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Climate-change policy: why has so little been achieved?

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Abstract While the scientific evidence for climate change grows, the policy responses have so far had little or no impact on the build-up of emissions. Current trends in emissions are adverse. The paper considers why the disconnect between science and policy exists and, in particular, why the Kyoto Protocol has achieved so little. Some contributing factors considered are: the focus on carbon production rather than consumption in the architecture of Kyoto; the flaws in the analysis presented in the Stern Report (notably on the impacts of climate change on economic growth, on the costs of mitigation, and on discounting); and the political economy of the choice of policy instruments, the politics of the rents that arise, and the technology bias. The challenges facing the Copenhagen conference are noted, and it is concluded that, with a recasting of the economics of climate change, the prospects for closing the gap between the science and policy are grim.

Key words: climate change, Kyoto, Stern Report, energy policy, climate change policy, climate change science

JEL classification: Q48

I. Introduction: the scale of the problem

Few now doubt that climate change is occurring, and that it is human activity that is a prime cause. The science of the greenhouse effect has been well known for a century, but the complexity of the climate makes any precise prediction of the relationship between specific concentrations of particular greenhouse gases and changes in global temperatures extremely difficult. We are condemned to live with the uncertainty.

But that uncertainty is not unbounded, and we have already had significant temperature changes and, in the Arctic, fairly rapid climate change. The prospect of an ice-free North Pole in summer is not far away, and the Arctic Ocean is opening up for shipping through the Northeast and Northwest Passages.

While the science of the climate and the empirical evidence mount up, the policy responses have so far had little or no impact on the build-up of emissions. A concentration of 400

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parts per million (ppm) of carbon dioxide[1] equivalent (CO_2e) will soon be reached (the pre-Industrial Revolution level was around 273 ppm). A doubling of concentrations is all but inevitable, and 750 ppm by the end of the century is predicted on a business-as-usual scenario.

Business-as-usual is, indeed, what is most likely for some time to come. Emissions are not being stabilized, but rather are on a path of rapid increase. Fossil-fuel consumption is going up, there is plenty left to exploit, and the dirtiest fossil fuel—coal—is expanding its share. Carbon emissions are predicted to rise by around 50 per cent by 2030 (IEA, 2007), on the back of a similar rise in energy demand. There is no global decoupling of the energy ratio. Indeed, global warming is making new sources of oil and gas easier to exploit—notably, in the northern regions (Canada and Russia, in particular) and in the Arctic seas as the ice retreats. There are also abundant (highly polluting) tar sands to exploit (in Canada, again), and most oil reservoirs are abandoned after half or less of the oil has been extracted. More worrying from a climate-change perspective, there is enough coal to last well beyond this century—and, given recent oil price increases and the wide dispersal of coal reserves, it is not surprising that coal is increasingly the fuel of choice for electricity generation. China, for example, plans some 1,000GW of new coal electricity generation by 2030 (IEA, 2007). There are, in short, far more fossil-fuel reserves than the capacity of the atmosphere to absorb them, and little evidence that they will be left in the ground in at least the short to medium term.

The global response so far has been meagre. The United Nations Framework on Climate Change Convention (UN FCCC), agreed in 1992, built upon the Intergovernmental Panel on Climate Change (IPPC) which had been established in 1988—an unprecedented international scientific collaboration.[2] It also kicked off the process which culminated in the Kyoto Protocol (UN FCCC, 1998), built around the fixing of national greenhouse-gas emissions-reduction targets for some developed countries. But Kyoto has so far delivered little: it has not made *any* appreciable difference to climate change—nor would it have done, had it been fully implemented and the targets delivered. The framework does not include binding caps on the USA, and provides no targets for India and China. Indeed, it only became operational because the Europeans bargained World Trade Organization (WTO) membership and other concessions with Russia.

In its defence, it is claimed that the Kyoto agreement provides a tentative step towards a post-2012 framework and, within Europe, it enabled the European Union Emissions Trading Scheme (EU ETS) to get under way as a prototype for a global emissions-trading regime. This defence rests, however, on the assumption that Kyoto is, in fact, a well-designed approach and that EU ETS could not have been started without Kyoto. Neither, arguably, turns out to be correct.[3]

So why is there such a disconnect between the science and the evidence on the one hand, and the policy response on the other? The disconnect is all the more surprising because it has been widely claimed—notably in the immensely influential Stern Report (Stern, 2007)[4]—that the costs of action now are comparatively small; smaller even than the typical annual differences between forecast and actual GDP. A 1 per cent GDP cost to stabilize emissions is perhaps less, even, than the current impacts of the credit crunch. Indeed, some claim that

[1] Throughout carbon dioxide (CO_2) is used as a proxy for greenhouse gases.

[2] The IPCC has produced a series of reports (IPPC, 1995, 2001, 2007), and reactions, notably House of Lords (2005), but as an exercise in *international* collaboration, it is unprecedented.

[3] Indeed, the UK set up its own emissions-trading scheme to address its domestic 2010 carbon target. See Marshall Task Force (1998).

[4] The references throughout are to the 2007 version of the Stern Report.

mitigating climate change is actually GDP-positive, and such a possibility is included in the Stern Report ranges.

One possible answer is that the disconnect is a function of education, information dissemination, and lags in the political process. According to this view, it is not at all surprising that it has taken a couple of decades for the evidence to be gathered and analysed, and for politicians to absorb and lead the public towards new policy initiatives, but now action will follow quickly, as indeed witnessed by the recent Bali Conference, the new EU climate-change package announced in January 2008, and moves in the USA in the run-up to the 2008 presidential election. A second possibility is that the Stern Report analysis is flawed, that the costs are much higher than estimated, and that the political economy of climate-change policy is much more constraining. On this view, the easy compatibility between economic growth and climate change, which lies at the heart of the Stern Report, is an illusion. And, given higher costs and serious threats to economic growth, the fact that politicians have founded their arguments to the public on the basis of low costs has been counterproductive. This paper explores this second view, for, if it is correct, the necessary task of education and information needs to be recast.

The climate-change policy optimists work not only on the assumption that the costs of mitigation are low, but also that there will be a global agreement based upon the Kyoto principles after 2012, with *binding*, *tight*, and *credible* carbon caps. Again there is another more pessimistic view: that the prisoner's dilemma will make a credible top-down global carbon cartel very difficult to achieve, and that any agreement will require very significant fiscal transfers from Europe and the USA to China, India, and other developing countries. Some countries—notably in the Arctic regions—may actually experience some gains from climate change, and hence also require considerable financial inducements to join in.

This paper considers why the disconnect between science and policy exists. In section II, the serious adverse trends are noted, especially in the energy and transport sectors. Section III explains why Kyoto has achieved so little. Section IV turns to the key concepts. Kyoto is based upon carbon production, not consumption, which conveniently places the burden of emissions reduction on those countries which *produce* energy-intensive goods, rather than those which *consume* them. The relationship between carbon consumption, sustainability, and economic growth is reconsidered. Section V considers the Stern Report, its economic framework, and, in particular, its estimates of the damage and mitigation costs. It is argued that both may be significantly underestimated. Section VI considers policy options and policy costs, and section VII looks forward to the negotiations at the forthcoming Copenhagen Conference and beyond. Section VIII concludes.

II. The context: adverse trends

Current climate-change policy has been designed on the basis of the current economic structures and how marginal emissions reductions can be made from this starting point. It begins with where we are and then aims to reduce emissions towards future targets—notably, in 2020 and 2050. These, in turn, are based upon an overarching global ambition to halt the rise of emissions to around 450–550 ppm CO_2e, a concentration that is roughly linked to limiting global warming to around 2° centigrade. There is no convincing analysis to suggest that this is an 'optimal' target, but rather an assumption that it could, in principle, be achieved and that two degrees may be a containable warming, which will not trigger rapid subsequent change.

These global targets are being translated into a plethora of sub-targets set at the European level, at the state level in the USA, and adopted by a number of localities and municipalities. It is the approach embedded in the Kyoto framework, and in the European ambitions for the post-Kyoto framework, and was the one at the centre of debates at the Bali Summit in 2007. But are these various targets enough? And is there any evidence that they are likely to be realized?

Unfortunately, global trends in the causes and levels of emissions—population growth, energy demand, and transport—suggest otherwise. The starting point is population and human consumption. Climate change has accompanied industrialization and a rapid increase in population, both of which have been facilitated by the harnessing of fossil fuels. The world population tripled in the twentieth century from 2 to 6 billion. Between now and 2050, it is projected to increase from 6 to 9 billion—to add more extra people than the entire world population in 1950. These additional people will be overwhelmingly concentrated in China, India, and Africa—each with a total population of roughly 2 billion by 2050. The first two are expected to continue their rapid economic growth, with China perhaps matching current US consumption levels by 2050. China and India will in the process probably add around 1 billion cars, and will require the associated energy to sustain their much higher levels of consumption. Africa may be a different story.[5]

Energy-demand patterns do not simply map on to population-growth projections, though the correlation is closest for China and India. The IEA (2007) reference scenarios are helpful in this regard, less for their predictive precision than for their value in setting out the parameters of the trends and policy contexts. Furthermore, the IEA focuses on 2030, which is midway to the 2050 target—and this is the period within which technological progress will have limited impacts on the capital stocks. It is the timeframe within which scientists say urgent action must be taken to avoid irreparable damage.

