed to be a general feature of appropriate policy. As Stern-Stiglitz emphasise (and see section 7 below), the kind of change we require will need a whole range of complementary policies if it is to deliver the necessary change in a satisfactory way.

### ***6.3 Discounting***

A further challenge for the economics of climate change, that is not just an issue for the IAMs, but arises as a key question in formulating approaches to major, intertemporal problems, is discounting. The discussion of discounting around climate change has been, in my view, somewhat weak and often not well-founded in basic theory.

The important concept to consider here is the social discount factor,  $\lambda$ : the relative social evaluation of an extra unit of account (e.g. consumption) in the future, relative to an extra unit now. In economics we generally use relative prices, here shadow prices, to guide choices, decisions or trade-offs. The proportional rate of fall of the social discount factor is the social discount rate.

In a simple aggregative framework without uncertainty, the social discount factor can be described by the Ramsey equation.

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<sup>13</sup> A related approach is taken by Kaufman et al. (2020), who estimate the CO<sub>2</sub> prices needed in the near term for consistency with a net-zero CO<sub>2</sub> emissions by 2050 target. They arrive at estimates, in their model based on marginal damages, of US\$34 - US\$64 per tonne in 2025 and US\$77 - US\$124 in 2030. The IMF have proposed \$75 a tonne by 2030 (IMF, 2019). More recent work looks at the possibilities of price differentials across different countries (IMF/OECD, 2021).

The social discount factor is the primary logical concept and it can be misleading to jump too quickly to a focus on its rate of change without examining carefully what should shape the primary concept itself (see below):

$$-\dot{\lambda} / \lambda = \eta g + \delta,$$

where social utility is a function of consumption,  $\eta$  is the elasticity of social marginal utility of consumption,  $g$  is the growth rate of consumption and  $\delta$  is the pure-time discount rate. The definition of pure-time discounting is the attaching of a lower weight to individuals and their associated utility simply because they occur in the future; it is the discounting of individuals or utilities because they occur later (and not because of any assumption about consumption levels).

It is the social discount factor,  $\lambda$ , the relative shadow price, that is the important concept to focus on. The essence of intertemporal valuation is embodied, on the margin, by this relative shadow price. Under most, or many at least, systems of value, relative valuation will depend on judgement from two perspectives. The first concerns the levels of living in the future, relative to now. How much you judge the value of units of consumption or income in the future, relative to now, depends on how well-off you think those in the future will be then. That is endogenous because how well off they will be depends on what we do now. This relative shadow price depends on our decisions and is not exogenous to them. This is of particular importance in this context, because if we act recklessly on climate change, future generations could be much poorer than ours.

The second concerns how much you value future generations relative to this generation, irrespective of what they might consume or produce. Pure-time discounting is essentially discrimination by date of birth. Other than the possibility of extinction (for example, from an asteroid crashing into the earth), which is something that you can build directly into the analysis, there is no serious ethical argument in favour of pure-time discounting (see Stern, 2015; chapters 5 and 6 for an extended discussion of the issues and key references; also the pair of articles in the *Journal of Economics and Philosophy* (Stern, 2014a and 2014b)<sup>14</sup>.

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<sup>14</sup> For a rather mathematical account of some relevant issues, see Chichilnisky et al (2020).

Finally, on discounting, we must note that there is little point in looking for ethical values relevant to social discounting in capital markets, because capital markets: (i) do not reflect ethical social decisions; (ii) they embody expectations and views about risk that are hard to identify; and (iii) they involve many imperfections. Nevertheless, one often seems to hear the mistaken argument that social preferences can be derived from these markets.

## 7. New approaches to the economics of climate change

I have tried to explain the limitations of the IAMs in tackling the big questions at issue: the understanding and management of extreme risk and of rapid structural change. So, what are good approaches to the economics of climate change? We are going to need a suite of different models, a variety of perspectives, and a collection of different ways of understanding different parts of the problem. And then good judgement in putting all these pieces together.

