Human Development Report **2007/2008**

Fighting climate change: Human solidarity in a divided world

Human Development Report Office
OCCASIONAL PAPER

Climate change: Sustainable growth, markets, and institutions

Dieter Helm

2007/6

Climate change: sustainable growth, markets, and institutions

Dieter Helm

Professor of Energy Policy

University of Oxford[1]

April 2007

I. Introduction

Over the last decade, climate change has moved from a peripheral policy issue to centre stage, and from the narrow confines of scientific research to the stuff of everyday politics. Few now deny that climate change is taking place, and few deny that the causes are in large measure anthropological. The debate now has moved on from the question of *whether* climate change is occurring to *how* it can be tackled.

It is perhaps not surprising that politicians' desire to show leadership by signing up to ambitious targets has not been matched by much by way of supporting analysis of the mechanisms and policy instruments to achieve them, and in particular the implications for energy and transport systems.

Part of that lack of detailed engagement with the design of policy is a consequence of a serious underestimation of the scale of the changes required and the costs of achieving them. In this respect, perhaps the most worrying aspect has been the readiness of political leaders to take at face value the conclusion of the Stern Report (Stern 2006) that the costs of mitigation policies may be as low as 1% GDP (or perhaps even less), and therefore the comforting implication that people may not have to adapt much of their lifestyles in order for the problem to be addressed. Current lifestyles and patterns of consumption may need to adjust at the margin, but the 1% challenge is not likely to require a significant

[1] Comments to dieter@dhelm.co.uk. See also www.dieterhelm.co.uk.

reduction in living standards. Indeed, the Stern Review is explicit that conventional economic growth and tackling climate change are compatible: economic growth (as measured by GDP) is *assumed* to continue throughout the twenty-first century, continually raising our standards of living, and therefore consumption. In the Stern Review world, by 2010 we will all be very rich—in developed countries, perhaps four times as wealthy as now. Such a vision is comforting to politicians—they can show leadership in tackling the problem, happy in the knowledge that voters will feel little pain.

This view is at best contentious. The costs, it will be argued in this paper, might be (much) higher, with tackling climate change both causing serious checks to economic growth and requiring reductions in expected living standards. Put simply, we may be living beyond our sustainable means. The implications for policy—and politics—are considerable. The easy cohabitation with economic growth may not be so straightforward, though it depends in large measure on what we mean by economic growth. We need to look again at what the Stern Review and others have assumed not only about the costs and our current consumption levels, but also about the effects of climate change on future growth rates. GDP is not a very environmental friendly concept: it fails to take proper account of resource depletion (including the climate and biodiversity) and it does not count in the externalities. Once these are included, a second argument can be made: that GDP growth and tackling climate change are not so natural bedfellows.

Sorting out the costs and benefits of mitigating climate change and the relationship between climate change and economic growth is not just an academic exercise; it sets the context for policy interventions. The scale of the challenge matters, and if this turns out to be large, the premium on the design of efficient instruments will be considerable. Current policy interventions tend to be complex, confused and often overlapping, with the result that the very limited progress so far with emissions reductions has typically been expensive. Fortunately, more efficient market-based instruments exist—such as emissions trading—although their success depends on the careful design of the new carbon markets. To trade carbon requires that the ownership of carbon be defined, and that carbon reductions that are traded are credible. While there are lessons to learn from local experiments with such trading—such as the UK emissions trading scheme and the EU emissions trading scheme (EU ETS)—the challenges of designing such instruments at the international level are immense.

To make such mechanisms work at the international level requires detailed attention to the supporting international institutions. If developed countries are to pay for carbon reductions in developing countries like China, they need to have confidence that the baselines for such reductions are credible, and that the emissions reductions paid for actually take place. This institutional challenge is on a par with the creation of an international exchange rate and monetary regime after the Second World War, and requires an analogous initiative in international institutional building.

The paper is structured to follow through these three themes: beginning with the economic costs and benefits of mitigation (and adaptation) and their relation to economic growth; moving on to consider the appropriate international policy instruments, notably emissions trading and carbon taxes, required to achieve the emissions reductions efficiently; and finally considering the necessary international institutional architecture to facilitate credible international agreements and to ensure that these are effectively implemented.

II. The carbon arithmetic: how damaging is climate change and how much might it cost to mitigate it?

Climate change is such a massive process over a very long time span that it is not surprising that both the economics and the science are matters of dispute. Climate change is not a simple 'truth', but rather a theory about the greenhouse effect, and a hypothesis about the relationship between human emissions and this effect. The relationship between the climate and human activities is far from clear and precise: climate change has happened in the past—indeed it is 'normal' in geological history—long before the human age. Human activity is therefore not a necessary condition for climate change. The issue is whether it is *sufficient*.

This paper is not, however, about the science. It is assumed for the purposes of this paper that climate change is happening and that human activity is a major cause. The conventional wisdom of the Intergovernmental Panel on Climate Change (IPCC) is taken as given. Rather, the paper focuses on the economics, and the recent Stern Review provides an obvious focus for identifying the issues and the uncertainties—not least because politicians have rushed to embrace its conclusions, typically without bothering to read the text itself and examine the underlying assumptions.

The central claim in the Stern Review is that the balance of expected costs and benefits dictates urgent action now to reduce emissions. This claim is based upon three main building blocks: the expected damage; the expected costs of mitigation; and the discount rate, which connects the present to the future. The Stern Review recognises the uncertainty about each of these, but concludes that there is no obvious disconnect between addressing climate change and economic growth—it is just another economic problem which human ingenuity, technology and investment can solve. What is more, it is a very limited problem, costing around 1% global GDP each year to fix it.

In each of the three elements that support the conclusion, the numbers in the Stern Review are, given the time horizon, open to serious challenge. Further, the combination of the various components only supports the conclusions of the review because of Stern's ethical judgements about discounting. Otherwise, on the Stern Review's own analysis, it could be argued that we should in fact do very little, and not with much sense of urgency. There is, I will argue, a very good case for urgent action now, but on a rather different basis from the Stern Review's, and these differences have quite radical implications for the design of policy and institutions.

The damage and discounting

The Stern Review estimates that climate change without action to mitigate will cost between 5 and 20% GDP when discounted back to the present, expressed in terms of the adjustment to current consumption per head, and that this is roughly equivalent to the impact of the inter-war depression of the twentieth century. It is not that consumption now will actually be reduced—the effects come much later in the century. It is rather that this is the range that Stern comes up with when discounted back to the present: it is his valuation now of these future potential losses to future generations.

