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A new global deal on climate change

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Abstract A global target of stabilizing greenhouse-gas concentrations at between 450 and 550 parts per million carbon-dioxide equivalent (ppm CO_2e) has proven robust to recent developments in the science and economics of climate change. Retrospective analysis of the Stern Review (2007) suggests that the risks were underestimated, indicating a stabilization target closer to 450 ppm CO_2e. Climate policy at the international level is now moving rapidly towards agreeing an emissions pathway, and distributing responsibilities between countries. A feasible framework can be constructed in which each country takes on its own responsibilities and targets, based on a shared understanding of the risks and the need for action and collaboration on climate change. The global deal should contain six key features: (i) a pathway to achieve the world target of 50 per cent reductions by 2050, where rich countries contribute at least 75 per cent of the reductions; (ii) global emissions trading to reduce costs; (iii) reform of the clean development mechanism to scale up emission reductions on a sectoral or benchmark level; (iv) scaling up of R&D funding for low-carbon energy; (v) an agreement on deforestation; and (vi) adaptation finance.

Key words: climate change, ethics, uncertainty, instrument choice, climate policy, game theory, emissions trading, clean development mechanism (CDM), international negotiations

JEL classification: H41, Q54, Q56

I. Introduction

Climate change may not turn out to be the greatest challenge humanity faces in the twenty-first century, but there is no doubt it requires extremely serious and sustained global attention. The basic structure of the problem is now well known: humans emit greenhouse gases (GHGs), particularly carbon dioxide (CO_2), but also methane, nitrous oxide, and hydrofluorocarbons

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(HFCs), through consumption and production. These flows of emissions accumulate into stocks of GHGs in the atmosphere. The rate of accumulation depends upon Earth's 'carbon cycle', whereby CO_2 is reabsorbed into the oceans and land. Over time, the accumulated GHGs trap heat and the result is global warming. As the planet warms, the climate changes, which affects human and animal life through rising sea-levels and events such as storms, floods, and droughts. While the fundamental science has long been clear, the specific processes and impacts (both positive and negative) involve considerable uncertainty. Many of the impacts will be felt in the distant future, but it is also likely that serious impacts will be felt by many people currently alive.

While the basic science of global warming is simple, the causes and likely impacts of climate change are highly complex. This creates a major communication challenge—significant proportions of citizens in both Britain and America still do not believe that the world is warming owing to human activity (see the beginning of section III(v)). Formulating appropriate policy in the face of scientific complexity, an ambivalent general public, and a major international prisoner's dilemma, is exceptionally challenging. Solutions require an understanding of many disciplines beyond economics, including philosophy, politics and international relations, business, law. and international development, to name but a few. The inherent interdisciplinary nature of the problem creates great challenges in bringing all the relevant analytical tools to bear in an appropriate manner.

The economics of climate change is still relatively young, and needs to mature swiftly if we are rapidly to develop appropriate policy responses. GHG emissions are classified as a global public bad, possibly the most significant yet in human history. However, the economics required goes well beyond that of Pigou (1932) and Coase (1960). For instance, our conventional shortcuts break down over long time horizons, under Knightian uncertainty, and for non-marginal challenges. Transitioning from business-as-usual to stable atmospheric concentrations of GHGs is not a small perturbation around an existing path; it requires shifting from one growth path to another, and, in so doing, changing relative prices across the global economy.

The intellectual challenges are substantial; the practical challenges are enormous. Global emissions are currently increasing, driven by growing use of power generated by coal, which is abundant and therefore cheap. In the next 20–25 years, under business-as-usual, China alone will emit cumulatively more than the USA and Europe combined over the last 100 years, driven in large part by its coal consumption. As energy security continues to move up the political agenda, coal will become increasingly appealing, despite the carbon downside. This provides an indication of the necessity of agreeing an international response quickly, and the fifteenth Conference of the Parties (COP) in Copenhagen in December 2009 provides a critical opportunity to do so.

Section II discusses the appropriate global emissions-reduction target for climate change—no global deal is possible without one—including consideration of developments since the Stern Review. Section III sets out the shape of a global deal that would put the world on a path towards achieving a 450–550 ppm target, starting from the world target declared at Heiligendamm, Germany, and confirmed at Toyako, Japan, of 50 per cent reductions by 2050, with rich countries contributing at least 75 per cent of the reductions. Section IV examines the key instruments needed to implement the global deal. These include global emissions trading to reduce costs (IV(i)); reform of the clean development mechanism (CDM) to scale up emission reductions on a sectoral or benchmark level (IV(ii)); scaling up of R&D funding for low-carbon energy, particularly carbon capture and sequestration (IV(iii)); an agreement on deforestation (IV(iv)); and adaptation finance (IV(v)). Section V concludes.

