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Economic development, climate and values: making policy

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The two defining challenges of this century are overcoming poverty and managing the risks of climate change. Over the past 10 years, we have learned much about how to tackle them together from ideas on economic development and public policy. My own work in these areas over four decades as an academic and as a policy adviser in universities and international financial institutions has focused on how the investment environment and the empowerment of people can change lives and livelihoods. The application of insights from economic development and public policy to climate change requires rigorous analysis of issues such as discounting, modelling the risks of unmanaged climate change, climate policy targets and estimates of the costs of mitigation. The latest research and results show that the case for avoiding the risks of dangerous climate change through the transition to low-carbon economic development and growth is still stronger than when the Stern Review was published. This is partly because of evidence that some of the impacts of climate change are happening more quickly than originally expected, and because of remarkable advances in technologies, such as solar power. Nevertheless, significant hurdles remain in securing the international cooperation required to avoid dangerous climate change, not least because of disagreements and misunderstandings about key issues, such as ethics and equity.

1. Introduction

The two defining challenges of this century are overcoming poverty and managing climate change. We can and must rise to them together: if we fail on one, we will fail on the other. I have been working on public policy and economic development throughout my professional life. For the last decade, I have also been strongly focused on climate change. Accordingly, these two subjects constitute the major focus of this Perspective: §2 focuses on economic development and public policy; §3 on climate change. Drawing on my own research and policy experience, in each case I will give my perspective on how research in each field has developed.

The subjects are intertwined: they interact with one another in various important ways. To grapple with both challenges requires understanding processes of change, and examining the logic of public policy and its relations with values (hence the title of this paper). §4 considers the evolution in research concerning the relationships between climate and development/growth. It also considers how an understanding of these relationships has shaped real-world politics.

2. Economic development and public policy

Public policy plays a fundamental role in framing and fostering action to improve development opportunities and mitigate and adapt to climate change. Indeed, well-designed policy will clearly recognize that growth, poverty reduction and climate change are all hugely interwoven. In order to focus on climate change (the subject of the next section), this section will deal only with broad strands reinforced by selections from my experience with economic development and public policy.

My own perspectives on economic development were set out in my 2005 book [1]. It articulated much of what I had learned and argued at the European Bank for Reconstruction and Development (EBRD) and World Bank on the key elements of strategies for development. This was, at a broad and summary level, twofold: building an *investment climate* where entrepreneurship, be it at the level of the farm or large firm, could flourish; and *investing in and empowering people*. The former included, in particular, infrastructure that functioned effectively, and government policies and administration that were predictable and not malevolent or disruptive. It was based on the observation that government-induced policy risk is a major deterrent to investment the world over. Investing in and empowering people include not only education and health, although these are crucial, but also conventions and institutions that allow people the opportunity to shape their own lives. Rights of girls and women are especially important here. The application of the basic principles embodied in this twin strategy can foster rapid growth and development within which people have the opportunity and power to change their lives and to overcome poverty.

With this in mind, setting overall strategies on development should first be founded on an understanding of how individual lives, and the economies in which they live, change and develop. At the heart of my own understanding is a microeconomic study of economic behaviour and change in one village in North India (Palanpur in the Moradabad district of the state of Uttar Pradesh). The research helps inform the wider issues around growth and development in India across the last six decades [2]. I have been involved in the project for 40 years since we first studied the economy of the village, focusing on the impacts of the green revolution, in 1974 [2,3]. The previous surveys of 1957/1958 and 1962/1963 provided a robust baseline.

We now have seven studies,[1] the last five of which have involved me directly; one for every decade since national independence, with the latest one being this year (2014/2015). It is a dataset that is unique: in each of the 7 years, we have a 100% sample of village households. The Palanpur research helps understand how people's lives change along with the changing economy around them. In the 1950s, the income of the village came almost entirely from agriculture. The abolition of the Zamindari system, in which land was controlled by one or two landlords ('tax collectors'), gave land to the tenants. They then invested in agriculture, particularly in irrigation which allowed double cropping. For the first 25 years (approx. 1957–1983), the growth in the village was driven by the intensification of farming, including with new varieties of wheat associated with the green revolution. Since 1983, growth has increasingly been driven by involvement with the outside economy, mostly via commuting to nearby towns for unskilled jobs. For individual families routes upwards have been around investment and entrepreneurship inside and outside agriculture, and around finding paid non-farm activities. Routes downwards have been sickness, bad luck, alcohol and gambling.