Politicians instantly latched onto the 20%, but 5% is just as legitimate a base, and such an estimate in a century's time would not be of very great concern if discounted back to the present by a conventional discount rate. There are many other possible causes of 5% (or even 20%) GDP loss over the century, of which war (especially nuclear) and infectious diseases might rank at this sort of magnitude. A depression such as that of the 1930s is quite possible, but it is far from obvious that we should take 'urgent action' now to deal with this possibility, although we might (but don't) want to take such action in the case of a possible nuclear war.[2] Furthermore, given the manifest suffering of a billion of the world's poor now, it is far from obvious why they should not rank as at least as important as those in the distant future. So, to put this simply, the damage projected by the Stern Review might even be considered not very scary, and probably not enough to mandate 'urgent action' now. It is—as most of his critics have pointed out—his ethical assumptions about the discount rate which make the difference and focus on climate change separately from all these other challenges and concerns.[3]

The upper end of the damage range coincides with the upper temperature forecasts of the IPCC. Suppose that temperatures did rise by 5°C, would the change really be equivalent to just 20% GDP? How would perhaps 10 billion people (up from the current 6 billion (UN 2007)) cope by 2100? In the Stern Review's analysis, it is assumed that these future people will be very wealthy in aggregate, as a result of economic growth for a century at almost 2% per annum. Global warming is not, on this view, a show-stopper: the growth in wealth carries on, but there are some negative effects on growth as well, which need to be put into the balance. Others—primarily environmentalists—question how economic growth can continue at all in such circumstances, seeing the climate (and the associated

---

[2] See Schelling (2006) for a discussion as to why nuclear war has so far been avoided.
[3] See Weitzman (2007) for a penetrating critique.

damage in biodiversity and environment) as a crucial factor input. Although technical change is assumed to carry on—thereby pushing out the supply function—it is not the only motor of economic growth. Endogenous growth includes other factor inputs, notably education and health. But the climate itself (and the other environmental dimensions) might have at least as great a role in the production function.

Some thought has been given to this way of looking at the problem, and in particular the transmission mechanism from the climate and environment into economic growth. In the Stern Review, these linkages are fairly primitive. The loss of perhaps half of all the species by the end of the century hardly figures at all, and the implications of war and conflicts over diminishing resources are largely ignored (although the Stern Review does acknowledge that these are left out). Given that these factors are largely ignored, it is reasonable to assume that the Stern Review's damage function is an underestimation (a point Stern himself openly acknowledges throughout the report).[4]

The Stern Review comes close to recognising that this damage might have the effect of stalling future growth in its calculations, though in the roundabout way of using a low discount rate. The justification of this discount rate is complex and technical, and is perhaps the most controversial part of the analysis. But the issues come down to three parameters. The first is the value of time. The Stern Review assumes that the pure cost of time—the social time preference rate—is close to zero. The argument here is necessarily an ethical one, and, in this respect, the Stern Review is not strictly an economic analysis at all. We should, it is argued, be close to indifferent between utility to people at different points in time. It is an ethical judgement with much support, though in practice our current savings rates indicate that we pay scant regard to it. On the contrary, in the last decade there has been a significant mortgaging of the future through a dash-for-debt in many developed economies, with increases in personal, corporate and government borrowing. The implication is either that future growth rates are expected to be (much higher) than Stern's 2%, or that people do not share the Stern Report's view of a near zero time preference rate. (In the Stern Review, it is close to zero, rather than zero, since

[4] See also Stern's oral evidence in House of Commons Environmental Audit Committee (2007b).

he assumes a very small extinction risk *for humans, but not other species.*) But the fact that people do not behave according to the dictates of an ethical principle does not invalidate that principle: that is why it is an *ethical* principle. If people do in fact *behave* unethically (by not saving enough for the benefit of future generations), the policy implications are stark: the gap between behaviour and the zero time preference rate needs to be closed. That gap is arguably very large—we are currently acting as if the discount rate is very high. Furthermore, if an international agreement depends upon enough countries believing that enough countries will in fact start to behave in this ethical way, the existence of the gap itself may deter such an agreement.

The second aspect is the growth rate. Stern assumes that economic growth will go on throughout the century at almost 2%, making developed countries at least four times richer by 2100, even if no mitigation takes place. Some developing countries (notably China and India) will catch up to something like twice the developed countries' current consumption levels. The result is that, since future people will be so much richer than we are, if we are indifferent between aggregate consumption now and aggregate consumption in the future, we should spend a lot more now to equalise out spending over time. Just as our parents were poorer than us, so we are poorer than people in 2100. That might be the rationale for the current high borrowing rates. As we shall see below, the problem here is that if the analysis is in terms of GDP and if GDP keeps going up, future damage is less important. But GDP does not take account of damage to environmental assets (or any assets) and the externalities are not priced into its calculation: hence the root of the problem is not the discounting per se, but rather GDP itself—to which we return below.

The third main component of the discount rate is the distributional weights to be placed on utility—how much should inequality in utility matter. We can envisage all sorts of distributions at various points between now and the future. We may be in aggregate much better off in total consumption, but some may be much better off than others, and there are likely to be many more people, so GDP per head might not rise at the same rate. In addition, in the intergenerational equity considerations, very poor people *now* might have a claim on the resources *now* which would have been spent to future generations' benefits by mitigating climate change now. Adding distributional weights is therefore inevitably both complex and controversial—and, again, a matter of ethics, rather than economics. It might be reasonable to argue that the cost–benefit calculation should be in two stages: first, without the distributional weights, and then with a range of different distributional weights according to the ethical judgements.

It is also worth noting that the ways in which these distributional weights are added to the cost–benefit calculation reveals a similar gap to that in respect of individual time preference: the actual concerns shown for the poor now are revealed as very low, as shown notably in aid budgets. If considerable distributional concern for the effects of climate change on the future poor is the appropriate ethical judgement on which to calculate the damage in GDP terms, then, again, the gap with actual behaviour might induce caution in striking an international agreement, as expectations may be based on actual rather than ethically preferred behaviour.

Finally, the calculation of the discount rate is complicated by one further consideration. This is the value of utility itself and the preferences of future people. The safest assumption is to assume that future people are like us—they have the same preferences. But even here there may be doubts. In terms of the environment, might not future people value the much-diminished environment they inherit more highly than we do? Much of it will be rare and attract a rarity premium; in addition, richer people might treat the environment as a luxury good.[5] On the other hand, they may not value what they will not observe. We place little utility on species that are already extinct. Since we cannot know what future preferences will be, it is better to focus on the changing relative prices of environmental goods.