II. Global targets

(i) The inescapability of ethics

Any global deal will be based upon one or more global climate-change targets, inevitably requiring consideration of normative, and specifically ethical, issues (Broome, 1992; Beckerman and Hepburn, 2007; Dietz *et al*., 2008). By emitting GHGs, humans in the past and the present are causing harm to other humans in the present and the future. While reducing emissions is costly for the current generation, while continuing to emit will be costly for future generations. Balancing the different interests at stake raises questions that are fundamentally and inescapably ethical. This is true of many, if not all, policy areas where individual interests come into conflict, but it is particularly salient in climate policy, where the conflicts of interest are also international and intergenerational. Ethics is also important from a pragmatic perspective: nation states will not sign up to an agreement they perceive to be unfair, and focusing exclusively on efficiency will do little to guarantee fairness or equity.

In the economic analysis of domestic policy, equity implications are often ignored or downplayed on the basis that they can be addressed separately through the taxation and transfer system. This intellectual shortcut can be appropriate as a theoretical device, sharpening the focus on important questions of efficiency. However, it provides only limited guidance to domestic policy formulation, because even national taxation and transfer systems are subject to important limitations.

There are two reasons why the limitations of taxation and transfer systems are particularly relevant to climate change. First, there are no simple mechanisms to redistribute wealth to future citizens, nor can they be represented in current deliberations, yet the conflict of interest is precisely between future and present generations. Second, it is impossible to apply taxation and transfer systems across international borders, yet climate policy involves conflicts of interests between citizens of different countries.

For these reasons, equity cannot be ignored. Yet some commentators suggest that a 'descriptive' approach, which focuses on determining the efficient outcome, and which generally advocates the use of current interest rates to do so, is plausible for climate change policy formulation (e.g. Baker *et al*., 2008). Even if efficiency were the sole objective, current interest rates are inadequate, for several reasons. First, in imperfect economies, Drèze and Stern (1987, 1990) show that it will not generally be true that the private rate of return on investment (PRI) will be equal to the social rate of return (SRI), and, similarly, private discount rates (PDRs) can diverge from the social discount rates (SDRs). In the general case, PDR $\neq$ SDR $\neq$ SRI $\neq$ PRI, and current market interest rates provide imperfect guidance to efficient social discount rates. Second, given uncertainty over long time horizons, the efficient certainty-equivalent discount rate will eventually decline through time (Weitzman, 2001, 2007). Third, current marginal interest rates will not yield efficient results for a non-marginal problem such as climate change (see section II(ii)).

Hence a 'descriptive' approach that employs current interest rates will not even yield the efficient future discount-rate path, let alone resolve the difficult ethical issues created by climate change. Instead, it is necessary to adopt an approach that directly accounts for the five challenges noted above: international ethical issues; intergenerational ethical issues; economic imperfections; compounding uncertainty over time; and non-marginality.

The fact that an economic assessment of climate-change policy must incorporate an explicit ethical analysis does not mean that we should insist on one particular ethical route. A number of ethical perspectives can, and should, be brought to bear. Approaches that focus directly on the consequences of climate change, such as cost–benefit analysis, command attention; so do procedural approaches highlighting rights, freedoms, and the prevention of harm, as well as approaches based on needs and virtues. Because of their importance, these value judgements must be made explicitly and directly, in a process that is open for public discussion and critical scrutiny (Sen, 1999, p. 80). Universal agreement on the appropriate value judgements is impossible. There is no easy technocratic solution, such as the recommendation that ethical parameters should simply be consistent with today's marketplace (e.g. Nordhaus, 2007).

How should we decide which of the competing ethical frameworks should be employed to develop a global climate-change target? Moral and political philosophers have proposed various methods for determining and aggregating moral values.[1] Given the impossibility of universal agreement on values, and even on the method of aggregating values, and given the centrality of ethics to climate change, sensitivity analysis over ethical frameworks and parameters is very important. Such analyses can actually aid the development of our ethical intuition by clarifying the consequences of particular ethical standpoints.