Over the period as a whole however, incomes *per capita* have risen by an average of around 2% per year. Increasing involvement in the outside world, through for example travelling and a transformation in communications via mobile phones, has greatly broadened perspectives of those in the village and deepened their involvement in the politics of the state and country. Schooling is starting to increase, but provision in the public school is still very weak, and while education of girls has started to increase, it still lags far behind boys. Education has not yet played a strong role in the economic activity of Palanpur, but that is likely to change in the next decade or two. This is a village where economic mobility has increased, poverty has decreased, and inequality has risen, as a result of these basic, but fundamental, processes of growth and change. While it is changing it remains a poor village.

3. Climate change

It is now, in 2015, 10 years since I was commissioned by the British Prime Minister, Tony Blair, and Chancellor of the Exchequer, Gordon Brown, to carry out a review of the economics of climate change.[2] Of course, the Stern Review [4,5] was not the first major work on the economics of climate change: although a relatively young discipline by comparison to other applied areas in mainstream economics, research on climate change economics developed from the late 1980s as scientific and political interest grew. Bill Nordhaus at Yale University has been a pioneer in the field and has published many important papers, including his landmark study in 1991, 'To slow or not to slow: The economics of the greenhouse effect' [6], which was the first analysis of the costs and benefits of abating greenhouse gas emissions, in the context of an overall model to inform policy on climate change [7]. Integrated assessment models (IAMs) attempt to integrate the science of climate change with economic modelling: a model used in many of Nordhaus's papers (the Dynamic Integrated Climate Economy model, or DICE) has been a prototype for many other IAMs.

The Review was published on 31 October 2006, and launched with both the Prime Minister and Chancellor at the Royal Society in London. The report itself was divided into six parts and 27 chapters, covering the scientific evidence for climate change and the options for limiting its impacts through mitigation and adaptation. Initially presented in temporary binding and posted on the website of HM Treasury, the Review was published, with a few minor amendments, as a single volume by Cambridge University Press in January 2007.

It is beyond the scope of this paper to present a summary of all of the findings of the Review, but instead I focus on four key issues that were highlighted and that have remained subjects of discussion among both the research community and policy-makers over the past 10 years: discounting, modelling the risks of unmanaged climate change, climate policy targets and estimates of the costs of mitigation.

All these discussions must be set in the context of an understanding of the mechanisms at work. Human activities result in emissions of greenhouse gases; the Earth's systems cannot absorb them all at current flows, and thus concentrations (or stocks) in the atmosphere rise; global warming and climate change thus occur as a result of a stronger greenhouse effect; the impacts are on humans in large measure via water, or its absence (storms, floods, droughts, desertification, sea-level rise). There is uncertainty in all these steps. We thus have a process that is long-term, full of uncertainty, with consequences potentially way outside human experience and where the effect depends on the sum total of human emissions. These features make the public understanding of the problem itself, and policies to tackle it, extremely difficult. The science 'conspires' to render the making of policy very troublesome.

Further, there are severe dangers of delay. Carbon dioxide is long-lasting and difficult to extract from the atmosphere at scale once it has been released. Thus, the later we leave action, the higher the concentration levels and the worse the 'starting point'. And we are already at levels that are not far away from the maximum concentrations associated with a reasonable chance of avoiding dangerous climate change, conventionally and reasonably, above 2°C [8]. The problem is compounded by the fact that much high-carbon infrastructure and capital equipment can be very long-lived.

(a) Discounting

Probably the main issue in the Stern Review that academic researchers focused on was the subject of discounting. The discount factor for good i at time t is the social value of (a unit of) that good at that time relative to a unit of that good now. The discount rate for good i at time t is the proportional rate of fall of the discount factor. Clearly, both the factor and rate depend on i and t. In a world with uncertainty, highly relevant in the context of climate change, we should index discount factors and rates by the state of nature as well. Uncertainty is then often embodied in valuations, assessments and choices by taking expected values across states of nature. We would expect a discount factor for good i in some state of nature at time t to be low where good i is scarce at time t and times are hard. Given that the climate and the availabilities of goods and services in the future depend on what we do now on emissions, discount factors and rates are clearly endogenous to our decisions. They cannot be read off from current markets or be assumed to be determined in some way outside our models.