These issues about future preferences will have an important impact on climate change through the composition of the spending of the future very rich people. Just what will they spend four times our current income on? Will their preferences be for travel? For holidays? For sports? These activities are all likely to require additional energy, and the use of environmental resources and land. Although there is no shortage of energy (since

[5] On the relative price effects and discounting, see Hoel and Steiner (2006).

the sun rises every day), it is likely that on the path from here to 2100, much more of the earth's fossil-fuel resources will be used to satisfy that extra consumption. Indeed, by just 2030, energy demand is forecast to rise by some 50–60%, and the most rapidly growing fuel is currently coal. Much growth will happen in fossil-fuel years, even if, eventually, technological progress allows low-carbon energy sources to dominate in the last half or even quarter of the century. Taking urgent action now requires reversing a very adverse trend.

These considerations lead to profound questions about the nature and sustainability of economic growth, to which we return below.

The costs of mitigation

The Stern Review's damage costs may be underestimates as economic growth is checked, but the Review's costs of mitigation are also likely to be underestimated. The Stern Review suggests that the costs of mitigation are likely to lie in the range +1 to –3.5%, with a central estimate of 1% to stabilise at 500–550ppm by 2050. This is probably the most widely quoted number from the report. Though it is not trivial, it is nevertheless a tractable number, and to put it in context, it is about the same or less than the typical annual error on GDP growth forecasts. Just as we would not greatly notice if growth turned out to be 1% below the forecast in any one year, the costs of mitigation would not materially affect the population in any noticeable way. (By way of example, Germany's growth rate in the late 1990s and first half of the 2000s, and Japan's since its 1989 stock market crash, have both been more than the 1% below long-term trends—without heralding disaster for the bulk of their populations.)

How could this be? How could the global economy (which is on a trajectory to *increase* emissions by about 50% by 2030) be decarbonised for such a small cost, given that it is overwhelmingly a carbon one? Electricity is generated mainly from fossil fuels, transport depends on oil, and much of industry uses gas. And the current fuel source that is expanding is coal. A transformation from a high- to a low-carbon economy requires the replacement of much of the capital stock.

The Stern Review supports such a low number for two separate reasons: microeconomic and macroeconomic. On the microeconomic side, there is a single chapter (nine), backed up by a single supporting paper, itself based upon 'judgements' about the unit costs of different technologies and fossil-fuel prices, and derivative on a number of (dated) past studies. A table presenting these heroic assumptions is provided (p. 252), and it is easy to raise a host of objections to such obvious simplifications. (Interestingly, no analysis is provided of the forecasting performance of such exercises in the past—even the recent past.) This chapter provides what is, in effect, an engineering cost function and then aggregates up through an input–output model (the MARKAL model) to produce a total cost.

Such exercises suffer from at least four generic problems. The first is that the technologies which will meet the problem are assumed to be known to the modeller—both for carbon-reducing scenarios and the business-as-usual case. It is the latter which is particularly questionable in the judgements in this chapter: fossil-fuel technologies may themselves show considerable technological progress, moving the goalposts away from low-carbon technologies. Whilst this may not be too problematic in the short run, for a problem such as climate change, the possibility of new options or changes to existing technologies is considerable.[6]

The second is that the results are only as good as the assumptions about the costs, which are exogenously determined. The technology costs are based on studies, and are subject to potential selection bias. Put simply, choose a low enough number for each chosen technology and then assume enough technical progress to reduce costs, and the costs of tackling climate change become correspondingly small. The problems of capture of the numbers by vested interests (either directly from the technology advocates or from funded academic research) should not be ignored, and *ex post* comparisons of forecast costs and outcomes turn out to show significant divergences. Indeed, this has been a pervasive feature of the energy sector: advocates of nuclear once claimed that its

---

[6] For example, the Central Electricity Generating Board in the UK looked at a choice between coal and nuclear in its investment appraisals in the 1980s, ignoring combined-cycle gas turbines, which, by 1990, were to become the technology of choice for large-scale generation.

electricity would be ‘too cheap to measure’, while advocates of energy efficiency have repeatedly claimed that a number of very large measures were NPV-positive, yet the take-up has not reflected the claim that it is free.

The third generic problem is the costs that are left out. Engineering cost functions are just that—based on the engineering costs only, and leaving out the wider system and policy costs. In practice, these other costs may be considerable and even exceed the engineering costs. An example illustrates this point: in the UK, the National Audit Office and Ofgem have estimated that some wind generation under the Renewables Obligation has shown actual costs to customers to be several orders of magnitude greater in cost per tonne of carbon abated, compared with other mechanisms, such as the EU ETS (NAO 2005; Ofgem 2007).

The fourth generic problem with the cost estimates is the aggregation. Whereas adding a marginal increment of, say, wind power to an electricity system might add little additional costs to the system as a whole—or indeed to the costs of implementation—once certain thresholds are reached, the effects may be non-marginal. The case of decentralised generation is a critical one here: a large high-voltage system can accommodate some wind, but, beyond a certain penetration level, decentralised networks are required with system-wide costs. Such system-wide costs vary with the technology: for example, the adoption of large-scale nuclear power (as in France) would slot into existing high-voltage systems more easily than decentralised wind or solar.

Although we do not (by default) know what technical progress will turn up, it is nevertheless likely that, taken together, these four problems point to the conclusion that the costs set out in the Stern Review are likely to seriously underestimate the challenge of mitigation. It would be unwise for politicians and policy-makers to rely on the 1% number.

Macroeconomic studies are used by the Stern Review to support the microeconomic results. These studies start from the determinants of national income (consumption plus investment) and then make the obvious point that the switch to low-carbon technologies is a massive investment opportunity. Hence, since investment goes up, growth goes up too, provided that the higher costs of non-carbon technologies are not so great as to reduce consumption by a comparative amount. A series of models are then used to generate this result, and the science and the economics are brought together through integrated assessment models (IAMs).

This result is a very Keynesian one, focusing on the aggregates themselves rather than providing a causal mechanism to get from this investment to economic growth. They do not place much emphasis on what *sort* of investment is taking place, and how this relates to utility. In principle, on this argument, *any* investment increases growth. A sharp escalation in nuclear weapons programmes would be equally valuable from this aggregate growth perspective. But what matters is not whether income measured in this way is higher, but whether people are better off in utility terms. Do they want the resulting output? To answer this question, we need to look more closely at what we mean by economic growth—and, when we do so, a further weakness emerges in the Stern Review's argument that economic growth and addressing climate change are likely to be easily compatible.

Economic growth—what it does and does not mean

The apparent consistency between addressing climate change and economic growth turns on what 'economic growth' means. The conventional measure is GDP—gross domestic product—and it provides a very partial approximation to economic wellbeing. From the climate change perspective, two aspects of the GDP measure are particularly problematic—the lack of any account of the change of asset values and the lack of depreciation; and the absence of an account for market failures, notably externalities and public goods/bads.