Stern (2007) discussed a range of plausible ethical perspectives, although arguably still did not do justice to a rich and evolving field of thought (Beckerman and Hepburn, 2007). In making a concrete proposal for a specific, quantitative global climate-stabilization target, on which a global deal might be based, Stern (2007) adopted a largely utilitarian perspective, and determined that the recommendation of strong action to mitigate climate change was robust to a range of different ethical parameters within a utilitarian framework. Utilitarianism is one of many approaches, and it is not necessarily favoured by moral philosophers, but the broad recommendation of strong action to mitigate climate change by reducing GHG emissions would be supported by many tenable ethical viewpoints.

(ii) The consequences of non-marginality

Even ignoring equity (which, as we have just argued, is impossible), the shortcuts of cost–benefit analysis encounter further problems in that mitigating climate change does not constitute a small perturbation around business-as-usual, but, instead, involves a shift from one economic growth path to another. In this context, the most basic mistake made by many commentators is to use a marginal concept (e.g. an exogenous interest rate) to make non-marginal comparisons between different macroeconomic paths. Climate policy will shift the pattern of growth for a whole collection of capital goods, particularly natural capital, and thus change the interest rate on manufactured, natural, and other types of capital (Sterner and Persson, 2007). Each path has an implied set of discount factors and rates associated with it (Stern, 2007, pp. 27–31; Hepburn, 2006). Thus it is incorrect to apply past interest rates, which refer to a given historical path, to vastly different future paths. Even if a 'descriptive' approach were adopted (but see above), it would need to compare the appropriate general equilibrium rates in a forward-looking manner, along different future paths, rather than simply use current or historical interest rates.

As a result, analogies with the theory of marginal investment under certainty are problematic. Concluding that climate mitigation is an 'inferior investment', compared with the

[1] Some of the more influential approaches include the 'reflective equilibrium' notion of Rawls (1971), the 'argument from received opinion' discussed by Hare (1971), the use of opinion polls (Miller, 1999), the theory of 'discourse ethics' (Habermas, 1990), and works by Griffin (1996), Barry (1995), and others. See Dietz *et al.* (2008) for further discussion in the climate-change context, and Saelen *et al.* (2008) for a specific application which aggregates stated public preferences through an internet survey of 3,000 people.

short-term pay-off from investing resources elsewhere, is unsafe; the next 200 years are highly uncertain, and the underlying structure of the economy will be transformed as changes to our climate alter the human and physical geography of the planet. The relative prices that apply along a business-as-usual pathway are significantly different to the relative prices applicable to a growth path with strong mitigation, or to a hypothetical path with no climate change whatsoever. For climate policies with impacts over 200 years, specifying the relevant path, and its associated relative prices, matters enormously to the analysis.

(iii) Recent developments and the global target

While Stern (2007) did not identify a specific numerical stabilization target, the analysis strongly suggested that the upper limit to the optimal stabilization range should not be above 550 ppm CO_2e, and that stabilization below 450 ppm CO_2e would be excessively difficult and costly. Hence, a stabilization range of 450–550 ppm CO_2e was identified. Since the Stern Review, there have been several advances and developments in the science and economics of climate change. The following sections examine how these developments impact the global target proposed by the Review.

The risks of climate change

Various commentators asserted that the Review drew heavily on studies that were pessimistic in their assessment of climate change and its impacts, giving relatively little attention to more optimistic views (Tol and Yohe, 2006; Baker *et al*., 2008) If anything, however, recent developments suggest the opposite. In retrospect, the Review could be viewed as being overly optimistic in each of the four steps linking human emissions to climate change: (i) future emissions growth; (ii) the carbon cycle linking emissions (flows) to concentrations (stocks); (iii) the climate sensitivity, linking concentrations to temperature increases; and (iv) damages from a given temperature increase.

First, the Review was probably optimistic, not pessimistic, in its assumptions about future emissions. Chapter 6 of the Review (Stern, 2007, pp. 173–88) employs the second highest of the four scenarios in the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios, or SRES (IPCC, 2000), namely the A2 scenario. However, the highest of the four scenarios, A1F1, is probably the best description of business-as-usual emissions, as indicated by Garnaut *et al*. (2008, this issue), as well as Pielke *et al*. (2008). This is primarily due to rapid growth in the developing world, particularly China and India, driven by increases to coal-fired power generation (ECIEP, 2006).