The Review took a broad view of potential consequences of climate change across its 27 chapters. However in one chapter (chapter 6), the Review pursued (following a literature which, on the whole, is in the tradition of Nordhaus [6]) a narrow and simplified approach which sets the problem in a one-good growth model. In attempting to determine the potential costs of climate change impacts within this narrow framework, the Review used a standard approach from welfare economics, formally involving the summation across individuals of social utilities of consumption. This sum or aggregate provides a measure of social well-being. The relationship between the aggregate and the goods and services in the consumption of each household is called the social welfare function. In assessing costs in this way, value judgements are required about, for instance, how much to value a loss of consumption by a rich person relative to a poor person, or by a person today rather than a person in the future.

Typically when the approach of welfare economics is applied in this type of model, an increment in future consumption is assumed to be worth less than an increment in present consumption, for two reasons. First, if consumption continues to grow into the future, people will be richer, and a unit of consumption will be valued at less than it is today. Second, it is assumed that there is a preference to 'take utility' sooner rather than later. This is 'pure-time discounting'. Where the utility accrues to future generations it involves attaching lower social values to lives which start later (remember this part of the argument is about date of birth not level of consumption). The Review pointed out that a high rate of pure-time preference is equivalent to discrimination against future generations, on the basis simply of date of birth. A 2% pure-time discount rate means that the life of someone born 35 years from now (with given consumption patterns) is deemed half as valuable as that of someone born now (with the same patterns). Further, one could not assume that future generations would automatically be richer than the present one, particularly if the impacts of climate change fundamentally undermine economic growth.

The fact that future consumption is intricately linked to decisions made today implies that it makes no sense to argue, as some have, that the Review used a single, low discount rate. That is to misunderstand the theory of discounting and the explicit modelling and argument of the Review. As the rate of change of consumption varies over time so too will discount rates. Further, the probability distributions of consumption are themselves endogenous to our decision-making, indeed fiercely so in the case of climate change.

Similarly it is a mistake to think relevant discount rates in this context can be 'read off' from markets. Those markets are predicated on future views of policy (usually implicit assumptions) that the decision-making itself seeks to change. In addition, the capital markets in question are often full of imperfections,[3] and thus it is incorrect to argue that the prices reflect relevant social values. Further, they are based on fairly short-term private decisions, not the long-term public decisions that are at issue here.

It is another mistake to try to suggest that the long-term decisions examined here are precisely analogous to shorter-run investment decisions, such as building a bridge (i.e. that the decisions at issue constitute small 'disturbances' or adjustments to an otherwise growing economy or given path). We are examining strategies with profound long-term effects on the structure and growth of an economy and the uncertainties it will face.

There is no alternative, as I have argued in 2009 [9] and 2014 [10,11] for example, to an explicit and careful examination of the underlying ethics and uncertainties. Short-run standard economist 'fixes' on discount rates are generally dangerous mistakes in this context. The only way forward is for economists to better understand the normative foundations of their discipline and to engage seriously with ethics.

(b) Modelling the risks of unmanaged climate change

Although I think that the findings of the Stern Review remain as relevant and cogent now as they were when they were first published, I now think that it understated the consequences of climate change for two main reasons.

The first is that the Review has sometimes been perceived as promoting a somewhat mechanical benefit–cost analysis as the appropriate way of considering the relevant merits of action and inaction. While the arguments that the costs of inaction greatly exceed the costs of action, which were strong at the time of the Review, are still stronger now, we have since greatly deepened our understanding of the dynamics of economic change and international interactions. Performed in a sensible way, and tailored to the structural and ethical basics of a problem, a benefit–cost analysis can prove insightful, and I hope it was in the Review. But applied in a narrow and mechanical way, a benefit–cost analysis can be misleading. If, for instance, the future potential consequences of climate change are quantified only in terms of a single dimension (e.g. consumption or GDP), the scale of damage and disruption to human lives can be overlooked. Consider, for instance, trying to describe the Second World War only in

terms of its impact on global GDP, without referring to the millions of lives that were lost. In retrospect, I think that while it is useful, and followed structures from the literature being reviewed, there was excessive emphasis in public discussion of the Review on the fairly narrow cost–benefit approach and one-good model of chapter 6. While chapter 6 was well-founded and important, it was just one of 27 chapters, most of which embodied broader conceptions of the issues at stake.