The IEA predicts a 50 per cent increase in global energy demand by 2030—i.e. in just over two decades' time—with China and India accounting for around 45 per cent of that increase. These enormous increases map almost exactly on to projected CO_2 increases. Both energy demand and carbon emissions are rising faster than population growth. The IEA constructs an 'alternative energy scenario' in which all the current policies that governments around the world have devised to combat climate change are implemented and even then CO_2 emissions still rise by 25 per cent by 2030. In other words, we are heading substantially—and rapidly—in the wrong direction.

There is, in fact, very little reason to place much reliance on the alternative scenario. Much of the capital stock which will be in use in 2030 in the energy sector is already in place. Asset lives in the electricity industry are typically around 30 years or above—indeed, some coal generation in Europe and the USA is up to 60 years old. And in the replacement cycle for the energy capital stock, the relevant decisions to change the marginal carbon intensity for 2030 (and even to a considerable extent for 2050) are likely to be made in the next decade, and these reflect a substantial bias towards coal- and gas-fired generation. Germany and the UK are both, for example, considering new coal-fired power stations. New nuclear investments will have a marginal impact when set against nuclear plant closures up to 2030, and there is little prospect over this time horizon of carbon sequestration and storage making much impact.[6]

[5] See the paper by Paul Collier, Gordon Conway, and Tony Venables in this issue (Collier *et al*., 2008).

[6] Nuclear power stations have a typical lead time of around 10 years. Given that existing nuclear plants are reaching the end of their lives in a number of European countries (notably Germany and the UK), plant closures and output reductions are likely to exceed new plants coming into the systems in Europe until at least the mid- to late 2020s.

Indeed, in the energy sector, the key global shift in the fuel mix is adverse—towards coal. With the increase in oil (and therefore gas) prices since 2000, and with growing concerns about security of supply as oil and gas production is increasingly concentrated in the hands of autocratic governments, the share of coal projected in the IEA reference scenario in total energy demand rises from 25 to 28 per cent. Most of this is in China and India—with China (currently with nearly 80 per cent coal-fired generation) adding about two large coal power stations per week at present, and projected to add perhaps 1,000 GW of new coal plant by 2030. (To put this into perspective, the total capacity of electricity generation in the UK (all fuels) is around 80 GW.) China's generation by 2030 will be equivalent to current levels of the USA and Europe combined.

The position on transport is not encouraging either. While it is true that some of the capital stock turns over a bit faster, and there are significant fuel economies that can be made (and some scope for hybrid and electric cars), these trends are swamped by the increased demand for cars. Chamon *et al*. (2008) suggest that car ownership remains low up to a *per capita* annual income of about US$5,000, and then takes off rapidly above that level. They estimate that 'the number of cars worldwide will increase by 2.3 billion between 2005 and 2050, and that the number of cars in emerging and developing countries will increase by 1.9 billion'.[7] The trends in developed countries are adverse, too. In the UK, new car registration increased 13 per cent between 1996 and 2006, while air passenger numbers increased by 54 m between 2001 and 2006 (Office of National Statistics, 2008).

The importance of the embedding of carbon-intensive production capacity in the capital stock in China and elsewhere is not just in respect of power stations and cars. It applies to energy transmission and distribution systems, which may be designed for large- or small-scale technologies, and it applies, too, to the transport sector. New airport capacity causes demand to increase for aviation. China has recently been reported to be increasing its regional airports capacity in the order of some 97 new regional airports by 2020,[8] and it is notable across Europe that governments are encouraging new runway and terminal capacity.[9] The expansion of road networks encourages car use, too. Once these infrastructures are built, the marginal costs are significantly below the average costs, and marginal cost pricing leads to greater utilization. A carbon economy embeds fossil fuels into the fabric of its infrastructure.

The implication of these broad (and often crude) IEA scenarios is that the rapid economic growth (and associated population increases) of China and India is at the core of any serious attempt to decarbonize the world economy. Whether China builds 1,000 GW of coal-fired electricity generation and whether it adds half a billion cars with conventional engines is of an order of magnitude more important to climate change than virtually any other trend. The corollary is obvious, too: climate-change policies matter largely insofar as they address these global trends, and local policies such as wind generation in remote locations are relevant largely insofar as they have an impact on behaviour in these developing economies. It does not, of course, follow that developed countries should not reduce their own emissions—indeed,

[7] IMF (2008, p. 10, box 4.1). The current number is around 0.5 billion.

[8] General Administration of Civil Aviation, China, January 2008. Chinese passenger air traffic grew 16 per cent in 2007, and is projected to increase by 11.4 per cent p.a. until 2020. Freight is projected to grow at 14 per cent p.a. over the same period.

[9] In the UK, major airport expansions are planned for Heathrow and Stansted. The 2003 White Paper, 'The Future of Aviation' reports that UK air travel has increased fivefold in the last 30 years (Department for Transport, 2003). Half the population now flies at least once a year. Unconstrained (by capacity) forecasts are for demand to *double* or *triple* by 2030.

on the contrary, as we will see, much of this growth in emissions in countries such as China is driven by developed countries' demand. The point here is that, so far, climate-change policies have had virtually no effect on these trends.

We return below to the China question and who is responsible for this growth of emissions and who should pay to decarbonize the Chinese economy. But before we do this, we need to consider whether this projected increase in China's emissions is really likely to materialize (and, to a lesser extent, the impacts of other rapidly developing countries). Three countervailing factors are relevant here. The first, and probably the most important, is whether China's economic growth—and therefore the derived demand for carbon—can be sustained. Are there any reasons why the projections of GDP growth of some 10 per cent per annum for the foreseeable future may turn out not to be delivered?

The answer is complex and beyond the scope of this paper to scrutinize in any detail. However, it is worth noting the possible causes of a much lower growth path. The first is world demand. China is an export-oriented economy (exports comprise some 45 per cent of its GDP). Like Japan in the 1970s and 1980s, it exports significantly to the USA, and then, in effect, lends the money to the USA to pay for these goods (with roughly a 50 per cent domestic savings ratio). A serious recession in the USA would represent a setback for the Chinese economy (as it did for the Japanese at the end of the 1980s).

A significant adjustment in exchange rates might also reduce the demand for Chinese exports—and, indeed, this is already under way. But there would be offsetting factors. Domestic consumption might absorb some of the demand shock, and then there are alternative markets in Europe and elsewhere. China's competitive advantages—notably cheap land and cheap labour—may erode somewhat, and this is already reflected in rising inflation. Yet they are likely to remain powerful engines for growth—especially when the doubling of its population to 2050 is taken into account.

A second possibility is that the oil-price shock may disproportionately affect China since it is energy-intensive. So far, however, the increase in oil prices from around $10 a barrel in 1999 to over $100 in 2008 appears to have had little impact. Furthermore, the oil-price effect is inversely related to the effect of a US recession—since the latter might weaken oil demand and hence lead to lower prices (and, indeed, the fact that oil is priced in dollars exaggerates the scale of the price increase). To an extent, too, China has some strategic options in responding to higher oil prices, some of which are already being deployed. These include the scramble for resources (notably in Africa and the Caspian, but also in enhanced relations with the Middle East exporters), and, of course, further exploitation of coal reserves.

Some argue that, however intense the dash-for-resources, China (and others) will fail because they will run out. In other words, what will decarbonize the world economy is that there will not be enough carbon resources left to deplete. A particular version of this argument is called 'peak oil'.[10] It is argued that the peak of conventional oil production has been already reached, and that production will decline over the coming decades, just as demand rises. Prices will, therefore, increase very sharply, setting off a significant substitution effect. From a climate-change perspective, it is argued that this would be good news, but there are major weaknesses with the peak-oil hypothesis. There may well be lots more resources to discover, notably in an increasingly ice-free Arctic Ocean, and then in Antarctica (as well

[10] The concept is associated with the *Hubbert Curve*, named after M. King Hubbert, who predicted in 1956 that US oil production would peak between 1965 and 1970. He subsequently predicted that global oil production would peak in 1995–2000.

as elsewhere). Existing 'depleted' oil wells typically retain over half the initial reserves, and new technologies (not least using CO_2 to increase pressure through oil-enhanced recovery) may be effective.[11] Then there are many near substitutes which may be available, notably tar sands. Once these are included, Canada, for example, becomes one of the top three oil-reserve countries. These sources may be even more polluting than conventional ones. There is also lots of coal.

A third possibility is a political implosion as part of a revolt against communism and authoritarian state power. But even in this scenario (and twentieth-century Chinese history has examples of major political turmoil and consequent stagnation), it is worth bearing in mind the attraction of higher consumption to the wider population and, therefore, that such events may not do more than temporarily reduce economic growth.

It would, therefore, be prudent to assume, for the purpose of designing credible climate-change policy, that none of these is likely *sufficiently* to derail China's economy in such a way as to offset the projected emissions growth—at least in the (crucial) short to medium term to 2030. We are, therefore, left with the question of whether climate-change policies can facilitate a benign decarbonization of the Chinese, Indian, and other rapidly developing economies over the next two decades or so—against the adverse trends identified above. This is the central challenge for the forthcoming Copenhagen Summit in 2009: to achieve a significant and rapid *reduction* in emissions in the context of a sharply *rising* trend.

III. Policy has achieved very little so far—Kyoto and all that

Faced with these powerful adverse trends, how much progress has been made so far to slow down the rate of growth of carbon emissions, and how far has the groundwork been laid for a coherent and credible global response? The answer on both counts is worryingly little.