GDP is *gross*, not *net*, and hence a country that consumed its capital stock, or increased its debt to finance consumption, would increase its GDP, but not necessarily its welfare. Where the environment in general—or the climate or species in particular—is treated as part of the capital stock then if the GDP growth rates are adjusted for depreciation (to create *net* national product), economic performance can look very different. Depletion of non-renewable resources needs to be compensated for before consumption can be deemed to rise. Indeed, one measure of sustainable economic growth is that level of consumption increase which is net of non-renewable resource depletion. Put simply, there should be an accounting offset for all the natural resources utilised in the economy that cannot be replaced by natural processes. This would include oil, gas and coal, and many environmental assets. Although there may be ambiguity about when a resource shifts from the renewable to the non-renewable category, even a cautious adjustment is likely to radically change the perception of economic performance. For example, the phenomenal economic growth of China would look much more modest if the non-renewable energy requirements were taken into account, even before the desertification, salination of agricultural land, and the wide-scale environmental damage done by major projects such as the Three Gorges Dam are taken into account.

The environment—including the climate—is then an asset which is treated as 'free' to the economy and hence to consumers in conventional GDP accounting. When we use it up, the capital stock reduction is ignored, and the use value is treated as consumption. An increase in consumption increases the GDP (the sum of consumption plus investment, adjusted for external trade). Treated as a stock, the environment yields a flow of services, and some of these are excluded from conventional economic growth calculations in two ways. Pollution is not priced, so we typically do not include the idea that pollution should be paid for. Positive benefits from the environment are also excluded. No account is made for the utility value of open landscapes, wilderness and natural resources, other than those captured through conventional economic activities such as tourism, fishing and the like. These two omissions in traditional growth accounting reinforce each other: because the environmental services are not fully taken into account, we tend to undervalue environmental assets, and because we do not pay for the pollution and other damage caused by modern economies to the stock of environmental assets—such as biodiversity and the climate—we over-exploit them.

It is therefore almost certain that the sort of economic growth that politicians think is consistent with tackling climate change and environmental protection is nothing of the sort: GDP creates the illusion of economic growth, but it is environmentally inefficient, and in particular is associated with a level of consumption which is too high. This neatly ties in with the ideas of sustainability and sustainable development, and the discount point made above. Sustainability is often loosely invoked as a principle, but it does have a rather precise meaning in the context of the climate change debate. The idea is simple—that, as a moral principle, we should ensure that future generations are at least as well off as we are—a sort of Rawlsian principle across the generations (maximising the welfare of the least well-off generation). Environmentalists then tie this idea in with the idea that present consumption is not sustainable, in the sense that it is destroying the environment, and that we should therefore reduce our lifestyles to ones that are less demanding on the environment. Modern capitalism is, on this view, nothing much more than a giant act of selfishness by the current generation at the expense of those to come.

We have established that if economic growth is measured through GDP, and if maximising GDP is the objective then, since the environmental aspects will be insufficiently taken into account, consumption will be inefficiently high. But it does not necessarily follow that *growth*, once GDP had been adapted to take account of its environmental effects, could not then be unsustainable, and for two reasons. First, future generations will have more advanced technologies than we do. So the aggregate supply function will be further out to the right—just as we have the Internet, iPods and so on, which our parents' generation did not, so future generations will have opportunities which we can only begin to imagine. This is what might be called the 'enlightenment principle'—that, through science, things can only get better. It is a major reason for discounting the future, and indeed there is no evidence to suggest that the rate of technological progress is slowing down.

Thus, if we are over-consuming now, future generations may still be able to consume more, given their more advanced technologies. But even with such technologies, they may not in fact be able to enjoy them because they may run out of climate, biodiversity and other environmental assets. This introduces the second sustainability idea—that there may be a limit to how far human and physical capital (man-made capital) can compensate for the loss of natural or environmental capital. Economists tend to be optimistic about this substitution; after all, it is what humans have been doing for thousands of years, fighting back nature and replacing wilderness with towns, cities, roads and houses. ‘Taming nature’—the great human endeavour—has largely been about replacing it with physical capital and exploiting its resources for our benefit.

But assuming a high level of substitution between man-made and environmental capital may not be possible going forward. Climate change (and biodiversity) may prove to be the first global examples where that substitution is limited, although there are many who argue that adaptation can offset many of the effects of global warming—from air conditioning to flood defences.

Now, given the discussion about the costs and benefits of climate change above, suppose that this substitution effect is more limited than many have assumed and more limited than captured in GDP. What then would follow for the Stern Review-type calculations? The answer is a radical one: a measure of sustainable net national product, with an elasticity between man-made and natural capital of (significantly) less than one (incomplete substitutability) would imply that the current level of consumption is too high—that we are consuming beyond our means. The sustainable consumption level would incorporate a depreciation number (we would have to pay for the depreciation we are causing, so the value of our total bundle of man-made and environmental assets would be kept at least constant) and we would pay for the pollution we are causing—in terms of climate change, we would pay for the emissions of greenhouse gases. Then, once the consumption level had been rebased to the sustainable level, growth in this measure would be compatible with protecting the environment (including the climate), and there would then be no incompatibility between this measure of economic growth and tackling problems such as climate change. The resulting growth rate would almost certainly be lower, and as the environmental consequences of global warming and biodiversity loss bite later in the century, it may be close to zero. Indeed, given population growth, it may even be negative. As a result, the discount rate would be likely to be correspondingly lower as time passes, perhaps tending to zero in the second half of the century. Put another way, the problem with the Stern Review is that it has got the wrong measure of economic growth.

The results are likely to have dramatic effects on the design of economic policy and indeed on the way economic performance is portrayed. The challenge now is analogous to that in the run-up to the Second World War, when modern national accounts were first created: we need now to reinvent the accounting framework. Nevertheless, there have been some heroic ballpark attempts.[7] To give some flavour of the magnitude effects, it is far from obvious that China's 10% per annum economic growth (the great leap forward of our generation) represents much by way of net progress at all, but rather a massive consumption of natural resources. It may in practice be a sustainable net growth rate of little more than 1% pa. Just how large the effect is depends on the value of the damage—the social cost of carbon in the climate change case—and these estimates vary enormously (Helm 2005).

In terms of climate change policy, the way in which these factors are incorporated into the economy is to establish a price of carbon—to charge the polluters for the pollution. This price can either be set directly, or the alternative is to accept that planners cannot know enough of the market utility functions and cost functions, and instead to fix the quantity on the basis of scientific evidence, and then let the market reveal the price. Although there are a number of ways of doing this, the Europeans have adopted an emissions trading scheme (the EU ETS) to achieve this, and much political capital has been placed on using this means to achieve the end of limiting climate change. It is to emissions trading as an instrument that we now turn.