The second reason is that the Review was misunderstood by many as suggesting that current generations of IAMs, used by economists to estimate future costs of climate change impacts, are able to capture the scale of the potential consequences. In fact, the Stern Review, in reviewing the literature, was explicit about the limitations of these models, and warned that 'the omission of abrupt and large-scale changes at high temperatures creates an unrealistic negative bias in estimates' [4,5]. It pointed out that for the PAGE 2002[4] model that the Review used, for a high-climate scenario and including non-market impacts, mean total losses were calculated to be 13.8% in 2200, with 5th and 95th percentile values of 2.9% and 35.2%, after a rise in global average temperature by 8.6°C above its pre-industrial level. But again, the Review stressed that '[t]hese estimates do not capture the full range of impacts', and '[t]he costs of climate change could be greater still' [4,5]. Indeed a temperature increase of 8.6°C is colossal and could potentially wipe out much of humankind. These percentage losses do look far too small, but they reflect the models in use at that time.

Studies published since the Review have highlighted still further the limitations of the estimates produced by IAMs for the potential impacts of unmitigated climate change. Ackerman *et al.* [12] showed that one of the standard models, DICE, indicates that a rise in global average temperature of 19°C would only reduce global GDP by 50%, even though it would mean much of the globe was hotter than the physiological heat threshold for human beings. It is perhaps little surprise, then, that one senior economist, Robert Pindyck, declared that IAMs 'have crucial flaws that make them close to useless as tools for policy analysis' [13].

I have recently re-assessed the way in which IAMs portray damages from climate change and have argued that there are four basic features of these models that lead them to badly underestimate the potential future losses from unmitigated climate change [14]:

— underlying exogenous drivers of growth (in aggregated one-good models);
— damage functions (usually, but not always, multiplicative) that relate damage to output in a period only to temperature in that period;
— weak (quantitatively) damage functions; and
— very limited distribution of risks.

The IAMs usually work with an aggregated output, which is determined by factors of production, and which can be damaged by climate change. A general functional form in such models presents output H at time t as a function of production inputs F, as follows:

$$H = F(K, N, L, t, T),$$

where K is capital, N is labour, L is land and T is temperature, all at time t (each of K, N and L could be vectors). This formulation involves the assumption that economic output depends only on variables at time t, including temperature. However, these models rarely allow that capital, labour and land in this period could be influenced by earlier direct damage, and damages are usually modelled as loss of output flow rather than damages to stocks. In reality, capital, labour and land in this period could be influenced by earlier direct damage, for example by the effects of a hurricane or flood in a previous period, and such direct effects are rarely incorporated in the models, or if they are, they are assumed to be small. Hence, even large potential losses in the future can seem relatively small relative to increases in output resulting from an exogenous rate of growth, a feature of growth commonly assumed in such models.

In a new paper, Simon Dietz and I [15] show how making some changes to the basic assumptions underlying the standard DICE model can lead to radically different estimates of the impacts of climate change. By taking more strongly into account the endogeneity of economic growth, increased damages from climate change impacts associated with rising temperatures and the risks of a wider range of potential impacts, we show that economic losses could be far higher than estimated by the standard models, and could lead to estimates of major decreases in the standard of living for people across the world.

Where do we go from here? It is clear that if IAMs are going to be of significant use in the future to policy-makers who want to weigh up the potential costs of inaction on climate change, we will need a new generation of models that are better able to take into account the scientific evidence about the impacts of rising greenhouse gas levels. The current generation of models, for the reasons described, has a very strong downward bias. They should be capable of speaking about the scale of risks we face. Specifically, economic modellers should abandon the assumption of damages being focused on current output and should incorporate lasting damage in the models. They should embrace a real possibility of creating an environment so hostile that physical, social and organizational capital are destroyed, production processes are radically disrupted, future generations will be much poorer, hundreds of millions will have to move and many may perish.

But we also have to make policy in real time while we are trying to build better models and learn about the many underlying uncertainties. That is part of the art of policy advice, policy modelling and policy making. The challenges of learning and deciding at the same time are particularly severe when delay is dangerous.

(c) Climate policy targets

Chapter 13 of the Stern Review considered the different types of potential goals for climate change mitigation policy. It assessed the strengths and limitations of various objectives, ranging from defining a maximum tolerable level of impacts to setting a target for a reduction in annual emissions of greenhouse gases to be achieved by a specific date. The Review chose a target based on a target stabilization level for atmospheric concentrations because it was a single quantifiable variable, it could be linked to human actions (with a degree of uncertainty), and it would be relatively easy to measure progress towards the achievement of the target. On the other hand, a stabilization target had the disadvantage that there would be

uncertainties about the magnitude of the impacts that would be experienced or avoided.