The starting point was the so-called Rio Earth Summit in 1992, which gave rise to the UN Framework Convention on Climate Change (UN FCCC, 1992). At this summit, there was a very widespread agreement to act—and this consensus was achieved largely because the Convention did not, in fact, mandate much by way of immediate and binding actions or economic impacts on the nation states. It was an agreement without many immediate political or economic consequences. It promised much and cost little. What was, however, achieved was to set up a process and a negotiating forum, and the role of the IPCC was reinforced, being tasked to examine the science and policy options, with a view to creating a consensus on the facts, the forecasts, and the policy recommendations that would form the basis for the development of international agreements to limit greenhouse-gas emissions.

The IPCC processes and reports have, not surprisingly, been controversial, but the IPCC has largely achieved its main aims. It has provided the international scientific forum for analysis and debate, and although its conclusions have had to be negotiated, they have proved remarkably robust. Dissenting academics and others have from time to time cried foul, and in important respects they have been proved right. However, it is notable that this dissent has been more heavily focused on the economics and policy aspects and less on the pure science.[12]

[11] Oil-enhanced recovery (OER) is already a deployed technology in Norway. See http://www.Norway.org.vn/business/oil/carbonemissions.htm

[12] See, for example, House of Lords (2005) and Lawson (2008).

But the success of the IPCC has not been matched by the development and implementation of policies to reduce emissions. It provided for a periodic 'conferences of the parties' (COP) process, with the most important outcome being at the third COP, which produced agreement on the Kyoto Protocol, signed in 1997 (UN FCCC, 1998). This had two main dimensions: the setting of targets for the reduction of emissions from industrialized countries; and the establishment of a framework for the evolution of wider and deeper reductions subsequently.

Let's start with the targets. There are several considerations here. First, do the targets set make any noticeable difference to global warming? The targets cover the main industrialized countries (excluding the USA after its withdrawal in 2003). In practice, this means the EU—Canada is not making much progress on meeting its targets (emissions up by over 20 per cent since 1990), and Australia is outside.[13] The Japanese position is not good, despite low economic growth (emissions rose 8.1 per cent by 2005 from the 1990 level). The targets for new members from the former Soviet block left lots of headroom, as their economies contracted in the 1990s after the collapse of the Berlin Wall, and this provided the 'hot air' which the other EU members could trade into.

For the EU, it is important to specify the counterfactual—what would have happened to greenhouse-gas emissions up to 2012 in the absence of the Kyoto targets? There are three parts to this counterfactual: the dash-for-gas, and the reduction in coal-burning activities in a number of core countries (notably the UK and Germany); the migration of energy-intensive industries offshore to the developing countries; and the impact of higher oil prices since 2000. Counterfactuals cannot, of course, be observed, but it is reasonable to assume that the outcome would not have been markedly different. The first two had little to do with climate change, and the oil price increases were unrelated, too. The targets themselves are more typically being overshot than met, as Table 1 indicates.

The Kyoto Protocol and the COP process as currently constructed are not delivering significant aggregate greenhouse-gas emissions reductions in the EU, *sufficient* to have a noticeable effect on global warming. And these numbers flatter the true underlying position. The Kyoto targets do not included aviation and shipping, which are merely noted items.[14] In both cases, these have risen strongly since 1990, and given the greater damage caused by emissions in the atmosphere from aviation, its growth is alone enough to undermine the limited reductions claimed as directly caused by the Kyoto Protocol targets.

What about the second part of Kyoto—the evolutionary framework towards an eventual deeper and wider agreement? The defenders of Kyoto suggest that the COP process has been successful in bringing together a coalition of parties incrementally adding more body to the climate-change negotiations, and that, at Bali, the USA signalled a willingness to participate, and that at Copenhagen in 2009, the main players will all come on board for a new agreement for the post-2012 period. They point, too, to the initiative by the EU to pre-announce that it will unilaterally reduce its emissions by 20 per cent by 2020 and offer 30 per cent by 2020 if others take similar measures (EU, 2008).

There are, however, two counter-claims: that Kyoto demonstrated how difficult it is to bring on board the major players; and that a better and more comprehensive agreement could be achieved without the Kyoto architecture getting in the way.

[13] Within the EU, Spain and Portugal had by 2002 both *increased* their emissions by over 40 per cent above the 1990 levels.

[14] See NAO (2008) for a discussion of the various measurement issues, and Helm *et al*. (2007).

Table 1: Kyoto targets and outcomes for EU member countries (%)

	Kyoto target	2005[a] outcome
Austria	–13.0	18.1
Belgium	–7.5	–2.1
Cyprus	No target	63.7
Denmark	–21.0	–7.8
Finland	0.0	–2.6
France	0.0	–1.9
Germany	–21.0	–18.7
Greece	25.0	25.4
Ireland	13.0	25.4
Italy	–6.5	12.1
Luxembourg	–28.0	0.4
Malta	No target	54.8
Netherlands	–6.0	–1.1
Portugal	27.0	40.4
Spain	15.0	52.3
Sweden	4.0	–7.4
United Kingdom	–12.5	–15.7
Former Communist states		
Bulgaria	–8.0	–47.2
Czech Republic	–8.0	–25.8
Estonia	–8.0	–52.0
Hungary	–6.0	–34.5
Latvia	–8.0	–58.0
Lithuania	–8.0	–53.1
Poland	–6.0	–32.0
Romania	–8.0	–45.6
Slovak Republic	–8.0	–33.6
Slovenia	–8.0	0.4

Note: [a]2005 is the latest full year for which data are available.
Source: EEA (2007).

As Victor (2001) and Barrett (2003), among others, have demonstrated, the problem of climate change does not easily lend itself to a global agreement to reduce emissions. The analysis of the conditions for such a top-down agreement to work tolerably well have been researched by international-relations specialists for decades, and, in the environmental field, the Montreal Protocol on ozone depletion has provided a pertinent (and much misunderstood) case study (Barrett, 2003, ch. 8). Climate change is so intractable because the basic conditions for agreement—and for compliance and enforcement—are largely absent. To name but a few of the problems: the allocation of responsibility for the existing stock of carbon in the atmosphere (which developing countries point out was put there by the industrialized countries) is complex; carbon emissions per head are low in those countries most rapidly increasing their emissions; some countries (and, particularly, some countries' political élites) may actually benefit from climate change, and generally the effects vary greatly between countries; there are powerful—multidimensional—free-rider incentives; the measurement of emissions (including, to list just a few, rain-forest depletion, soil erosion, methane from permafrost melting, aviation and shipping, agriculture, and ocean and other sink depletion) is at best weak; and there are, at present, no serious enforcement mechanisms. It is hard to think of an international problem which lends itself less to a coherent, credible, and sufficiently robust and comprehensive general agreement.[15] To put it in perspective, limiting nuclear proliferation is trivial by comparison.

It is further complicated by the fact that these problems all arise in the context of negotiating a climate-change agreement as a stand-alone exercise. But international negotiations are not only multilateral but over a multiple number of issues. Thus climate change sits alongside trade negotiations, nuclear weapons negotiations, and migration and human rights negotiations. Russia, for example, ratified Kyoto in the context of WTO and other EU-related discussions.

Some of these problems can be addressed through the Kyoto discussions. But those which are core—notably basing an agreement on national emissions-production-based reduction targets—are not so straightforward in Kyoto and, indeed, may prove a hindrance. Targets may have to be flexible, they may require the development of global financial-transfer mechanisms, and they may require linkages to the WTO trade framework and even to military mechanisms. New institutions may be needed, too. And the linking factor here—a serious weakness of Kyoto—is that what matters for an international agreement is the consumption of carbon, not its geographic production (as we shall see in the next section). Of course, Kyoto provides a forum, but it is far from obvious that it is the only, or best, one.

These considerations lead to two conclusions: that little has, in fact, been achieved in terms of emissions reductions under Kyoto; and that Kyoto at best provides a forum for debate going forward. But a gradual widening of the number of countries adopting national emissions targets, and a gradual tightening of these targets is unlikely to do much to address the urgency of the climate-change problem. What may be required is to go back to the fundamental problems of the climate-change negotiations, and to address in particular the problems of major international fiscal transfers—in other words, how to craft an agreement in which industrialized countries pay developing countries not to increase emissions, and provide them with the technology to achieve this. But to consider how to do this, we need to step back and look at the underlying economics of climate change—in particular, the consumption (as opposed to production) of greenhouse gases, and the relationship between carbon consumption, economic growth, and sustainability.

IV. Carbon consumption, economic growth, and sustainability

(i) Consumption, not production

The Kyoto Protocol employs the measurement of emissions based on the UN FCCC methodology. It takes a geographical approach to emissions responsibility—all (and only) emissions generated from *production* activities within a country's territory are attributable to that country's emissions total. And, as noted above, the UN FCCC approach is not comprehensive: among other things, it excludes aviation and shipping.

From this accounting methodology, the Kyoto targets follow. If the methodology fails to provide an appropriate basis for the assignment of responsibility between national states then any agreement based upon this foundation is unlikely to prove credible. And since, as we shall see, it does not, Kyoto is (perhaps fatally) flawed.

[15] A series of proposals for a post-Kyoto agreement are set out in Aldy and Stavins (eds) (2007).