Economic analyses of climate change must first capture **extreme risk**, including possible large-scale and unforeseeable consequences. Second, they should recognise that many key markets have **critically important failures** (beyond that of the GHG externality), that crucial markets may be absent, and that there are limits on the ability of government to “correct” these market failures or absences. Third, they should embody **rapid technical and systemic change**, often in very large and complex systems such as cities, energy, transport, and land use, and allow for increasing returns to scale. Fourth, they should examine rapid changes in (endogenously determined) **beliefs and preferences**; and fifth, take into account **distributive impacts** and risks, both at a moment in time and over time, and including those associated with structural change. All of this will unavoidably involve explicit analysis and discussion of **value judgements**. These components, or sets of questions, are difficult to incorporate in standard integrated assessment modelling, but are at the core of the issues around understanding policy towards climate change. We must deepen our economic analysis to incorporate them. We should also recognise that questions embodied in, or similar to, these components arise in many other parts of economics, where major risks and fundamental change are at the core of the challenge under examination. Thus, the issues we are raising here on understanding policy towards major challenges concern economics as a whole, and not just the economics of climate change.

It is not possible in the space here to develop arguments around all the areas just described. By way of example, and an important one, I will delve a little deeper into market imperfections. Table 1 outlines six important failures that policy design must take into account. These different market failures point to the use of different instruments, but the collection should be mutually reinforcing. These failures interact.

**Table 1: Six market imperfections relevant for tackling climate change<sup>15</sup>**

<b>Market Failure</b>	<b>Description</b>	<b>Policy Options</b>
Greenhouse gasses (GHGs)	Negative externality because of the damage that emissions inflict on others.	Carbon tax/ cap-and-trade/ regulation of GHG emissions (standards).
Research, development and deployment (R,D & D)	Supporting innovation and dissemination.	Tax breaks, support for demonstration/deployment, publicly funded research.
Imperfection in risk/capital markets	Imperfect information assessment of risks; understanding of new projects/technologies.	Risk sharing/reduction through guarantees, long-term contracts; convening power for co-financing.
Networks	Coordination of multiple supporting networks and systems.	Investment in infrastructure to support integration of new technologies in electricity grids, public transport, broadband, recycling. Planning of cities.
Information	Lack of awareness of technologies, actions or support.	Labelling and information requirements on cars, domestic appliances, products more generally; awareness of options.
Co-benefits	Consideration of benefits beyond market rewards.	Valuing ecosystems and biodiversity, recognising impacts on health.

There are also important absent markets. We cannot trade fully, over long horizons, on future carbon. We cannot trade over new technologies because we do not know what technologies lie in the future. As a matter of basic theory, a competitive equilibrium with some absent markets cannot be assumed to be Pareto efficient. Such absences mean that expectations, and how they are formed, are crucial for investment. They can and should be shaped by public action, including by the key public policy and financial institutions which set direction.

<sup>15</sup> Note that the policy options in the third column are not exhaustive.

At the same time, there are difficult issues around knowledge of, or confidence in, future policies, in terms of their possible effects in relation to market participants. That issue is of real relevance to the shaping of expectations. The more that governments can build in predictability about how policy will change as learning occurs, the greater will be the confidence underpinning investment, innovation and future commitments. That is why I have emphasised (section 4.2) “predictable flexibility”. Part of confidence is based on track records which, unfortunately in the context of climate change, have seen chopping and changing (Stroebe and Wurgler, 2021).

Further, given that governments are made up of complex compromises and coalitions, are limited in information and capabilities, and are not necessarily long lasting, we must recognise in our analysis that there are limits on their ability or willingness to “correct” for market failures and absent markets. Governments cannot fully commit to future actions in a credible way. They may have short time horizons, they may have different, narrower, objectives, and they face major administrative and political constraints. In thinking about public policy, we have to put all these considerations together and take into account how policies are constrained, might shift and can go wrong. And we can ask how to build strong institutions, which can survive across different parties in power and pressures of vested interests.

These considerations underlie the rationale for the climate change legislation and the carbon budgets in the UK. The Climate Change Act and the Climate Change Committee, with its carbon budgets<sup>16</sup>, are good examples of where the law and institutions can play a valuable role. Indeed, the law is beginning to play a strong role in other countries too. In April 2021, Germany’s Constitutional Court upheld a claim challenging the constitutionality of certain provisions of the German Climate Protection Act. The court ruled that Germany’s legal requirement to meet the overall goals of the Paris Agreement, together with insufficiently strict 2030 emissions reduction targets, imply a rate of emissions reductions after 2030 that places an unreasonable burden on future generations (Setzer and Higham, 2021). This decision prompted the German Cabinet to approve a bill that raises the ambition of the emissions reduction targets enshrined in the Climate Protection Act (Boldis and Lütkehaus, 2021). And in the Netherlands, the District Court of The Hague ruled in May 2021 that Royal Dutch Shell must cut its global carbon

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<sup>16</sup> The Climate Change Act became law in the UK in November 2008. It sets out emission reduction targets that the UK must comply with legally. The Act also provides a system of carbon budgeting; a series of five-year carbon budgets that set a pathway for the UK to meet its targets.



emissions by 45% compared to 2019 levels by 2030, due to an “unwritten standard of care” that Shell owes to Dutch residents under the Dutch civil code (Grimmitt, 2021).