III Emissions trading and other instruments

Why market-based instruments are superior to picking winners

Central to any serious attempt to tackle climate change is the establishment of a (long-term) price of carbon, so that the economy integrates the carbon consequences of choices by consumers and business into economic activity. This price helps to close the gap

[7] See Dasgupta (2001) for a comprehensive review of the issues.

between GDP and a measure of sustainable economic activity—at least in respect of climate change.

The price required needs to reflect the social costs of carbon, and this in turn has two components: the marginal damage done by adding a tonne of carbon to the atmosphere; and the depreciation of the environmental assets. The latter point depends on whether the climate, and biodiversity, are treated as renewable or non-renewable resources. If the latter, we need to compensate for the permanent loss of the asset (for example, the natural resources or the extinct species). As discussed above, this might be in terms of man-made capital if this is an adequate substitute. In the case of the climate, whether the current climate is renewable is a rather complex question, since no one climate is necessarily optimal—and climate has always been changing. Nevertheless, we might want to include in the calculation of the social cost of carbon not only the marginal damage caused by adding more to the atmosphere, but also the past damage caused by emissions since the Industrial Revolution. In other words, it is not just the damage done by *adding* more to the stock of carbon in the atmosphere, but also by having too high a stock as a result of past actions. Much of the current debate treats bygones as bygones—it is about limiting *further* damage, not restitution. (A similar approach is taken with respect to biodiversity, although here some limited restitution is now being undertaken.)

In due course, the climate will adjust: the sea will absorb carbon, as will vegetation—indeed, the fossil fuels which have contributed so much to global warming are simply stored carbon from plants millions of years ago. The problem here is, however, one of timing: in geological time, even biodiversity loss can be made up (indeed current biodiversity is in geological terms very high), but we are adapted to the *current* climate and environment. There is not enough human time to adapt to the climate change forecast on business-as-usual so as to create a new optimum, in terms of numbers, agriculture and settlements. We are tied to our special place in geological time, and to doing the best we can for the 9 billion people likely by mid-century. Adaptation will indeed be important, but mitigation towards the climate we are adapted for is the task, and hence the price of carbon needs to incorporate both the marginal damage and the depreciation of the atmospheric stock.

As noted above, there have been many attempts by economists to calculate the social cost of carbon in order to inform the setting of carbon prices. These studies have produced a very wide range of estimates, and this reflects the massive uncertainties in these calculations. The result from a policy perspective is that they have been largely ignored: there is no carbon tax based on an estimate of the social cost of carbon. Rather, policy-makers have taken two approaches: to set carbon taxes on the basis of the political context, or to set quantities instead. In the latter regard, targets are set for emissions reductions, such as the European Commission's recent target of a 20% reduction by 2020—and then the price (or cost) emerges from the attempt to meet the target. The most ambitious attempt to fix quantities in a market context is the EU ETS.

Market-based instruments, such as pollution taxes and tradable permits, have a number of attractive characteristics from an efficiency perspective, when compared with traditional command-and-control mechanisms. They are technology-neutral, and neutral between the supply and demand sides of the market. The informational requirements on policy-makers are much lower, and they are less easy to capture by vested interests through lobbying and related activities. In particular, they avoid all the main difficulties associated with MARKAL-type exercises (noted above), which put the policy-maker in the planning role, and are likely to encourage politicians to pick winners.

The choice between different types of market-based instruments—between taxes (fixing prices) and permits (fixing quantities)—depends upon risk and uncertainty. (If certain—if, for example, the MARKAL-type judgements are right—then it does not matter whether prices or quantities are fixed). If, given that the future is uncertain, it is making a mistake about the damage that matters (a bit more pollution will have major consequences) then permits are better; but if it is the costs we are worried about (if they turn out to be higher than anticipated, the effects are very significant) then we fix prices.[8]

In principle, climate change falls into the price category. The damage function is fairly flat, whereas, at least in the short run, the cost function is likely to be steeper. Yet this is not carried into policy—to taxes rather than permits. The reasons for this are complex,

[8] The classic exposition of this policy choice is Weitzman (1974).

but two stand out: it is easier to get international agreement on quantities rather than to set agreed carbon taxes; and because taxes provide revenues to government, whereas permits (if grandfathered) do not, and hence industry is likely to lobby for permits. In this latter case, the income effect is neutralised, with the focus on the substitution effect. It is therefore not surprising that the EU ETS has developed rather than a European carbon tax (though, at the national levels, many governments also have elements of implicit carbon taxes as well).

The EU ETS

The EU ETS is, as its name implies, a tradable permits system. In order to emit carbon, a specified group of emitters is required to hold permits or permissions. These specify quantities, and once the initial endowment has been determined, companies within the scheme can buy or sell these permits. The core idea is simple: those who can reduce emissions at the lowest costs will sell permits to those who can only do so at higher costs. The fixed quantity of pollution is therefore met at the total lowest cost. The price of the permits represents that minimum cost—the marginal cost of pollution—and it is whatever the market determines. Unlike carbon taxes, the price is the *outcome* of the market process; it is not set by the policy-maker—a fact that politicians have had difficulty recognising.

The simplicity of the core idea is not, however, carried over into the practicalities of designing such a market. On the contrary, the detailed specification of the market and its subsequent regulation turn out to be very complex. The initial decisions are: whom to include (the *domain of the scheme*); whether to hand out permits through grandfathering or to auction them (the *distribution method*); what the time limits of the permits are (the *period*); and how quantities can subsequently be changed (the *revision problem*).

The EU ETS required decisions on all these issues. It was initially set up for a trial period 2005–08, to be carried over into a second phase 2008–12, which is currently being determined.[9] The quantities set were (very) loosely related to the Kyoto targets in national allocation plans (NAPs), and focused on large combustion plants, primarily in the electricity generation sector, and grandfathered, conveying important (and valuable) property rights to the incumbents. New entrants have a reserved quota, but, for reasons largely (but not exclusively) unrelated to the EU ETS, there was little prospect of much entry. Indeed, the permits themselves are strategic assets in the oligopolistic context of generation markets.

The first period was very much a trial; it was set for only three years, and without indicating how permits would be let in the second period—or, indeed, what would happen in 2012, after the end of the second period. As a result, the EU ETS could only provide a short-term price of carbon in the context where, for investment and R&D reasons, a long-term price was required. During the first period, companies needed to consider whether their actual emissions at the end of the period would be the basis for permits in the next period, because, if this were to be the case, reducing emissions in the third and last year might not be profit-maximising.