A country (for example, the UK) could have a relatively low production of greenhouse gases, but at the same time have a high consumption level. It could produce low carbon-intensive goods (such as services, rather than manufacturing), but import and consume high carbon-intensive goods (steel, aluminium, glass, and chemicals). In the UK's case, the shift of high carbon-intensive production to China, India, and other developing countries has had this effect. Furthermore, it could achieve a given Kyoto target by moving energy-intensive industries offshore—without making any noticeable difference to climate change.

Some numbers indicate the scale of these effects. On the UN FCCC basis, the UK's record is impressive, having already surpassed the Kyoto target of a 12.5 per cent reduction by 2008–12. Just adding back in aviation and overseas activities of UK residents puts a dent in this performance—emissions have fallen only 11.9 per cent. Even this adjustment puts the UK's meeting of the Kyoto target in jeopardy. But taking all greenhouse gases embedded in imports and subtracting greenhouse gases embedded in exports, Helm *et al*. (2007) provide a crude estimate that emissions between 1990 and 2003 have *increased* by 19 per cent.[16] Consider the impact on Kyoto, and its two claimed advantages: that it commits the developed countries to reducing emissions; and that it provides a framework going forward. It is immediately apparent that it fails on both counts. Industrialized countries can increase (and have been increasing) their carbon consumption (probably significantly), and developing countries are unlikely to agree that the industrialized countries' responsibilities are exhausted by addressing their current and future carbon production. As China has pointed out, although it might *produce* high emissions, these are *on behalf of* consumers in developed countries, and therefore the consumers should pay for the relevant reductions. The polluter is the consumer, not the producer.[17]

Just to complete the criticisms of the production-based Kyoto framework, note that, in addition to failing on both counts above, it creates major distortions in efficiency terms, too, making it a high-cost method of reducing emissions (we return to these policy costs below). In the Kyoto world, countries have differential greenhouse-gas caps. Given that emissions are closely tied to energy intensity, energy-intensive industries face a distortion on the basis of geographical location, which is a function of policy not underlying costs. Hence the problem of 'carbon leakage': production simply shifts from high cap to low (or no) cap locations, thereby, in the process, exacerbating the gap between carbon production and consumption.

(ii) Carbon consumption and economic growth

If current carbon consumption provides a better measure of the responsibility for global warming (leaving out, for the moment, the past consumption), it follows that the scale of the compensating financial transfers from industrialized countries to developed ones will have to be on a scale significantly greater than currently under discussion following Bali. To put it into perspective, the USA comprises around 25 per cent of the world economy, with the EU at around 20 per cent. Adding in Canada, Japan, and Australia takes the number over 50 per cent. If the carbon intensity of consumption in industrialized countries were similar to that in developing countries (it may, indeed, in aggregate be greater since the latter tend to be

[16] NAO (2008) argues in response that because the calculation of carbon consumption is more complex—and hence uncertain—we should *therefore* continue to use production-based measurements. In other words, it is better to be more precisely wrong than approximately right (Wiedmann *et al*., 2008).

[17] See the article by Jiahua Pan, Jonathan Phillips, and Ying Chen in this issue (Pan *et al*., 2008).

labour-intensive), the share of the total costs of meeting the global targets would be at least half.[18]

The policy implications of this point are considered later. But first the implications for economic growth that this focus on carbon consumption illustrates need to be explored. In the conventional approach—as, for example, used in the Stern Report—economic growth is measured by GDP. Estimates of the costs of climate change and the costs of mitigation are expressed in terms of GDP forgone. Behind these estimates lies a series of assumptions about the counterfactual—what would happen in the absence of climate-change and abatement measures.

Though this framework is one in which climate-change policy is typically addressed, it is important to recognize that GDP is not a particularly useful indicator. Indeed, it is hard to think of the relevant climate-change policy question to which GDP is the answer. GDP is particularly inappropriate for the consideration of environmental issues, and for longer-term contexts (Dasgupta 2001, 2008). It has no asset counterpart, and hence no account is taken of asset depreciation. For example, for the UK, the GDP performance in the last two decades has no offset for the depletion of North Sea oil and gas. In environmental economics, changes in the stock of non-renewable assets (often referred to as natural capital) are a core component of economic performance: indeed, it is often argued that much of apparent economic growth is, in large measure, the depletion of natural capital. As Dasgupta (2008, p. 6) puts it: 'GDP... is not a measure of long run human well-being, meaning that movements in GDP... are a poor basis for judging economic progress.'

There are a number of measures which improve upon GDP. Net national product (NNP) takes account of assets and depreciation. Then there are attempts to incorporate shadow prices for environmental services.[19] If assets are incorporated, then it matters greatly what substitution between different types of assets—particularly between natural and man-made capital—is assumed. In the conventional approach, this is one-for-one: non-renewable assets can be depleted provided there is a commensurate investment in man-made capital to compensate. Such an assumption lies at the heart of the sorts of calculations made in the Stern Report analysis: thus we can carry on getting better off by, say, 3 per cent p.a. GDP growth *ad infinitum* as we gain more and more man-made capital to compensate for the loss of environmental assets. So a reduction of the species on the planet by, say, 50 per cent by the end of this century (a distinct possibility) can be compensated for by an offsetting improvement in whatever replaces iPods and other new and existing technologies.

Once it is assumed that the substitution effect is less than unity, the GDP 3 per cent growth rate becomes unreliable. In due course, the feedback mechanisms from the reduction in natural capital reduce the ability of the economy to function, as (environmental) costs rise. The feedback in conventional accounting is indirect through costs rather than assets since, as noted, GDP does not value assets. Climate change is likely to be one such cost escalator, together with the related loss of habitat and biodiversity (some of which is caused by climate change, and some independently by population growth and other effects). Over the short run, these effects make little perceived difference; over the longer run, their effects can be profound. Hence, the assumed GDP growth may not materialize. It is at best a short-run indicator—and climate change is a long-run process.

[18] The exception here is China, where since 2000 there has been a shift *towards* energy and carbon intensity. See Rosen and Houser (2007).

[19] See Dasgupta and Mäler (2000) and Dasgupta (2001) for a more detailed discussion.

These considerations are important for two separate reasons: GDP may not be a proxy for the level of consumption that is consistent with a sustainability criterion—the prevention of the consumption possibilities of future generations falling below our own (non-decreasing utility over time); and the GDP measure of the costs of climate change which the Stern Report gives may be a significant underestimate, because climate change (and biodiversity loss and all the other environmental damage from economic activities) may lower the growth rate. We deal with the second issue in the next section, and concentrate here on the sustainability criterion.

Sustainability is an interpretation of a principle of equity over time. It measures the consumption possibilities over time against a constraint: they must not deteriorate. People in the future will have better technology (we can assume that technical progress will continue and saturation effects are unlikely). In this sense, they will be better off. The supply function will continue to shift outwards. But with ever more people, and with biodiversity loss and climate change, their consumption possibilities (per head, and even in aggregate) may be reduced. The oceans are already highly polluted, agricultural land is being affected by salinization and desertification, and global warming will have serious effects on the areas where population is most heavily concentrated. There will be some compensating benefits from increased temperatures to some agricultural areas (and from high-carbon concentrations in the atmosphere benefiting some plant growth). And there will be the gains from new technology. But the net effects of these factors are captured by some measure of economic well-being which incorporates the depreciation of natural capital (including the climate and biodiversity) and the associated costs.

The kinds of information necessary to construct this sort of measure do not exist in conventional GDP accounts. Nevertheless, some conjectures can be made about the impact of a more comprehensive measure which can be linked back to the argument made above about carbon consumption. The IPCC target of stabilization at 450–550 ppm is not based on any explicit optimization exercise, but it can be taken as a proxy. Beyond that level, climate change may have ‘dangerous’ consequences, and it may not be easy to control. In other words, once this level is reached, we are into the ‘fat tail’ of the probability distribution of global temperature outcomes—of really big economic effects from more dramatic climate change. One way of thinking about this is that, as the concentration of greenhouse gases rises, so the substitution between natural and man-made capital declines.

The IPCC (and the UN FCCC) argue that we should avoid this prospect, and should do this through a stabilization of emissions now. Since we are, by definition, on a business-as-usual path, the implication is that the current consumption path does not meet the sustainability criterion. By how much are we over-consuming? On the IPCC’s analysis, the answer is: by the costs of reverting to the 450–550 ppm path, adjusted first for the outward movement out of the supply function owing to man-made capital appreciation, human capital, and technical change over the same period, and adjusted second for other related and unrelated environmental damage. What would it take to revert to the 450–550 ppm path? The answer is: the reduction of carbon consumption to the preferred path. How far are we above it? This is the amount measured by the path of carbon consumption over time, incorporating the aviation and shipping, and the net carbon composition of imports and exports. From the calculations referred to above, in the UK case, it may perhaps be more than 30 per cent when the difference between consumption increases are compared with the required consumption falls. The EU and the USA may not be greatly different. This is the gap which scientists tell us must be urgently addressed in the next decade or two.