Second, the Review was optimistic in the assessment of the links between human emissions and atmospheric carbon stocks. It did not take into account the fact that the carbon cycle is likely to weaken as a result of, for example, the possible collapse of the Amazon forest at temperature increases of above 3–4°C, or the decreasing absorptive capacity of the oceans. Further, the Review did not account for the fact that a thawing of the permafrost is likely to result in additional methane release. Omitting these positive feedbacks in the carbon cycle may have led to a significant underestimate of the risks.

Third, the Review was optimistic in its assumption of how increased carbon stocks affect temperatures. The Review employed the PAGE2002 model, with triangular distributions for the climate sensitivity parameter, implying that the highest (and hence worst) possible values were cropped. The full spread from *all* (100 per cent) of the Review's Monte Carlo runs is roughly coincident within the IPCC AR4 'likely' (66 per cent confidence interval) range. The Review was therefore more optimistic than the IPCC on climate sensitivity. Other research indicates that much higher values still of the climate sensitivity cannot be ruled out (e.g. Stainforth *et al*., 2005; Meinshausen, 2006).

Fourth, the Review might be seen to have been optimistic in its mean estimates of damages from climate change. It was calculated that a 5°C warming would reduce *welfare* by the *equivalent* of a reduction of 5 per cent of GDP (Stern, 2007, p. 180). However, as Stern (2008) notes, a temperature increase of 5°C would most likely transform the physical and human geography of the planet, leading to massive human migration and large-scale conflict. As such, welfare reductions of this magnitude appear likely significantly to underestimate the damages from climate change from 5°C warming (Stern, 2008).

In summary, while the analysis in the Review provided a fair picture of the damages from climate change given the scientific and economic knowledge available at the time, it is arguable in retrospect that the Review was, if anything, too optimistic in its assessment of the risks of climate change.

The costs of mitigation

The world economy will probably have grown three-fold by 2050, so absolute emission reductions of around 50 per cent would require cuts of 80–85 per cent in emissions per unit of output. Further, since emissions from some sectors (in particular agriculture) will be difficult to cut back to anything like this extent, and since richer countries should make much bigger proportional reductions than poor countries (see section V), richer countries will need to have close to zero emissions in power (electricity) and transport by 2050.

Clearly, this is no small challenge. However, technology that is already available makes close-to-zero emissions in power by 2050 possible, if costly. Furthermore, a large-scale increase in R&D, coupled with reasonable long-term carbon prices, is likely to deliver further advances in zero-carbon power. Close-to-zero emissions in power would deliver close-to-zero emissions for most of the transportation sector. This would, however, require radical changes to the source and use of energy, including much greater energy efficiency.

In this context, costs will be a strong function of three endogenous variables. First, policy is very important—bad policy will lead to the uptake of more expensive options. Second, the rate of technical progress is very important to reducing costs, and this should be promoted by a dramatic scaling up of funding for R&D (see section IV (iii)), so that the range of options is widened and costs are reduced. Third, costs are also strongly dependent upon the speed at which emission reductions are necessary. Starting now allows more time for planned choices, gradual replacement of capital stock, and discovery of new options. This is the measured, lower cost approach. Delaying further, and then eventually moving in haste if and when damaging climate impacts change public opinion, is likely to be the expensive option.

The Stern Review reported results from two different approaches to estimating the costs of moving on to a pathway consistent with stabilization at 450–550 ppm. The first approach, based on bottom-up costs of specific technologies, suggested average costs of around 1 per cent, with a range of −1 to 3.5 per cent (Anderson, 2006; see also IEA, 2006). The reported results were based on good policy, specifically the assumption that costs would be kept down through pricing mechanisms that provided for flexibility in the type, timing, and location of emissions reduction.

The second approach looked at top-down macro modelling of costs of emissions reductions (see also Barker *et al*., 2006). Both the bottom-up (ch. 9) and the top-down (ch. 10) studies produced numbers in similar ranges, with mean estimates of around 1 per cent of world GDP. There is considerable uncertainty in these estimates. Bad policy or delayed decisions could give higher numbers. Stronger technical progress could give lower numbers, particularly in the context of an efficient emissions-trading scheme that provides firms with flexibility to take advantages of shifting cost curves, as experience with sulphur dioxide in the United States demonstrates (Carlson *et al*., 2000). This uncertainty reflects the fact that policy-makers cannot predict *ex ante* the cheapest ways to achieve emission reductions.