When the EU ETS was first set up, it was expected that prices would be positive, but not high (perhaps around €10/tonne). The price depended on the expected balance of the supply and demand for permits, and this in turn relied upon reported information. The experience has been chastening: after a gradual start with prices moving up towards €20/tonne (above initial expectations), information disclosures from a number of governments confounded expectations, and prices then collapsed to a negligible positive price. The results were disappointing and led to, first, claims of windfall profits for the incumbents, as costs were passed through to customers in higher prices (leading some politicians to regard the scheme as little more than a 'racket'), and then, second, to claims that it would make a very limited contribution.

Although the first period has been volatile and provided little by way of incentives in terms of the wider climate change problem, it can nevertheless be said in defence of the

---

[9] See House of Commons Environmental Audit Committee (2007a) for a detailed review of the lessons to be learnt from the EU ETS to date.

EU ETS that it is only a trial period, and that having thrown up a host of teething problems, the scheme can now be built upon to provide a major European and eventually global mechanism for tackling climate change.

To provide this function, a number of additional problems will need to be tackled. The first is the translation of a short-term scheme into a long-term one, to provide the basis for a long-term price of carbon. Now that the EU has adopted a 2020 target for a 20% emissions reduction, the challenge is to design an EU ETS phase three which maps onto the overall target from 2012 to 2020. How much reliance the EU is prepared to place on the market and the long-term price of carbon is a political matter: it depends on how much of the overall 20% target is to be met through regulation and picking winning technologies. In particular, the EU has additional policies for energy efficiency and renewables, with 20% targets for each of these for the same period. Should these be achieved, the EU ETS may turn out to be a residual policy, although in the process it might reduce the costs of meeting these other targets, depending on how these other policies are financed.

But even 2020 is not far enough ahead to comprise a long-term price of carbon consistent with the investment horizon. Very little by way of new nuclear could be operational by 2020 (were it to be an option), much wind development is beyond that date, as is all carbon sequestration and storage, and most R&D. Since it is new technologies, perhaps augmented by nuclear, and energy efficiency which will probably carry the burden of addressing climate change, a 2020 date for phase three would be of limited value unless a guide were given for the post-2020 framework so that a future price could emerge.

These comments assume that the quantity will be given for the periods, and not interfered with *ex post* during the period. But here there is a further complexity: some emissions reductions might be made outside the EU, through the Clean Development Mechanism (CDM) and Joint Implementation (JI), as provided under Kyoto. Although these contributions are limited through to 2012,[10] thereafter there will be an obvious temptation to buy in emissions reductions from outside the scheme to keep the price down for

[10] As agreed in the Marrakesh Accords, they can only be 'supplementing'.

competitiveness reasons. To the extent that participants perceive that politicians might find this route attractive—both to demonstrate that they have in fact met the target, and to protect jobs and industry—this will undermine confidence in the fixed quantities, and depress the price expectations.

That expectation is compounded by the desirability of generalising the scheme to provide the basis of international action on climate change. By including more countries in the scheme, the portfolio of options is widened and the total cost falls. In particular, the scheme allows financial flows to China, India and other developing countries to pay them not to industrialise in such a polluting way. This fiscal transfer characteristic may in due course turn out to be more important than the standard efficiency arguments for a permits regime. Given the scale of the projected emissions increases in China and India, there can be no credible answer to the problem of climate change without mitigating the large coal-burn projected through to 2030. Put simply, we have to find a way to pay the Chinese (and others) to industrialise in a non-carbon-intensive way. The EU ETS has some potential to provide such a mechanism.

Other measures

The EU ETS, despite the current difficulties, is then pregnant with the prospect of developing into an international scheme. But this very possibility has the corollary that it is likely to be slow to develop, and be very vulnerable to the political decisions that will frame the post-Kyoto agreements. It will also require international institutions building, as discussed below. It is highly unlikely that EU ETS phase three will be decided in detail much before 2010 or 2011, and uncertainty about the CDM-type mechanisms will weigh on price expectations.

In these circumstances, the EU ETS cannot provide anything other than *one* policy instrument among many, and other measures will be needed too. These fall into three broad categories: additional market-based mechanisms alongside the EU ETS; measures to address R&D incentives; and energy efficiency policies.

Additional market-based instruments focus on carbon taxes: the direct setting of the carbon price. As noted above, the case for a carbon tax is, in principle, a strong one: it is the one way of ensuring a long-term price of carbon, and it ensures that the cost is known, at the expense of the total emissions being a variable. And a carbon tax has flexibility: it can be varied to meet a target as the responses of the market are revealed.

Why then has the EU ETS dominated? The answer lies in part with the easy translation of quantities in international agreements, such as Kyoto, into traded quantities (though carbon taxes can be varied to meet the targets). But the main reason is the income effect and the use of the revenues. Where permits are grandfathered, the income effect remains with the polluters. Carbon taxes, by contrast, typically accrue to governments, and hypothecation of revenue is neither typical, nor necessarily credible.

In practice, many governments have implicit carbon taxes, through the duties on petrol and other fuels, and some have explicit variants too. There is, in consequence, overlap between setting the price through carbon taxes and, at the same time, fixing the quantity through emissions trading schemes. These can in theory be combined, though current examples tend to be designed without regard to the interaction. If, as noted above, a problem with the EU ETS is that the time period is too short then a minimum price can be set through a carbon tax in addition to the price of permits, making the total price of carbon the sum of the two. This approach has the further advantage of dealing with price volatility in permits markets for future investments. It is also possible to design in a ceiling to a permits system, by creating a buy-out price, although when the ceiling price bites, the quantity itself rises, so that the quantity is no longer fixed.

R&D aspects of climate change policy arise not only from the longer time horizon—requiring a long-term price of carbon—but from the other market failures generic to all R&D. These are the public goods and sunk cost aspects. Once discovered, the marginal cost of a new technology is zero, but since R&D costs are not easily recoverable on exit, they are of greater risk than fixed costs in investment decisions. These problems have well-known policy solutions: patents and subsidies. Public provision, through universities and public research centres, provides another route.

Policies to promote energy efficiency have formed a core part of the response to climate change. Such policies are argued to be 'no regret', in that they make sense even if climate change turns out to be less serious, and they tend also to have social pay-offs. Reducing demand also turns out to be one of the few options in the short run (given that the capital stock is fixed), while waiting for investments in low carbon on the supply side, and for R&D to deliver. Since the problem is distributed throughout the housing and other buildings sector, and since the contractual relationships between the participants are often complex and transaction costs may be high, typically command-and-control regulation has been the policy instrument of choice.

In summary, climate change policy requires a long-term price of carbon. This can either be set directly through a carbon tax, or indirectly by fixing the quantity of carbon. The EU ETS has revealed many of the problems in designing permits systems, but nevertheless provides the potential to achieve reductions in emissions in a fairly efficient manner, and, perhaps more importantly, is pregnant with the possibility of facilitating fiscal transfers to developing countries. These market-based mechanisms are necessary, but not sufficient, and in practice a number of supporting, more conventional, interventions will also be needed for R&D and energy efficiency. All of these measures need an institutional structure for their implementation, and it is to this we now turn.