Consideration of these conceptual measurement problems suggests some radical conclusions. Emissions should be measured on a consumption not production basis. On a consumption basis, current emission-reduction targets for industrialized countries are comparatively trivial in comparison to the gravity of the problem, a shortfall which Kyoto underwrites. It is, therefore, unsurprising that Kyoto has made no significant difference to climate change. GDP provides little guidance to the climate-change problem, and the claim that climate change can be addressed without significant impacts (the widely quoted 1 per cent GDP number to which we return below) relies on an assumption that the accumulation of man-made capital, human capital, and technical progress is fast enough to offset the depletion of natural capital, of which the climate is a part. There is no good reason to accept this assumption, certainly over the time period scientists advise in which the increase in carbon emissions needs to be halted and then reversed. And the starting point is a level of GDP which does not account for the responsibility in respect of current carbon consumption. If past contributions were to be added to the responsibility calculation, a significant reduction in consumption levels in developed countries is implied.

V. Revisiting the Stern Report

The assumptions about growth and consumption are, unfortunately, not the only problems with the conventional approach to the economics of climate change. Please see the article by Ross Garnaut, Stephen Howes, Frank Jotzo, and Peter Sheehan in this issue (Garnaut *et al*., 2008). The focus here is on the Stern Report—notably because it provides a conventional approach, but also because its conclusions have been widely taken up by politicians and commentators, to the extent that it has become the new conventional wisdom on the economics of climate change. In addition to the possibility that the growth rate may be lower (possibly much lower) later in the century (and hence the predicted GDP measured loss of perhaps 5–25 per cent GDP by the end of the century may be higher), there are two other dimensions of Stern's arithmetic which are questionable: the costs and the discount rate.

(i) The costs of mitigating climate change

The Stern Report devotes just two chapters to addressing the costs of mitigation, to substantiate the claim that these will be between –1.0 and +3.5, with an average estimate of just 1 per cent to stabilize at 500 ppm. This matters, because the 1 per cent is the most widely quoted number from the Report, particularly by politicians, and provides the basis for the claim that economic growth need not be much harmed by reducing emissions to stabilize at 450–550 ppm.[20]

The two chapters purport to provide microeconomic and macroeconomic justification of the 1 per cent, and each is seriously flawed in important, but different ways. The microeconomic chapter is, in turn, based upon a single supporting paper (Anderson, 2006), itself largely derivative of a series of papers on technology costs, and it is hard to reproduce its results.[21]

[20] A few examples include Baroso, Blair, Brown, and Sarkozy in Europe. US politicians have been less willing to endorse this number.

[21] Nordhaus's criticism that the Stern Report has not been subject to the normal process of peer review is particularly important in respect of this chapter and the supporting paper (Nordhaus, 2007).

In essence, the microeconomics is not based upon economic cost factors, but more narrowly on technology. An ‘optimal’ supply function of technologies is presented on the basis of conventional models (which go under the general name of MARKAL), which provide a least-cost solution to the mitigation target.

The essence of MARKAL-type models is the assumptions: the assumed costs of each of the technologies considered and the learning and technology assumptions going forward. The optimal supply function is merely the transformation of the assumptions that are made about the costs of each selected technology. Such estimates are obviously vulnerable to appraisal optimism, and there are numerous lobbyists with vested interests in the numbers, since these influence policy and the associated allocation of the economic rents that result. A serious analysis would focus largely on the evidence for the assumed costs. Unfortunately, the Stern Report chapter and the supporting paper provide very little by way of guidance as to the reliability of these assumptions, and in particular do not report how past sets of assumptions have performed against out-turns. As a result, little (or indeed no) reliance should be placed upon them. Strictly, on this basis, the Stern Report’s 1 per cent on which politicians are relying is an *assumed* number.

But even if the underlying assumptions were soundly grounded, and supported by empirical evidence, the derived supply function is essentially restricted to the ‘optimal’ costs of the technologies, and takes no account of the fluctuations in the costs of the technologies as market conditions vary, and assumes that the policy framework will lead to their costless deployment. It is the (least) costs of the equipment, not the cost of producing the outputs. Neither turns out to be well-founded. A rapid least-cost roll-out of low-carbon technologies assumes that the manufacturing capability anticipates demand, and hence prices do not reflect imbalances between demand and supply. They are always in equilibrium. The evidence is to the contrary: for example, the prices of wind turbines have risen sharply as the dash-for-wind has been embedded in renewables policy; and now there is evidence in the sharply rising prices of new nuclear development technologies as manufacturing production lags demand. These price effects are of a significant order of magnitude—rendering the cost numbers in the Stern Report all but useless for the purposes of public policy design and implementation.

The technology costs assume that the energy systems are optimally designed to facilitate their deployment. No account is taken in the Stern Report of the costs of system-wide changes to the transmission and distribution, for example, and, in the case of wind, the assumptions about availability and back-up supplies are optimistic. While these may not matter at the margin, with large-scale deployment of these technologies, they are likely to be significant. Given the scale of the switch from high- to low-carbon technologies implied by the overarching targets, non-marginal deployment should be taken into account.[22]

Then comes perhaps the greatest gap in the Stern Report cost calculations—the policy costs.[23] There is a voluminous literature of government failure, regulatory capture, and the impact of rent-seeking behaviour within the policy process. Climate-change policy may or may not be the biggest externality, as the Stern Report suggests (actually it is a public bad), but it is likely to be one of the largest sources of economic rents from policy interventions.

[22] It is interesting to note that Cameron Hepburn and Nicholas Stern (2008, this issue) correctly place significance on the non-marginal nature of climate-change impacts on the one hand, but do not recognize the non-marginal nature of mitigation policies to achieve the sharp reductions in emissions on the other.

[23] Stern himself acknowledges this gap in his analysis. In the *Financial Times* (16 April 2008), he is quoted as saying: ‘I probably would have emphasized the importance of good policy [if writing the report again today] and how bad policy puts up the costs [of cutting emissions]’.

There is a large and growing climate-change 'pork barrel'.[24] It is highly unlikely that the policy costs will be zero. Indeed, there are good reasons to suppose otherwise—at every level of climate-change policy.

The starting point in analysing climate-change policy costs is Kyoto and its associated distorting incentive structure. Its design encourages two sorts of rent-seeking behaviour: by countries seeking advantage from their individual quotas; and by companies seeking to arbitrage between different geographic production caps. Every country has an incentive to overstate its costs of compliance and underestimate its opportunities for abatement. The very measurement base has economic rents attached to it. Countries also have an incentive to misreport performance. Companies have incentives to switch locations to minimize their carbon costs. These distorting incentives have been a common feature of negotiations since the UN FCCC, and there is no reason to suppose that they will go away.

To these policy costs in the overall design of international climate-change agreements need to be added the costs of specific policy interventions. In this respect, the UK is an interesting and instructive example. The incoming Labour government in 1997 committed itself to a unilateral domestic CO_2 target of a 20 per cent reduction by 2010 from 1990 levels (Labour Party, 1997). This was presented as an exercise in 'leadership': the UK would demonstrate that this target could be achieved, and at low cost, thereby providing an example which would be used to persuade the USA to accept Kyoto carbon caps.[25]

It has been a failure in all three respects: it is very unlikely to be achieved; it has been (very) high-cost; and it has not persuaded the Bush administration of the virtues of Kyoto.[26] Here the main concern is the costs. The UK set out a climate-change strategy to achieve this target through renewables (the Renewables Obligation and the Renewables Obligation Certificates) and energy efficiency, with some support from emissions trading (the UK ETS and then the EU ETS). These approaches were deemed preferable to nuclear power, which was effectively ruled out, notably in the 2003 Energy White Paper (DTI, 2003*a*). Much of the energy-efficiency programme was claimed to be net present value (NPV)-positive, while the estimates for renewables from the MARKAL model (discussed above) pointed to limited additional cost burdens.[27]

In practice, energy efficiency has not had a significant take-up and, in particular, individuals and companies have not been noticeable in their adoption of the claimed positive-NPV investments.[28] Indeed, an improvement in energy efficiency take-up appears to be more likely to result from the sharp increase in energy prices (which were not anticipated when the policy was set out—the 2003 White Paper assumed \$25/barrel oil for the foreseeable future). But it is on renewables where the costs of the policy have turned out to be orders of magnitude greater than indicated by the MARKAL modelling. A study by the National Audit Office (NAO, 2005, p. 4) found that the Renewables Obligation 'is several times more expensive than other measures currently being implemented by the government'. Compared with EU ETS carbon prices in the range £20–£30 per tonne of carbon, the UK renewables programme is staggeringly expensive. Perhaps only the Italian renewables programme looks more expensive. Recently it has begun to be appreciated that current biofuels policy may be

[24] This rent-seeking behaviour is also prevalent in the allocation of R&D funding. See Cohen and Noll (1991).

[25] The case was summarized by Tony Blair in *The Economist*: 'A year of huge challenges', 29 December 2004.

[26] Nor, indeed, any other senior US politicians on *the basis of the British policy approach*.

[27] An accompanying technical paper to the 2003 White Paper set this out (DTI, 2003*b*).

[28] On behavioural approaches and explanations, please see the article by Kjell Arne Brekke and Olof Johansson-Stenman (2008; in this issue).

even worse—not only in terms of costs, but also in terms of the very limited carbon savings and the impact on agriculture.