The GHG failure is top of our list of market failures. And carbon pricing has a critical role to play in tackling that market failure. However, we can see, from thinking about different aspects of market and government failures, that the policy question is much richer than carbon pricing alone. If we consider the very real circumstances of increasing returns to scale on mitigation action, strong risk, and worries about what government might do, we could argue that regulatory policies, such the phase-out of internal combustion engine (ICE) vehicles, have a strong role to play. The British government has set a date of 2030 (and the EU 2035), beyond which ICE vehicles can no longer be sold. That provides a very clear and strong signal, which gives car firms the confidence to pursue the major fixed costs around the development of alternative technologies and moving to scale. The banning of incandescent light bulbs is a powerful example of how new and much better technologies can be developed and driven to low cost by regulation, and how the move to scale of new technologies can be fostered by the clarity regulation can bring. This regulation did not specify technologies to replace the incandescent bulbs, but required their phase out because they were so wasteful. Before long the far superior LED system came through and costs were driven down.

In these circumstances of increasing returns and risk, alongside other market failures, such regulatory policies, alongside carbon pricing, could be more efficient and effective than carbon pricing alone. It is surprising therefore that some economists argue that the most efficient policy instrument is carbon pricing, and that we pursue others simply because this may be politically difficult. That is a theoretical mistake of real practical significance.

Much of structural change will be around the functioning of major systems, including: energy, cities, transport, land. Clean power is at the centre of the transition to net zero. The global electricity supply will need to quadruple over the next three decades and it will all need to be zero carbon by 2040 (IEA, 2021b; ETC, 2021) if we are to achieve net-zero emissions by mid-century. By 2050, around 2/3 of the world population is projected to live in cities, up from 55% in 2018 (UN, 2018). The choices made in cities on transport, infrastructure, buildings, and energy use, as they grow rapidly over the coming

decades, will determine whether the world can both manage climate change and realise the benefits of low-carbon growth.

A recent estimate has suggested that transformation to reduce the current “hidden costs” of food and land use systems across the world could generate economic gains to society of \$5.7 trillion annually by 2030 and \$10.5 trillion annually by 2050 (FOLU, 2019). These systems currently work rather poorly, so we have much to gain as we manage them better as we work to cut emissions. Indeed, in all too many cases, the structure of incentives embodied in agricultural policies and subsidies lead to land degradation, the poisoning of rivers and oceans, and the destruction of forests. Often the benefits of such policies accrue to richer enterprises.

Progress in digital and AI technologies continues to move very rapidly, and these technologies will be enormously helpful in improving the management of systems. In this way, we are fortunate that these new technologies are moving so fast at exactly the moment we have to make major systemic changes.

The need for new approaches to economic analysis of climate change raises an enormously rich research agenda. At the same time, action on scale is urgent. The transformation must be accelerated; we have to act strongly now. Thus we must think hard in real time about what we do now and its basis in current evidence, theory and judgement, whilst we pursue the most critical lines of research. That statement is true in general for those who have to make or advise on policy, but it applies particularly sharply here where urgency is of the essence.

I have emphasised throughout this paper that managing climate change requires fundamental transformation of our economies: and it requires conceptual and evidential frameworks that can guide the policies and actions that can shape such transformations. Let me highlight some key areas for research.

Changes in the **behaviours** and values of consumers, workers, shareholders, managers and voters are key to driving change in business and policy decisions, while business and policy decisions can also have a powerful influence on consumer behaviours. Understanding the **political economy**, and associated instabilities, constraints and opportunities, shaping the transition to net-zero will be important

both for creating effective policy frameworks to decarbonise at pace, and to accelerate the deployment of clean technologies across the economy. There has been a huge amount of progress in the literature in economics on behaviour, institutions, and political economy over the last 20-30 years. Interesting work on changing values in the context of climate is emerging (see e.g. Besley and Persson, 2020)<sup>17</sup>. Important areas for continued research include: behaviour change in the face of adjustment costs and missing information; and incentives and nudges.