IV Institutions

Why institutions matter: the credibility problem

Given targets, and having chosen the instruments, the next step in designing carbon policy is to consider the institutional context. Institutions matter because they provide the basis for credibility. If the nation states are to agree a new framework for addressing climate change post-Kyoto then targets need to be *credible*. Countries need to know that others will adhere to the agreement, will make the reductions they commit themselves to, that the performance data is robust and independently monitored, and that penalties and enforcement mechanisms are in place.

The credibility question has a number of dimensions. At one level, the issues are about trust and good governance. Corruption is a regrettable feature of much international action: in the climate change case, the scale of the transfers from developed to developing countries is likely to be large; and, at the specific project level, the gains to specific companies are also potentially significant. Given that the baseline against which to measure carbon savings is a matter for debate and analysis, rather than a simple observable 'fact', not only are there powerful incentives for corruption, but there is also ample potential scope to exercise it. The differences of objectives between the global public good and the interests of individual countries in free-riding form one dimension, but the differences between private profit and public interest in trading and other project-based policy instruments represents a second difference of objectives. These can be exploited through asymmetrical information: the principals pursuing the global good are much less informed than the recipients of the financial flows. This is a classic multiple principal–agent problem (see Dal Bó, 2006).

A second dimension of credibility is the *time inconsistency problem*: while governments queue up to make ever bolder commitments to targets for carbon reductions, the private sector will recognise that there is always the opportunity for governments to renege on these commitments, either simply for political reasons, or because the policy instruments turn out not to be necessary to achieve them.[11] The latter is a classic expectations game: if industry believes *ex ante* that the targets will be met then it believes that the instruments will be set at whatever level is necessary to achieve them, and therefore they invest to achieve them. Once the investments are committed, however, the instrument may not need to be set *ex post* at the expected level. Government then reneges, and industry can see through this incentive problem *ex ante*. Hence the government needs to commit *ex ante*, in a fashion which industry believes will not be reneged on.

---

[11] See Helm, Hepburn and Mash (2003) for an application of the time inconsistency to climate change policy design.

The monetary policy analogy

There have been a number of attempts to achieve this credibility through institutional design. The most notable in recent decades has been in monetary policy, where this problem classically arises. Independent central banks in the US, the EU and the UK have been set up with explicit legal frameworks, although, interestingly in the EU case, the supporting stability pact collapsed.

These recent new institutions fit into a broader pattern: after the Second World War, the IMF and World Bank provided a framework within which the international monetary system—and particular exchange rates—could be managed. The US led this process, giving credibility to the Breton Woods fixed exchange rate system.

The monetary policy analogy is, however, far from complete: in monetary policy there are a limited number of instruments, and, in the case of central banks, interest rate setting has been delegated. In the climate change example, the delegation of instrument setting is much more complex and controversial, and in practice instruments such as carbon taxes and emissions trading are likely to remain within more direct government control.

Nevertheless, the search for a credible institutional structure does point towards new international bodies, and the choice is likely to be between stand-alone new climate change international agencies and the UN.

The role of the United Nations

So far, this institutional context has been provided by the UN. The 1992 Framework Convention on Climate Change is a UN-brokered deal, and the Kyoto Protocol comes under this umbrella. The COP and MOP meetings that follow through on Kyoto have this context too. It is likely that any new protocol or treaty will have this UN context too. There is no other international agency that could conduct such negotiations: indeed, for the UN not to play the central role in negotiations would be to seriously downgrade its status.

But the UN framework does not necessarily mean that the *implementation* of a new climate change treaty needs to be conducted by the UN. The post-Second World War example of institutional building indicates that specific areas of policy delivery can be carried out through separate, but connected, institutions—particularly where specific knowledge and expertise are required. The case of monetary policy is again instructive here: it is not the UN, but rather the IMF and the World Bank which provide the institutional framework for delivery of monetary stability and development funding.

The role of institutions in enabling markets to function: what effective institutions need to achieve

Given that any new international agreement to limit carbon emissions will involve carbon trading and substantial fiscal transfers from developed to developing countries, the framework for this market will need to be created and regulated. Markets in carbon, like any significant markets, do not arise spontaneously. Markets are public goods, comprising a complex set of rules and processes, and the trades and transfers that go through them are forms of contract. The transactions costs of markets are minimised where these rules are credible, understood and easily enforced: then trust enables these transactions without the need to resort to much formal enforcement.

The converse applies too: where rules are weakly defined, where their enforcement is in doubt and where cheating is rife, markets tend to be inefficient, with correspondingly high transaction costs. In the case of a new global agreement on carbon emissions reduction, the experience of the EU ETS gives an insight into what some of the issues might be. The difference between credible targets and aspirations is very considerable: in the former case, these can be endogenised in private and public decisions, and if it is widely believed that governments will do whatever is necessary to achieve them then the private sector is mobilised to assume these constraints will bind on them, act accordingly, and thereby bring about the result. In many cases, important complementarities exist: for example, transmission grids, road and airport investment plans have significant cost implications for the timing of new electricity generation investments, and volumes of car and air travel respectively. A credible emissions reduction target may, for example, require a switch to public transport, but if the public transport investment is not made in a timely way, the switch cannot take place.

Credibility in climate change agreements and the instruments, such as emissions trading, to meet them requires that the targets are clear and transparent, that emissions are measured and independently verified, and that there are punishments and enforcement mechanisms for deviations from the targets. Once the international context is recognised, the question then arises as to how this can be done when jurisdictions vary. The conventional answer is through treaties, protocols and so on—the day-to-day stuff of international relations and diplomacy. But it is also immediately apparent that a new climate change agreement would require very intrusive powers to be held by a supranational body. It would need to be independent of particular powerful nations and be designed to minimise corruption.

In the former regard, it is obvious that the US's influence will be an important factor in the attitudes of other major polluters, notably China and India. Whereas after the Second World War, the US had credibility and international standing, its position has been compromised by recent US foreign policy, especially in the Middle East. It is much more likely that Europe can play this role, especially as it has committed to unilateral reductions in emissions, whereas the US has not.

The corruption and competence point is most relevant to the fiscal transfers that will inevitably be required. Here the UN has not covered itself in glory in recent years, with the Oil-for-Food Programme in Iraq being an obvious example. As a result, it is unlikely that the US would be willing to channel financial flows to pay for carbon emissions through the UN, and this in practice is a sufficient objection to render this avenue implausible. Leaving the UN to decide what constitutes a carbon reduction, to adjudicate and authenticate CDM and JI projects and to monitor more general compliance is probably too demanding, and the very scope for corruption in each of these components invites its exercise. Therefore the need arises to find some other institutional location, which can oversee both international carbon trading and fiscal transfers.