Since the Review was published there have been a number of new studies, both bottom-up and top-down. Examples of the former are those from McKinsey (Enkvist *et al*., 2007) and the International Energy Agency (IEA, 2007), both of which indicated costs either in the region suggested by the Review, or somewhat lower. Similar conclusions are drawn in the AR4 (IPCC, 2007). These types of analyses, while limited, are nevertheless useful in that they provide an indication of where carbon prices should be. In particular, for stabilization at 550 ppm CO_2e, it follows that by 2030 cuts at the world level would have to be of the order of 20 Gt CO_2e, suggesting a CO_2 price of around €30 per tonne (Enkvist *et al*., 2007), assuming the cost curves are accurate.

In summary, the evidence and analysis that has emerged over the last year has been consistent with the range of cost estimates for stabilization expressed in the Stern Review, or has even indicated that they may be on the high side. Fundamental to all these studies is that good policy and timely decision-making are crucial to keeping costs down. Whether or not we have good policy is, of course, not exogenous to the analysis. Pessimists look at certain policies and point to high costs. Optimists point to the experience with previous environmental trading schemes and argue that they serve as an incentive for innovation and often provide low-cost solutions that policy-makers had not expected.

Implications for the global target

We have seen that while Stern (2007) may have underestimated the risks of climate change, the mitigation cost estimates appear consistent with subsequent analyses, although the range of possible estimates remains wide. While the appropriate global target remains in the 450–550 ppm CO_2e range suggested by Stern (2007), it is perhaps more narrowly within the 450–500 ppm CO_2e range (Stern, 2008). The interim review by Garnaut (2008) indicated that Australia is now likely to seek agreement on an international target of 450 ppm, at the bottom end of that range. Given the conclusion that business-as-usual emissions are likely to follow the A1F1 scenario, a 450 ppm CO_2e scenario is very ambitious, and this target is almost impossible to meet without some overshooting.

More recently, some climate scientists have expressed the view that global targets are not ideally expressed in equilibrium quantities (e.g. Frame *et al*., 2006). They argue this is because: (i) equilibrium is many centuries, if not millennia, into the future; (ii) equilibrium parameters, such as climate sensitivity, remain poorly understood and difficult to estimate (Allen and Frame, 2007); and (iii) the transition to equilibrium will produce most of the damage. It may be that a cumulative CO_2 emissions target (Broecker, 2007; Wigley, 2007), may provide better guidance than targets expressed in terms of equilibrium parts per million of CO_2e in the atmosphere.

III. The global deal

A response to climate change will be more effective if it is organized globally and when it involves international understanding and collaboration. This need not necessarily involve a formal process such as the World Trade Organization (WTO), founded in legal structures and where no one is bound until the full deal is done, but can rather be based on a looser set of cooperative arrangements between states, built on a shared appreciation of the scale of the challenge. These arrangements should seek to minimize the costs of emission reductions, and ensure that the burdens are shared equitably in ways which take account of wealth, ability, and historical responsibility.

(i) Global emission-reduction targets

Starting from the view that an appropriate stabilization target is around 500 ppm, the first broad necessary area of agreement is on the rough pathway of global emission-reduction targets. The international discussion has already made significant progress, and a global target of 50 per cent reductions by 2050 was agreed at the combined summit of the Group of Eight (G8) and Group of Five (G5) nations, chaired by Germany in Heiligendamm in June 2007, and confirmed in June 2008 at the summit chaired by Japan in Toyako. While the base date was not specified, and other details were not spelled out, this serves as clear guidance. The 50 per cent target is for the world as whole and it is generally agreed that richer countries should take responsibility for greater reductions, in the spirit of the Kyoto language of 'common but differentiated treatment'. Taking responsibility implies paying for the emission reductions—it is less relevant whether the emission reductions occur within a particular national boundary.