The Review estimated that the atmospheric concentration of greenhouse gases at the time of publication was about 430 ppm of carbon-dioxide-equivalent (taking into account the basket of six greenhouse gases covered by the Kyoto Protocol) [8]. It noted that cutting emissions sufficiently to stabilize at 450 ppm could be difficult and costly, and so recommended a target of between 500 and 550 ppm, which could be achieved through action that might cost annually the equivalent of about 1% of global GDP. In retrospect, I now believe that the Review should have recommended a stabilization target of between 450 and 500 ppm in order to have a reasonable chance of avoiding unacceptably large impacts of climate change. The risks of climate change now look still more worrying, with many coming through faster than we anticipated then. Further, at COP16 in Mexico in December 2010, governments agreed that greenhouse gas emissions should be reduced to levels which could avoid a rise in global average temperature of more than 2°C; warming beyond that would be considered to be unacceptably dangerous. A 2°C target, as shown by the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) [8], requires concentrations to be stabilized well below 550 ppm.

There is some uncertainty about the relationship between pathways for global annual emissions and future temperature change. Research by my colleagues Alex Bowen and Nicola Ranger in 2009 [16], which remains valid today, suggested that to have a 50% chance of avoiding an eventual rise in global average surface temperature of more than 2°C above its pre-industrial level, global annual emissions of the greenhouse gases covered by the Kyoto Protocol would need to fall from about 50 billion tonnes in 2010 to 44 billion tonnes in 2020, less than 35 billion tonnes in 2030 and below 20 billion tonnes by 2050. That would mean that average *per capita* emissions would decline from about seven tonnes in 2010 to about two tonnes in 2050. If, in 2050, 2.5 billion people (the likely population of China, the USA and the EU) of the around 9 billion people were on average emitting eight tonnes per capita, then the other 6.5 billion would have to be emitting below zero on average. At present, the USA emits around 20 tonnes per capita and China is probably around nine. These calculations are not morally or economically prescriptive. They take no account of the history of emissions or of income per capita. They simply illustrate arithmetically the immensely important quantitative point that the scale of the necessary change is such that all countries must be involved in strong cutbacks of emissions.

More recent research (e.g. by the United Nations Environment Programme [17]) has suggested that the reduction in emissions over the next 20 years could be less ambitious if it proves possible later this century to have net negative global emissions. However, today, it is not clear that measures to achieve negative emissions could be viable on the necessary scale, and so it would be risky to plan for an emissions pathway that was heavily dependent on their advent and to delay action based on that assumption.

It seems likely that a new international agreement on climate change, which is being negotiated ahead of the UNFCCC's COP21, due to be held in Paris in December 2015, will include a commitment to cut emissions to avoid a rise in global average temperature of more than 2°C. It will be important to recognize the implications for emissions and concentrations of that commitment.

Policy for mitigation can be seen as 'avoiding the unmanageable', and policy for adaptation 'managing the unavoidable'. Over the last seven or eight millennia (the Holocene period), temperatures have been remarkably stable, fluctuating in a range of ± 1°C around an average [18]. These temperatures allowed our societies and civilizations to develop. We are currently at the upper bounds of this temperature range, in large measure as a result of changes brought about by humans. Indeed we are already experiencing extreme weather events and patterns that may go beyond the experience from that period. In the next two or three decades, we will be very likely to be outside of that temperature, meaning that building the resilience to droughts, floods, extreme storms, changes in seasons (i.e. adaptation to these events) will be very important. In this Perspective, I focus largely on mitigation, but that does not mean that adaptation is not important; on the contrary.

(d) Estimates of the costs of mitigation

As previously mentioned, the Stern Review estimated that stabilization of atmospheric concentrations of greenhouse gases at between 500 and 550 ppm of carbon-dioxide-equivalent would cost the equivalent of about 1% of global GDP per year. However, allowing concentrations to reach 550 ppm now seems to be too dangerous, and it is desirable to set a limit of no more than 500 ppm to have a reasonable chance of avoiding a rise in global average temperature of more than 2°C. I believe that meeting this more demanding target could be achieved for an equivalent annual investment of no more than 2% of global GDP, and possibly for much less. Indeed, as argued below, emissions reductions could be accompanied by better growth. It is important to emphasize that work since the Stern Review, including my own, increasingly analyses the transition to the low-carbon economy in terms of 'investments' rather than 'costs'.