The case for a new international body

In considering how to design a new international body, the obvious starting point is to look at existing examples. Fortunately there are many to choose from, but perhaps the two most interesting areas are: the international monetary institutions (since they oversee fiscal transfers) and the WTO (since it regulates markets through a rules-based approach). The monetary authorities are overwhelmingly US-based, and not simply for the obvious reason that the US was the only major player at the outset. These institutions need US support because the monies are often American, and in international monetary matters, the US is some 25% of the world economy.

In the climate change case, the source of monies and the dominant players are somewhat different. The US will of course have an important role to play, but so too will Europe. And on the polluting side, China is in the process of surpassing US emissions now, and over the next few decades it will dominate, with India catching up. These factors together point to a less US-centric model.

The WTO example is perhaps more immediately pertinent, and indeed there is a case for considering the WTO as a possible candidate to take on the climate change market regulatory role. However, the climate change issues do require a specialist set of skills and particular knowledge, and the scale and scope of the problem are such that it probably merits a stand-alone body.

V Conclusions

There has been a distinct shift in the public debate on climate change. It is no longer doubted that climate change is occurring and that human activities are an important cause. The debate is now about how to tackle the problem, and in particular how fast to try to mitigate emissions. It has been substantially heightened by the publication of the Stern Report, which claims that the damage could amount to between 5% and 20% GDP, and that mitigation now to stabilise emissions by mid-century at around 500–550ppm would cost around 1% GDP (within a range of +1% to –3.5%). Politicians around the world have latched onto this claim, and its appeal goes well beyond its analytical and empirical basis. If it only costs 1% GDP then the public need not be challenged by major life-style and standard of living changes. Stern gives the politicians the happy combination of a relatively low level of electoral pain and the comfort that economic growth (as defined by GDP) and tackling climate change are not in conflict.

The uncertainties around any such calculations are enormous: predicting costs, damages and technologies a hundred years or more into the future is a heroic exercise, and the history of the twentieth century suggests that any such calculations are at best brave intellectual exercises. Whilst the Stern Report is full of caveats and caution in its detail, the headline costs and benefits and its conclusions are not: they are bold and have led many politicians to believe them without understanding the underlying uncertainties.

In this paper, it has been argued that there are good reasons to question all of the main components of the Stern Report. In particular, two areas of concern have been highlighted: the claim that the costs will be as low as 1%; and the focus on GDP. There are very good reasons for expecting costs to be higher, perhaps much higher, not only because the costs for the technologies which form the Stern Review 'judgements' can be challenged, but also because many of the policy costs ignored.

The focus on GDP goes to the heart of environmental problems, of which climate change is but one example. GDP is the wrong way to think about environmental problems, precisely because it leaves out all the important environmental bits—the value of resources, resource depletion and the costs of pollution. This is not some arcane accounting point: the difference between Stern and much of the wider environmentalist community is that the latter question the sustainability of GDP growth, pointing out the over-consumption of a whole range of environmental assets, and take a much more cautious view about how far the loss of environmental assets (such as biodiversity and the climate) can be substituted for by man-made capital, and ultimately whether human activities can flourish without much of biodiversity and the natural environment.

The reason this is so important is that any assumption that conventional GDP will march on upwards throughout this century and beyond at around 2% per annum is bound to reduce our concern about the importance of the impact of climate change on future generations. They will, on a conventional accounting basis, be so much better off. This paper has suggested that this assumption is one of the most exposed to challenge in the Stern Review.

If, as is argued here, the damage to properly accounted economic growth is likely to be (much) higher than the Stern Review suggests, and if the costs of mitigation are likely to be higher too, the conclusion that follows is that current consumption levels are too high, and that the task of addressing climate change may require more radical action. Economic growth and climate change may not be such easy bedfellows, and politicians may need to confront a much more electorally challenging agenda.

In doing so, the premium on efficiency and cost minimisation will be correspondingly even more important. For a number of reasons, the EU ETS provides a basis for taking forward carbon trading—and thereby seeking out the lowest-cost emissions reductions—and for making the very substantial fiscal transfers that will be required from developed to developing countries. Such a grossed-up international trading scheme will need careful regulation, and the credibility of the arrangements pose significant questions for existing institutions. It is unlikely that the detail of such international arrangements can be left to the UN, and serious consideration should be given to designing a new global climate change organisation, building on the experience of the World Bank in respect of fiscal transfers and the finance of emission reductions projects on the one hand, and the WTO's expertise on the other, in respect of regulating markets and rule enforcement.

References

Dal Bó, E. (2006), 'Regulatory Capture: A Review', *Oxford Review of Economic Policy*, **22**, 203–25.

Dasgupta, P. (2001), *Human Well-being and the Natural Environment*, Oxford: Oxford University Press.

Helm, D., Hepburn, C., and Mash, R. (2003), 'Credible Carbon Policy', *Oxford Review of Economic Policy*, **19**:3, 438–50.

Helm, D.R. (ed) (2005), *Climate-change Policies*, Oxford: Oxford University Press.

Hoel, M. and T. Sterner (2006), **'**Discounting and relative prices in assessing future environmental damages', *Working papers in economics*/Department of Economics, No. 1999, Göteborg University.

House of Commons Environmental Audit Committee (2007a), 'The EU Emission Trading Scheme: Lessons for the Future', HC 70, London, March 1st.

House of Commons Environmental Audit Committee (2007b), 'Pre-Budget 2006 and Stern Review', HC 227, London, March 17th.

NAO (2005), 'Renewable Energy. Report by the Comptroller and Auditor General', HC 210 Sessions 2004–05, National Audit Office, Department of Trade and Industry, February 11th, London: TSO.

Ofgem (2007), 'Reform of the Renewables Obligation: Ofgem's response', January, Ofgem: London.

Schelling, T.C. (2006), 'An Astonishing Sixty Years: The Legacy of Hiroshima', *American Economic Review*, **96**:4, 929–37.

Stern, N. (2006), *The Economics of Climate Change: the Stern Review*, Cambridge: Cambridge University Press.

UN (2007), 'World Population Prospects: the 2006 Revision', Population Division, Department of Economics and Social Affairs, New York: United Nations.

Weitzman, M.L. (1974), 'Prices vs Quantities', *Review of Economic Studies*, **41**, 477–91.

Weitzman, M.L. (2007), 'The Stern Review of the Economics of Climate Change', book review for *Journal of Economic Literature*, forthcoming.