Taking account of these policy costs at both the international level and in national policy design, and adding them on to the technology optimism in the MARKAL numbers, adjusted upwards further for the lag in manufacturing of the technologies which is an inevitable part of a rapid decarbonization process, is likely to produce a number well above the Stern Report's 1 per cent. To produce an alternative estimate in terms of percentages of GDP is not only well beyond the scope of this paper, but conceptually very difficult. It requires an estimate of the scale of future policy costs, which in turn requires an analysis of the incentives in public-policy design and in implementation processes, and how lobbying interests seek out the economic rents from policy. It is illustrated by specific examples of policy failure—such as the renewables example in the UK. These examples might indicate several percentage points higher—but once recognized as non-trivial, there would be a feedback in terms of either better policy design, or greater reluctance to act at all. These very broad political economy effects are probably beyond precise statistical estimation—and, indeed, such estimates are probably unhelpful, not least because politicians are led to believe that there is more certainty than merited and, in consequence, are ill prepared for unanticipated cost shocks.

There is a final twist to these costs. Above we noted that, on a consumption basis, the implied cuts in the industrialized countries would be much greater. There would, therefore, be a more rapid deployment of low-carbon technologies, and many existing carbon-intensive assets would be stranded. The (non-marginal) disruption costs of the transition might be very considerable—for example, electricity security of supply might be seriously impaired if existing coal plants were rapidly shut down. There would be significant price effects, without a drawn-out period for individuals and firms to adjust.

Taken together, it can be concluded that the costs of mitigation from a microeconomic perspective are likely to be significantly higher than those predicted by the MARKAL modelling exercises. Indeed, the MARKAL model is best regarded as an idealized solution. This makes it all the more remarkable that the Stern Report should place reliance on such an approach—and the corollary is that policy-makers should place no reliance on the 1 per cent number.

The Stern Report, however, provides an alternative way of calculating the costs—one grounded in macroeconomics. Aggregate income is made up of consumption plus investment. The decarbonization process represents an enormous investment opportunity, and, as investment goes up, so too will aggregate income. Thus, it is argued that mitigation is a growth-inducing activity. This is a beguiling argument and, as with the MARKAL approach, it has an element of credibility. It is true that as investment goes up, *ceteris paribus* so too does aggregate income. But this is true of *any* investment. The important point is whether the investment—compared with other investments that might have been made—increases wealth in a way which increases the level of sustainable consumption (see Dasgupta, 2001). Energy-generating technologies are derived demands, and the microeconomic point raised above is that low-carbon technologies are probably higher-cost than the current carbon technologies. Furthermore, it is not even clear that the aggregate level of investment goes up: for a given demand for energy there is a vector of alternative ways of meeting it through different capital stocks. The low-carbon investment opportunity is mirrored by a declining high-carbon investment opportunity. The net effect on growth is unclear.

Then there is the consumption element of aggregate demand. If costs rise for (low-carbon) energy, and if energy demand is relatively inelastic, household budgets will contract, reducing aggregate consumption. Add to this the impact of the consumption-based measurement of emissions and the sharper emissions-reduction targets implied for industrial countries, and the impact on growth may be much more significant.

The implication of these considerations on the macro and micro approaches is that the costs of mitigating climate change are likely to be significantly higher than indicated by the Stern Report, with a resulting reduction in the sustainable level of consumption in industrialized countries. They are also inherently uncertain. The happy political message that we can deal with climate change without affecting our standard of living—which is a key implicit message from the Stern Report on which politicians have publicly focused—and do so in a sustainable way, turns out, unfortunately, to be wrong.

(ii) Discounting

The Stern Report has one more variable in deriving its result: that the discount rate to be used in marrying up the damage in the future to the costs now of mitigation should be low. This turns out to be needed because, if the discount rate were to reflect the evidence from current behaviour, the Stern Report calculations would indicate, even on its 1 per cent costs, that we should do little about climate change—since future people are going to be so much better off than us as a result of the compounding of 2–3 per cent economic growth for a century, and we currently discount their future utility at a positive (and significant) rate. By 2100, when the Stern Report expects that the damage may be equal to between 5 and 25 per cent GDP, the 9 billion or more people will have been on this 2–3 per cent p.a. growth scenario for the century and hence will all be living at or above the current consumption patterns of the industrialized countries. And in industrialized nations, people will be consuming at levels more than four times their current levels.[29] We should not now, on this basis, sacrifice some of our relative low levels of consumption to people in the future who will be much better off than we are now, just to avoid them being a little less than staggeringly better off than us.

This compound GDP growth rate is one part of the calculation. But it is on the discounting of future utility where the Stern Report deviates from observed behaviour. By using a sufficiently low time-preference rate over future utility, the balance can be tipped in favour of action now. That is what the Stern Report does, and it has been challenged on at least two broad levels. First, following Nordhaus (2007), there is little evidence that the sort of discounting practice the Stern Report advocates matches what we actually do. Thus, the Stern Report's discount rate relies upon a *moral* argument. However, moral judgements are, of course, open to dispute, and moral philosophers disagree about the principle of strict equity, which gives the Stern Report its zero (or rather 0.1, reflecting extinction risk) time preference—either as a principle of equity itself, or because other non-equity considerations count, too. Second, the 'fat tailers' argue that the real source of the claim that we should act now comes not from the discount rate, but rather from the possibility that the probability distribution of outcomes has a nasty sting in it—the 'fat tail', the low probability of a rapid and damaging climate change. Weitzman (2007) leads this critique.

These discounting issues have been the subject of a long and distinguished literature. From the perspective of climate-change *policy*, and in particular in crafting a post-Kyoto framework, it is important to separate out those issues which turn on welfare judgements and moral philosophy, and those which are matters of scientific dispute and evidence of behaviour. For

[29] Note, however, that these growth rates are unlikely to be uniformly distributed. Indeed, lower growth rates may well occur where damage is highest.

while the Stern Report—and, indeed, Ramsey (1928) on whom the Stern Report leans, quoting his famous remark that to discount at other than zero reflects a lack of imagination—might argue that public policy *ought* to be based upon a deep principle of equity, the post-Kyoto discussions will be grounded more heavily in the self-interest of the participants, more or less enlightened. So, while moral education may be important in improving the behaviour of voters and governments, and even if there was moral agreement on the principle of zero discounting (which there is not), it would be a considerable mistake to expect that it will, in fact, determine the outcome. This is to assume a rapid success for education and public persuasion overcoming the gap between the science and the (lack of) policy response. There is, as yet, sadly no evidence that such persuasive arguments are leading to individuals or countries changing their behaviour towards lower discounting of future utility.

Indeed, it is important to realize just how controversial the ethical foundations of the zero time-preference arguments are. The claim is that we should be indifferent as to the time period in which consumption takes place—that the interests of future generations count equally with our own. The sustainability criterion goes even further: it requires that they should be at least as well off as ourselves, and since there is uncertainty, this implies a slightly negative time-preference rate.

Why should this be? Is the claim even coherent? Does it apply thousands of years into the future, or are we more concerned with those in closer time proximity to those more remote? Is it limited by population? Would a faster rate of population growth mean that more resources should be sacrificed to the future? And is the underlying claim to equality robust? The claims to equality between existing people have had a mixed philosophical reception: why then should we apply them into the future when we clearly do not do so for current people?[30]

So the moral case for a zero time discounting should not be taken as given, but rather as highly contentious, and, not surprisingly, it is unlikely to be a prime motivation to the negotiations on future climate-change policy. In practice, we do not take equality between people in different locations now very seriously: few politicians would be elected on a platform of a major transfer of wealth from the industrialized nations to the developing countries necessary to equalize current living standards. One per cent GDP contributions to aid budgets remains the meagre global ambition. This matters, because any plausible set of policies to stabilize emissions at the IPCC-recommended levels will require significant transfers from industrialized to developing countries, and such transfers based upon self-interest are likely to be very different from those based on the idea of inter-generational equity.

Behaviourally, then, there is little basis for assuming that voters and governments will in fact use a zero time-preference rate. The case for urgent action now rests rather on the non-discounting reasons: that the damage is likely to be great, and, indeed, that the fat-tail argument should be taken seriously. Where the discounting issue matters is not so much in time-preference assumptions but rather in the impact of global warming on economic growth—the 2–3 per cent per annum growth assumption. Because of the direct damage, because environmental capital and man-made capital are not such easy substitutes, future generations may not be so much better off—and so they will not be so well placed to offset the environmental damage with their greater man-made capital and associated technologies. As argued in section IV, economic growth may not be so easily compatible with the effects of, and mitigation costs of, climate change. So, although the time preference rate may be higher, the growth component may be lower.

[30] See Hepburn and Stern (2008) in this issue for further discussion.

In summary, the Stern Report framework provides a useful coat hanger on which to examine the economics of climate change. But it is open to challenge in respect of its main components: the damage is likely to be greater and so are the costs of mitigation. The impacts on economic growth rates are likely to be more severe. We will not, therefore, be as well off in the future as we would have been on the basis of the 2–3 per cent GDP compound growth rates. What the Stern Report does is give a very conventional analysis, which points away from doing much about climate change now, only to rescue its conclusion with a dose of highly debatable moral philosophy. What remains, however, is the conclusion—that we should take urgent action now—which is correct, but for reasons almost entirely diametrically opposite to those of the Stern Report. What makes action necessary now is that, contrary to the Stern Report, there are good reasons for believing that the substitution of man-made capital to compensate for the damage to the environment (including climate change and its environmental consequences for biodiversity) is not unity, but rather less, and probably declining. The fat tail of more rapid and damaging climate change lurks, like the hidden underside of an iceberg.