Looking at developments on climate action and its costs over the last decade, we see that on the negative side, collective global efforts to cut greenhouse gas emissions have been weaker than was assumed to be necessary in the Stern Review. Annual emissions of greenhouse gases have been rising each year at a rate that matches a pathway outlined by the IPCC, which would have a probability of leading to rises in global average temperature of 4°C or more by the end of the twenty-first century. Therefore, even stronger cuts in emissions are now needed over the next 35 years to mid-century, to reach a pathway that is consistent with a warming limit of 2°C.

On the other hand, the rate at which some clean energy technologies have been developing is much quicker than the Stern Review expected. An excellent example of the dynamism of this kind of structural change is the progress made in solar photovoltaic (PV) energy installations. Extensive innovation and learning in solar PV have driven rapid cost reductions that have far exceeded forecasts. Solar PV module prices declined from around \$2800 per watt (W) in 1955 to around \$100 W^{-1} in the 1970s. Since then, the change has been remarkable: installed costs have fallen more than 50% since 2010 to around \$0.60–0.90 W^{-1} currently [19]. The cost of energy that can be delivered from these devices is competitive (i.e. without the need for subsidies and in the absence of appropriate carbon taxes) in perhaps 80 or so countries [18].

Indeed, the reduction in costs of low-carbon energy has been so rapid that policy-makers and their advisers have struggled to remain up to date. For instance, the Fifth Assessment Report of the IPCC [8] suggested that cutting emissions of greenhouse gases in line with the target of limiting global warming to no more than 2°C could cost the equivalent of between 2 and 6% of global consumption in 2050, but this was based on the outputs of models that were not able to take into account the latest reductions in the cost of renewables. Further, they are rather rigid in their assumptions about cost structures for alternative technologies in the sense of largely omitting the possibility of endogenous learning, a feature that seems likely to be strong.

There is one further important factor that has become more apparent since the publication of the Stern Review in 2006. There is increasing recognition that many of the measures and policies to mitigate climate change by reducing greenhouse gas emissions have multiple economic co-benefits, beyond avoided climate change impacts, that have not been formally accounted for in the estimates of costs by the Stern Review and the IPCC. Perhaps the most important of these is the benefits of reducing local air pollution from emissions of fossil fuels, such as coal and diesel. A study by Hamilton [20] for the Global Commission on the Economy and Climate concluded that particulate matter measuring 2.5 μm or less from the burning of fossil fuels and other sources is having a very substantial economic impact in many countries through increases in mortality. In China, for instance, the mortality impacts of PM2.5 could be equivalent to a reduction in GDP each year of more than 11% [20]. And other health costs and other hydrocarbon-related pollutants could add to these costs. Precise estimates of the economic costs of these pollutants are not easy to make, but there are strong grounds for thinking they are very large.

The Global Commission on the Economy and Climate, which I co-chaired with former President of Mexico, Felipe Calderon, estimated in *Better growth, better climate: the new climate economy report* [21] that more than 50% (possibly up to 90%) of the reductions in annual greenhouse gas emissions required by 2030 for a pathway consistent with the 2°C warming limit could be achieved through measures that (taking into account co-benefits) are in the direct interests of the countries concerned even if the climate benefits of such investments are not taken into account.

The rapid advance in technology, the powerful co-benefits of the kind just described, and the lessons of economic history around the innovation, investment and growth associated with waves of technological change have convinced me that we should think beyond the narrow cost–benefit analysis of 'costs of action'. Essentially, the transition to the low-carbon economy is a different growth strategy, full of learning, innovation and co-benefits beyond the reduction of climate risk, which is, of course, itself of fundamental importance. Such strategies were described in *Better growth, better climate*. They embody radical change in approaches to cities, energy systems and land use involving strong innovation, major improvements in energy efficiency, and cleaner and smarter infrastructure. Narrow interpretation or modelling in terms of incremental shifts and associated marginal costs of action do not really capture the essence of such changes.

In this sense, the perception of the choice as one of trade-offs between environmental and climate responsibilities on the one hand and economic growth on the other would be misleading and somewhat of an artificial horse-race. Essentially the argument is as follows. The risks of unmanaged climate change are immense, and it is crucial to act strongly to manage them. The transition to a low-carbon economy looks to be a path of development and growth that is very attractive in its own right: cleaner, quieter, more efficient, less congested, less polluted, more bio-diverse and so on. And in addition, and fundamentally, it carries much less climate risk. It does require investment and change. It will involve some dislocation. But it seems a very sound and attractive strategy.