We must analyse how to support a **just transition** which recognises the problems of dislocation. Some jobs will disappear; others will change radically. Some locations may be partially affected. There will be many new opportunities. Managing change so that all have a chance of benefitting will be not only an issue of justice, but also of political feasibility. Much of this will involve investment in people and places. And in some cases, direct income support.

The necessary transformation of the economy relies critically on changing key systems: energy, cities, transport, land use. These large and complex systems cannot be changed by fiddling with just one parameter, a whole set of policies will be required to foster change. For example, you would not sensibly attempt to redesign a city to reduce congestion and pollution just via a carbon price, even though a carbon price is extremely important for looking after cities. Understanding how to foster change at the system level will be vital. Part of that will be around sequencing. For example, much of transport and heating will depend on electricity so that, if they are to be decarbonised, then electricity will have to be expanded quickly and itself be decarbonised.

We are going to need to understand **innovation** in a much deeper and stronger way, because it is at the heart of the transition to net zero. The necessary innovation will go far beyond one particular technology, in one particular industry; it will be innovation across the whole range of our ways of doing things. Thus, more work is needed to understand the complementarities between different features of the innovation system, as well as between different types of innovation (Stern and Valero, 2020).

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<sup>17</sup> See also the important work of David Halpern and the Behavioural Insights Team. (e.g. The Behavioural Insights Team, 2020).

**Efficiency** is something we will have to scrutinise much more carefully than we have done in the past. The simplistic perspective that ‘all that exists is efficient because if it is not efficient it would not exist’ is less than convincing at the best of times, but is thoroughly unconvincing in this case. There are all kinds of inefficiencies that exist in our economies and we must try to understand their nature and origins and how to overcome them. Ideas around the circular economy, and resource efficiency more generally, will be of fundamental importance.

The functioning and role of **financial institutions and “de-risking”**, particularly in terms of the nature and scale of investments and activities they finance, will play a core role in climate action. There are important issues around financial regulation and the role of central banks (Dikau et al., 2021; Robins et al., 2021).

And, finally, **biodiversity**. The Dasgupta Review on the Economics of Biodiversity, published earlier this year, is an important piece of work, which provides a valuable framework for looking at the issue of biodiversity loss. Though the climate and biodiversity crises are not the same thing, there are key dimensions of the two which do overlap and interweave, and we are going to have to tackle climate change and biodiversity loss together. A changing climate threatens biodiversity and loss of biodiversity, including through release of carbon, exacerbates climate change. Of course, biodiversity loss comes also from over-exploitation of our natural world, beyond climate change.

The integration of **nature-based solutions** into climate policy risks focusing narrowly on afforestation, which can, in practice, encourage the establishment of monoculture plantations of fast-growing species (Seddon et al., 2019). This approach is neither best for long-term carbon storage (Hulvey et al., 2013) nor for preserving biodiversity. Instead, we should seek “nature-based solutions” that can promote diverse, intact natural ecosystems for preserving forest carbon sinks in the face of climate change (Sakschewski et al., 2016) and supporting human adaptation to climate change (Lavorel, et al., 2014). There is important research needed here on how to examine the mix of policies and the role of institutions that would help us to tackle these interrelated challenges.

## 8. Responsibility, opportunity, collaboration and leadership

The strategic challenge is to move to a net-zero carbon economy within a few decades. The economics of action must be focused on the achievement of fundamental economic change at real pace, where time matters (Stern, 2018). That will involve, as I have stressed, looking at innovation, behaviour change, political economy, and the dynamics of all those elements. And we will need all of economics to take on these problems: international, industrial, labour, health, education, environment, energy, economic history and more. We should not be too narrowly focussed on a sub-discipline within economics if we are going to take on big problems of this kind; we should be economists. And we must work with other social scientists, scientists and engineers. Though we may have our specialities, we have to recognise that most elements of economics come into the challenge of climate change. There has never been anything more important, there has never been anything more fascinating, and we have much to offer from our existing set of ideas and tools if we put them to use. And we must develop new analysis and perspectives around risks and change. That is why I think it is time for change in economics.

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