VI. Policy proposals: the EU climate-change package

What then is to be done? The European Commission (CEC, 2008) has proposed an apparently aggressive policy, with the deliberate ambition of inducing at Copenhagen and beyond an enhanced post-Kyoto international agreement. It comprises: a unilateral EU-wide target of 20 per cent emissions reduction by 2020, to be increased to 30 per cent if others (notably the USA) follow suit; an enhanced EU ETS for the period 2012–20, with significant permit auctioning; a 20 per cent renewables target of total energy supply by 2020, independent of the EU ETS and the overarching target; a 20 per cent energy-efficiency target for the same period; a biofuels target of 10 per cent by 2020; and a package of measures in relation to carbon capture and storage (CCS). It therefore has the politically neat 2020 20-20-20 format.

The package leaves a number of significant issues to be dealt with. These include: the extent to which the overarching target can be met through the buying-in of emissions reductions elsewhere (including the Clean Development Mechanism and Joint Implementation); and, most contentiously, the issue of the impact on competitiveness between the EU energy-intensive industries and those overseas in countries without such binding caps. For this latter problem, carbon taxes on imports have been proposed, or support for EU-based industries in international competitive markets, through such mechanisms as grandfathered permits under the EU ETS or direct subsidies.

The 2020 20-20-20 package is necessarily a political one: across the EU there are very different views about how climate change should be tackled. Some countries, notably France and now the UK, advocate the wide deployment of nuclear technologies. Others, notably Germany, advocate renewables *instead of* nuclear power. The role of Green parties in proportional representation electoral systems gives the median voters greater sway over energy and environmental policies, and there are broad ideological reasons why some pivotal electoral groups prefer small-scale, decentralized, and non-nuclear technologies. The politics of climate change goes well beyond what many Greens would regard as the narrow concerns of economic efficiency. Then there are divisions between those who enthusiastically advocate market-based mechanisms such as carbon trading over more direct technology intervention, and those who prefer more central planning.

The economic consequences (particularly the costs of mitigation) of the politics of climate change in Europe are considerable. The search for a consensus upon which the member states can agree is based upon inclusiveness. Hence the package contains *all* the main policy instruments: permits markets *and* renewables quotas *and* energy efficiency targets *and* biofuels targets. The result is over-determination and higher costs. For example, if the renewables, energy efficiency, and biofuels targets are met, the role of the EU ETS will be more marginal—and carbon prices may *fall* as the targets for these specific contributions are met. In reflecting this risk of a falling carbon price, the EU ETS caps are to be set independently, but the implication is then that it is not the overarching 20 per cent target that is driving the collection of policies.

Then there are the costs of the different policy components. Renewables, up until 2020 at least, means predominantly wind. It is likely to remain expensive relative to other options (which include the move from higher to less high carbon technologies, increases in thermal efficiencies, and a host of measures within the non-renewables category). As the wind penetration rises, driven by the target, the system costs rise too, both to manage the intermittent loads and to provide back-up supplies. These might change with new renewables storage technologies—batteries—but not over the time horizon of the target to 2020. In the meantime, the costs will need to be paid by customers and taxpayers, and there has been little consideration of the extent to which voters will support such policies as the costs are passed through, especially if other countries are not making comparable efforts. Not surprisingly, investors are correct to expect politicians to review and reform intervention mechanisms, and hence the cost of capital is increased.[31]

Though policy costs will play a (perhaps significant) part in political debate, the effectiveness in terms of climate-change mitigation will also feature prominently. In this context, the implications of the EU's package are especially relevant: that neither the renewables not the biofuels investments are likely to make much immediate difference to climate change. In the case of renewables, once the costs of the supporting (fossil) fuels are taken into account to ensure continuous supplies, the impact in parts per million on carbon concentrations is likely to be minimal at the global level. In the case of biofuels, there are good reasons for thinking that some (perhaps much) of the target will be counter-productive—actually *increasing* emissions relative to conventional fossil fuels. When the biodiversity and carbon-release effects of rainforest destruction to carve out land for biofuel crops are taken into account, and the impact on world food markets is added (including greater agricultural intensity and the cultivation of marginal land), the current biofuels policy is at best ill-conceived.

Though the politics have determined the shape and scale of the EU proposals, they are also a product of the limited policy options available in the short term (which in practice means at least until 2020). Between now and then, the capital stock has considerable rigidity. There will be a significant replacement cycle in power generation across Europe over the next decade, but much of this will have its impact in the following decade (2020–30). Nuclear and CCS are, in particular, largely post 2020-options. For this reason, and because renewables and biofuels will not make much difference to the overall problem—and both at relatively high cost—considerable emphasis naturally falls on energy-efficiency measures.

[31] The UK government is about to publish another review of the Renewables Obligation and Renewables Obligation Certificates scheme (BERR, 2008), and the opposition parties are also committed to reform. This is classic political and regulatory risk which has an impact on the cost of capital—itself very significant in overwhelmingly capital-intensive industries.

There is a widespread consensus that there is considerable scope to increase energy efficiency, and the impact of rising prices is likely to have a considerable incentive effect (though with a lag). Nevertheless, past expectations of policy impacts have rarely been met, and there are various reasons for expecting the costs and barriers to energy efficiency to be considerable. There have been numerous studies purporting to demonstrate that there are many NPV-positive projects available to individuals and business—that, in effect, much energy efficiency is free, independent of the climate-change policy objectives. Why then has take-up been so poor? The answer lies partly in the capital stock (notably buildings and houses), and the indirect costs of such investments. While some lobbyists and politicians conclude that the lack of take-up displays ignorance and even irrationality, the economists' preferred explanation lies in questioning whether the costs have, in fact, been underestimated.

The medium-term policy options (largely ignored in the EU climate-change package) look altogether more promising. Large-scale supply-side low-carbon technologies are moving from research to development and, indeed, even to deployment in demonstration plants or actual investments. The first candidate in this category is nuclear power. As France has demonstrated, it is possible to have a large nuclear programme without undermining economic performance—with some 59 pressurized-water reactors (PWRs), producing some 80 per cent of its electricity generation. Were Europe—and the USA, China, and India—to follow the French path, significant reductions in carbon emissions could be achieved from around 2020. But such a large-scale programme would raise many problems: the manufacturing capacity is not yet available, there are significant waste issues, and global nuclear-safety regulation is weak. There are also significant risks of the inevitable military nuclear proliferation which would follow.

A second option is CCS—a recognition that the coal is going to be burnt, and that policy should focus on making fossil fuels carbon-neutral, rather than exclusively focus on non-carbon technologies. The concept of CCS is relatively straightforward, and the technology itself arguably proven. How to separate out carbon as coal burns is well known, as is its pipeline transmission. Injecting gases into rock formation is also widely understood—and, indeed, demonstrated in a number of cases already. The delivery of CCS is rather a coordination and investment project in what will be a new utility infrastructure industry. For Europe, with partially depleted oil and gas fields in the shallow North Sea, the prospect of an extensive CCS network is a plausible option.[32]

In the medium term, there are few other large-scale options. But beyond 2030 all sorts of technologies might be feasible. There are good reasons for expecting rapid technological progress: both from a funding perspective and from the technological research options. There is no shortage of energy (the sun rises every day), and a host of theoretical ways to translate energy into usable forms. It might even be possible to use large-scale atmospheric engineering: by extracting carbon directly (rather than from coal power stations), and even by changing the reflectivity and absorption capacity of the atmosphere.[33] None of these more speculative ideas has yet produced convincing practical applications, but then this is not to be expected. The point about R&D is just that: to find out what solutions might be available.

Policy-makers are, however, faced with a plethora of technology advocates and lobbyists, all trying to gain access to the 'technology pork barrel' (Cohen and Noll, 1991). This

[32] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (2008).

[33] See the paper by David Victor (Victor, 2008) in this issue.

holds, too, for the existing policy options—from the enormous subsidies for ethanol, through to the support available for wind, tidal, and other renewable technologies. It is unlikely that these pressures will be resisted as long as technology-based policies are provided by governments. With the prospect of large revenues from cap-and-trade scheme auctions of permits, the politics of spending these revenues will be extremely important. Indeed, the prospect of cap-and-spend is one reason why US politicians have warmed to these sorts of schemes.[34]

These rent-seeking pressures, combined with the different time horizons to which the policies apply, make the policy failure likely to remain high. The implications for policy design are profound: economic efficiency and political expediency are likely to conflict in climate-change policy, especially where these policy costs are imposed in the future (and faced by future politicians and governments). It is in these circumstances that the case for market-based instruments is especially great. Almost all climate-change measures benefit from a rising price of carbon, and the price of carbon allows the market to sort out the more efficient supply- and demand-side responses. Indeed, it is notable that the technologies which governments have deliberately protected from market forces (such as wind) are precisely those which would not be developed on such a scale in the presence of a carbon price alone. And the political expediency is reflected further in the differential treatment of technologies too: renewables is widely protected from market forces, whereas nuclear, at least in the UK (but not the USA), is not.

With a core role for the price of carbon, not only is the technology pork barrel diminished, but two other benefits accrue, too. Carbon prices are not narrowly production-based: they address the need to focus on carbon consumption, not just production, as discussed in section IV. They also raise revenue, given that, at least in the short to medium term, carbon is inelastically demanded. What happens to this income effect matters, especially to technology. If technological progress is essential to the medium and longer term, carbon revenues provide a potential source of finance in a context where the scope for the expansion of general taxation is very limited, especially in Europe. Such revenues could be not only ring-fenced, but passed to independent bodies to reduce the scope for lobbying and capture (though not, of course, to eliminate it).