These arguments are developed and described in more detail in my latest book [18]. The 10 years since the Stern Review have both deepened and broadened my understanding of the economics of climate change. However, the basic insights of the Review were sound: the costs of inaction are much greater than the costs of action, on any sensible examination. And the 'greatest market failure the world has seen' does require strong policy.

4. The relationship between development, climate and cooperation: from theory to politics

This Perspective has so far mostly considered development and growth separately from climate change. However, as indicated in §3, there are important linkages between the two. This final section briefly considers the evolution of scholarship on the relationship between climate and growth/development, and how this research has informed the practice of politics, particularly the international negotiations on climate change.

The early economic literature on climate change assumed that, at the microeconomic level, when an agent acts to reduce emissions it incurs only costs [6]. Similarly, it is often assumed in macroeconomic modelling of climate mitigation [22,23] that reducing emissions entails a switch to lower-carbon activities with higher input–output coefficients and costs, resulting in both short-run losses in national output and consumption due to switching costs, and lower long-run output and consumption due to low-carbon substitutes being more expensive.

These traditional assumptions about the basic economic processes of mitigation have influenced scholarship in other academic disciplines. For example, most social science research on international climate change cooperation assumes that mitigation is costly for each participating state, yet produces only global, non-excludable benefits, meaning action is contrary to states' self-interest, and is thus characterized as a prisoner's dilemma and a tragedy of the commons [24,25]. Similarly, most research in the field of applied moral and political philosophy known as 'climate ethics' starts from this assumption, and seeks to develop principles for the ethical distribution of emissions duties, rights or entitlements [26].

No doubt influenced by scholarship in all of these fields, domestic and international climate politics has also proceeded on the basis of these assumptions. In particular, these assumptions have influenced the design and content of the main multilateral climate treaties to date: the UNFCCC and the Kyoto Protocol. The Kyoto Protocol model of climate mitigation sought to establish a regime of emissions reduction targets for developed countries (and former Soviet 'economies in transition') on the basis of principles of 'burden sharing' according to 'common but differentiated responsibilities'

[27,28], and sought to force those countries to comply with their commitments by making those commitments internationally legally binding and subject to an enforcement mechanism [27]. Equity discussions around burden sharing have been persistently divisive; meanwhile, the Protocol's enforcement mechanism was very weak, and in any case can be circumvented by non-participation (as was the case with the US) or withdrawal from the agreement (as with Canada)—such is the nature of public international law in a system of sovereign states.

As explained in §3, there is immense potential for the reduction of mitigation costs through innovation, for associated innovation-led economic growth and for co-benefits, which together call into question the traditional assumption that mitigating climate change is a costly burden that is antithetical to development. In fact, they suggest the opposite: the potential for more integrated and mutually reinforcing approaches to climate, growth and development. Consider, for example, how zero-emissions distributed solar photovoltaic systems and clean cook-stoves could provide access to safe, non-polluting energy services for the billion people who lack access to an electricity grid and the three billion who rely on the direct burning of biomass for cooking and heating [29].

This more complementary understanding of the relationship between climate, growth and development is gradually filtering into academic scholarship in the disciplines of economics [18,30,31], international relations [32], game theory [33,34] and climate ethics [10,11,35,36], among others. It has also influenced policy-oriented work, most explicitly in the work of the Global Commission on the Economy and Climate [21] and its associated country studies, but also in multilateral economic institutions [37–41], and it has begun to influence policy and practice in some developing countries [42–44] and developed countries [45]. It is also starting to influence the conduct of international climate cooperation, as exemplified by the emergence of new coalitions focused on providing support for joint development and climate actions (such as the Climate and Clean Air Coalition), by the recent G7 Communique of June 2015 [46], and by the US–China Joint Announcement on Climate Change by President Barack Obama and President Xi Jinping of November 2014, which focused strongly on collaboration in clean energy innovation, recognizing this to be the growth story of the future [47]. In such international initiatives, the potential for progress is great: if countries (and sub-national actors) understand the attractiveness of moving quickly to decarbonize their economies for their own domestic reasons, then international climate cooperation becomes more about coordination, sharing lessons, and accelerating and supporting otherwise-beneficial domestic transitions, albeit with developed countries moving faster and providing more of the necessary technologies, finance and other support for the transitions in developing countries [18]. This is the essence of my interpretation of 'equitable access to sustainable development', an equity concept emphasized in the decisions reached at the UNFCCC's COP16 in Cancún in December 2010 [11,18].