VII. Copenhagen and beyond

Present international negotiations are based around the COP at Bali in December 2007 and the EU policy package discussed above. At Bali, the main action focused on getting the USA to declare that it would participate actively in the next phase of the process leading up to the Copenhagen Conference in December 2009. In this limited, but important, aim, it was successful.

The core issues for Copenhagen remain those which have been on the table since the UN FCCC was agreed in 1992: how to get a global carbon cartel in place which commits the main emitters to an aggregate programme of credible carbon emissions reductions consistent with stabilizing emissions at the 450–550 ppm concentrations. The challenges to this undertaking

[34] For a discussion of cap-and-trade schemes in the USA, see the article by Robert Stavins in this issue (Stavins, 2008).

are well known, and little has changed the basic incentives and trade-offs. At the core is the prisoner's dilemma—it is in the interests of each party that the others reduce emissions, rather than themselves. That way, it is possible to gain the benefits of others' actions without bearing the costs oneself. No single party can on its own achieve the outcome of stabilization,[35] and all share in the benefits.

Matters are made worse than the simple characterization in the prisoner's dilemma by virtue of the distributions of costs and benefits. Some countries arguably actually gain from a warmer climate, while others are badly affected. Key participants are not democracies, and the interests of their political élites may be particularly badly affected by mitigation policies and their costs—including: China, whose élite is heavily reliant of fast GDP growth based on energy-intensive industries to retain power; and Russia, whose élite is heavily dependent on, and personally financially involved in, the main fossil-fuel industries.

Given the concentrated location of emissions growth, an inevitable part of any new agreement is that there will have to be significant financial flows from industrialized to developing countries. Yet this looks very hard to achieve: in particular, it is hard to imagine the USA making significant payments to communist China to pay for a lower-carbon industrialization which may have a further impact on competition between the two countries. This, indeed, has been a stumbling block since 1992, and the major reason why the USA pulled out of Kyoto. A minimum condition for the USA has been that China (and others) adopt binding caps on emissions. A condition for the Chinese is that the burden should not fall heavily on them, as their *per capita* carbon emissions are still low, it has been the USA and other industrialized countries that are largely responsible for the stock of greenhouse gases currently in the atmosphere, and (as noted above) its carbon-intensive exports are a response to US and European consumption demand.

As we have seen above, the Chinese argument has considerable merit when emissions are based upon a consumption rather than production basis. However, this does not in itself *solve* the problem: even if the parties could agree on the principles for responsibility, it would remain to establish a credible regime which could be monitored and, indeed, enforced. What incentives would the parties have to comply *ex post*? The free-riding incentives owing to the prisoner's dilemma would remain.

These difficulties appear immense, and are unlikely to be resolved at Copenhagen. Indeed, it could be argued that the way the negotiations are being framed *ex ante* is unlikely to produce a solution to the climate-change problem. Getting an agreement only constitutes a solution if it actually results in a reduction and then arrest of the growth of emissions—and fairly quickly. But, as we have seen, Kyoto is designed in such a way as to exclude the most important components. Being based upon geographical production, excluding aviation and shipping, shapes the negotiations in an inherently conservative and inefficient way. So even if tighter geographic production caps are agreed, the net result for developed countries will not meet the scale of the task—and, as a result, developing countries (which produce and export carbon) will find themselves asked to do proportionately more than their own carbon consumption dictates.

Kyoto is skewed, too, to the shorter term, within which there is little that can be done on a large scale. The key issues are *post*- not pre-2020—with the deployment of large-scale

[35] As Victor (2008) argues, in this issue, geo-engineering may be an exception. See also the article by Scott Barrett in this issue (Barrett, 2008).

technologies between 2020 and 2030, and new technologies thereafter. As a result, large-scale programmes for R&D may have more impact on the climate-change problem than shorter-term targets for renewables and biofuels—as pursued by the EU at the heart of its proposed approach to climate change. Indeed, the EU programme is skewed heavily to areas of more marginal significance to the overall problem. The exception is, perhaps, the EU ETS, but even here it is the use of the revenues—the income effect—which is probably more important than the substitution effect in the period to 2020, and these revenues are likely to go into general government expenditures rather than large-scale R&D, as, indeed, is clearly expected under the EU proposals. Politically demanding renewables targets may appear more attractive than longer-term R&D programmes—or even CCS and nuclear.

These difficulties have arisen in the context of a conventional wisdom which has built up around the Stern Report—that the problem as a whole can be tackled with just 1 per cent GDP cost. If even this number is proving a difficult political obstacle to progress in the developed countries then a recognition that the scale of the burden on the developed countries should be much higher—on a consumption basis—*and* that the costs of the problem as a whole may be much higher than 1 per cent indicates an almost insuperable obstacle. A coldly rational and objective analysis of the problem facing the negotiators at Copenhagen is that the sort of agreement that could be signed up to by the main players is one that almost certainly will not solve the problem—in other words, like the Kyoto Protocol, agreement is more likely to be achieved if its impacts are marginal.

What would it take to overcome these incentive problems? One approach is to persuade people of the ethics of climate change—an approach which is embedded in the Stern Report, and which is manifest in egalitarian proposals such as equal personal carbon budgets and GDP-per-head emission targets.[36] The chances of agreement on this basis in time to have an effect on the problem are remote. A second approach is to change the incentives themselves—the damage pay-offs in particular. If the science reveals that the fat tail is actually quite probable (that it is not, in fact, in the tail of the distribution), bringing forward the damage from climate change into the nearer term, with all its associated problems of migration, conflict, sea-level rises, and the direct effect of higher temperatures, then the perceived trade-off between damage and costs would shift. This is not an impossibility, and underlines the importance of the scientific research to the policy process.

A third option is to take away from the national dimensions some elements of sovereignty, as the UN has in wider conflict resolution. This might involve a delegation of the negotiations to a new international body. Already the move from the national level has helped in Europe: arguably the EU has managed to force member countries into tougher action than would have occurred had they engaged in the within-EU prisoner's dilemma debates. Such an international body might function analogically to the WTO, and, indeed, membership and compliance could then be linked to wider international issues—such as trade. By broadening the pay-offs through multiple international engagements and agreements, greater leverage might be gained, thereby weakening the free-riding incentives. Even net gainers from climate change—such as the Russian élites—might face costs from failure to reduce emissions, for example through international carbon taxes or trade discrimination for its carbon-intensive exports. Access to the benefits of technology transfer may also be easier in the context of an international body, as, too, might enforcement of agreements.

[36] House of Commons Environmental Audit Committee (2008).

But to agree about the design of such an institution, and to set it up, would take time—perhaps a decade—a serious obstacle it shares with the other two options. Moral education is a long-term endeavour, on a par with gender equality and the abolition of slavery. Science, too, takes time: as noted at the outset, we are condemned to uncertainty over the relevant time period within which action needs to be taken.

VIII. Conclusions

It is very grim. The trends are in the wrong direction, the timescale is short, and a Kyoto-style new agreement from 2012 is unlikely to make much difference to the underlying (upwards) trends in emissions. Without a fundamental rethink, we are likely to be doomed to significant increases in emissions, and the corresponding uncertain warming of the climate. The science suggests that it is probably more likely than not that rapid climate change will result later in the century with potentially quite catastrophic results.

Recognition of this likely outcome from the current approach to climate-change negotiations and policies is the first step to finding a more palatable outcome. The starting point is the economics of climate change—the title of the Stern Report. The core elements of that report have become the new conventional wisdom of climate change—and all three of the main ones are open to serious challenge. The damage is likely to be much greater than the numbers generated by assuming that there is a straight substitution between environmental and man-made capital, and that therefore economic growth can continue indefinitely adding to our wealth and consumption possibilities as long as man-made capital is created faster than the environment is depleted. The costs of mitigation are likely to be higher too—if only because the Stern Report assumes away policy costs. Zero time preference may be an admirable moral principle (though contentious even as a moral principle), but it is not reflected in behaviour, nor likely to be so.

Thus the case for urgent action—the Stern Report's recommendation—needs to be grounded on an economics which presents the problem of climate change to the politicians and the public in more robust terms—by analysing the consequences of a harder constraint on the substitutability of the environment for man-made capital, and with cost assumptions based upon empirically observed data rather than idealized technical supply functions. These jointly reduce the growth rate which is likely as global warming continues and mitigation measures are put in place, and it is this consequence rather than an idealized time-preference rate which dictates the case for urgent action.

Having recast the economics of the problem of climate change, the next step is to analyse the problem of international negotiations in terms of consumption rather than production—to get the accounting sorted out. The consequence is that, for developed countries, it is not only that the costs of mitigation will be (significantly) higher, but the amount required will be higher, too.

This representation of the nature of the problem and assignment of responsibility will initially make the process of gaining an international agreement at Copenhagen harder to achieve. But a Kyoto-based approach will, in any event, probably achieve agreement at the price of not making much meaningful progress towards addressing the underlying problem. This, in turn, opens the door to alternative approaches—including the couching of the negotiations themselves in an international context, with a new international institution, and thereby helping to internalize the endemic free-rider problems. It also opens up the possibility of bringing other aspects of international relations into play, notably trade, and focusing on international R&D and more longer-term technological options. These steps will take time—hence the grim prospects—but they represent one way of eventually closing the gap between the science and climate-change policy. Unfortunately, time is, according to the scientists, of the essence.

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