It remains to be seen, however, whether this kind of framing of the issues will be embraced by governments in the three key multilateral meetings covering these issues that will conclude in 2015: the finalization of sustainable development goals (SDGs) in New York in September; the conference on financing for sustainable development in Addis Ababa in July; and the negotiations towards an international climate change agreement at the UNFCCC's COP21 in Paris in December. In the negotiations for the financing of SDGs (and in the provision of overseas development assistance more generally), and in the financial support elements of the Paris negotiations on climate change, countries must find opportunities to finance actions that foster development and climate objectives in complementary and reinforcing ways [48]. Furthermore, while the climate negotiations have helpfully moved away from the divisive focus on legally binding targets and compliance mechanisms towards an approach that mixes decentralized and voluntary emissions pledges with a centralized process for recording and monitoring progress, a necessary innovation to make this process work over the long term would be the inclusion in the agreement of a process of (say) five-yearly reviews and revisions of mitigation commitments. This would allow commitments to be progressively ratcheted up over time, as the technological frontier expands, as examples grow, as the costs of low-carbon technologies continue to fall, and as countries increasingly see the attractiveness of low-carbon growth and pathways [18,21].

In the light of the issues raised in this section, future academic research could usefully focus on the following, more generally and with application to low-carbon transitions: identifying, describing, measuring, quantifying and monetizing the co-benefits of different types of climate mitigation and adaptation policies and actions; elucidating the complex dynamics that characterize, among other things, innovation in social and technological systems, patterns of financial investment, international cooperation, urban development, the politics of institutional and policy transitions, shifts in social norms and values, and changes in individual beliefs and worldviews; and developing just and equitable processes and policies that take into account these complex dynamics, including better understanding of the distributive effects of technological and policy transitions, and the relationships between climate action, poverty and inequality.

As I have argued here, the transition to the low-carbon economy can be full of innovation, creativity and rising living standards on all relevant dimensions. If we look at the issues in terms of collaboration, dynamism and opportunity rather than division, stasis and burden, we are much more likely to get domestic progress and international agreement. It is the former that characterize a modern understanding of the promise that lies in tackling climate change. In this way, we can rise to the two defining challenges of this century that I identified at the beginning of this paper: overcoming poverty and managing climate change.

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Endnotes

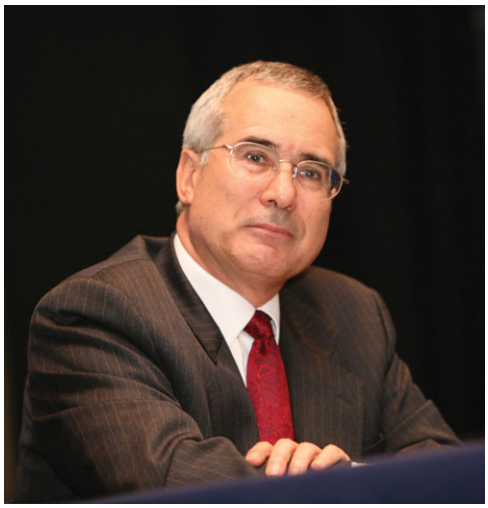
[1]The 1974/1975 study was jointly with Christopher Bliss. Since the early 1980s, Jean Dreze, Peter Lanjouw and Himanshu have played strong roles in this work.

[2]The Stern Review team was led by Siobhan Peters. Team members included Vicki Bakhshi, Alex Bowen, Catherine Cameron, Sebastian Catovsky, Di Crane, Sophie Cruickshank, Simon Dietz, Nicola

Edmondson, Su-Lin Garbett, Lorraine Hamid, Gideon Hoffman, Daniel Ingram, Ben Jones, Nicola Patmore, Helene Radcliffe, Raj Sathiyarajah, Michelle Stock, Chris Taylor, Tamsin Vernon, Hannah Wanjie and Dimitri Zenghelis. The late Dennis Anderson was a key adviser.

[3]Concerned with asymmetric information across various parties, market manipulation, limited ability to carry risk by different parties, and so on.
[4]The PAGE 2002 model was used because it was the best designed, among the available models, to take account of uncertainty.

AUTHOR PROFILE



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