(ii) Target sharing

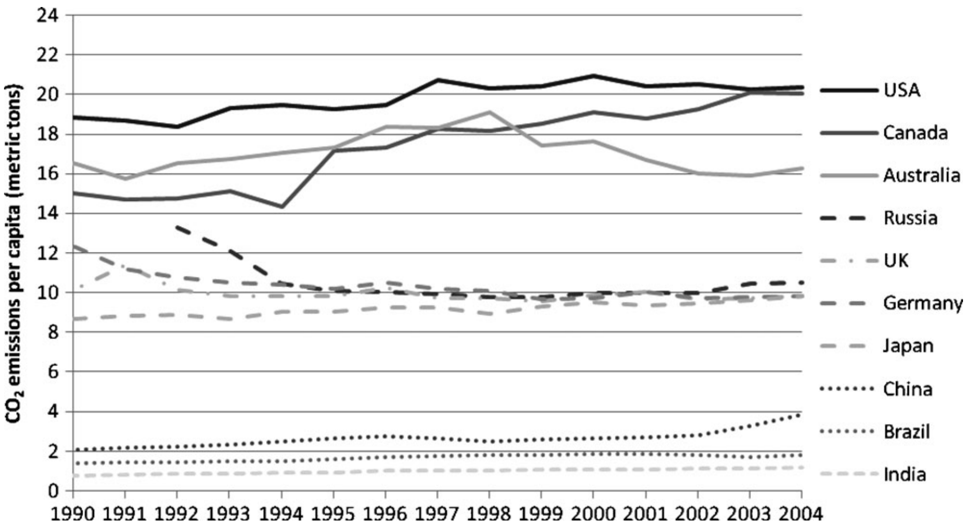
Currently global emission flows are around 40–45 Gt CO_2e each year. The world population is around 6 billion, so average global *per capita* emissions are around 7 tonnes. Reducing emissions by 50 per cent by 2050, to an aggregate flow of around 20 Gt CO_2e, will require *per capita* emissions to be around 2 tonnes, given that the world population will be around 9 billion by 2050. Even if emissions in rich countries fall to zero, people in poor countries will still need to emit only 2–2.5 tonnes, because 8 billion of the global population will live in currently poor countries. This basic arithmetic shows that the currently poor countries must be at the centre of any effective global deal.

This arithmetic is presented in terms of equalizing future *per capita* emissions, for simplicity, but this fails to account for emissions that have occurred over the last 200 years. The currently rich countries are responsible for around 70 per cent of the current stock of GHGs, and are continuing to contribute substantially more to increasing the stock than developing countries. The United States, Canada, and Australia emit around 20 tonnes of CO_2e *per capita*, Europe and Japan around 10 tonnes, China around 5 tonnes, and India around 2 tonnes, while most of sub-Saharan Africa emits much less than 1 tonne. Figure 1 illustrates *per capita* CO_2 emissions (but excluding other GHGs) from 1990 to 2004 for several countries.

In the lower part of Figure 1 are three big developing countries. China is experiencing extraordinarily rapid growth, fuelled in large part by coal-fired power, and is already above 5 tonnes *per capita* once all GHGs from all sources are accounted for (Figure 1 shows only CO_2 emissions up to 2004). It is likely that China will reach current European emission levels within 20 years or so, even with fairly conservative estimates of China's growth under business-as-usual.

With 80 per cent reductions by 2050, Europe and Japan would be around the required 2 tonnes global average level in 2050, if the 50 per cent overall reduction is achieved. At

Figure 1: *Per capita* CO_2 emissions (in tonnes)



Source: US Department of Energy's Carbon Dioxide Information Analysis Center (CDIAC) for the United Nations Statistics Division.

current emissions of around 20 tonnes *per capita*, the USA, Australia, and Canada would need a reduction of 90 per cent by 2050 to achieve emissions at the global average of 2 tonnes. Thus a 50 per cent overall reduction and an 80 per cent rich-country reduction would still leave average rich countries flows above the world average in 2050.

This does not reflect a strong commitment to equity on the part of the rich countries. A target of equal allocations of emissions by 2050 (allowing for trade) may be seen as being a fairly pragmatic one, on which it might be possible to obtain agreement. If the entire globe is subject to caps, then whether the caps are on the basis of production or consumption matters only to the initial allocation. Either way, rich countries will most likely continue to emit more than the poor, but they will pay poor countries to purchase these rights.

(iii) National targets

Many nations and sub-national states have already adopted targets consistent with emission reductions along this pathway. California has a target of 80 per cent reductions by 2050. France has its 'Facteur Quatre': dividing by 4, or 75 per cent reductions by 2050. The UK has a 60 per cent target, but in November 2007 the Prime Minister indicated that this may be increased to 80 per cent. Australia, under the new government elected at the end of November 2007, has now signed the Kyoto Protocol, and has a target of 60 per cent, and 80 per cent is under consideration after the Garnaut Review is published this summer.

But setting long-term targets is the easy part; achieving them will be altogether more difficult. Action is required immediately, so shorter-term targets are being set. At the European Spring Council, 20–30 per cent targets were set for 2020, and Germany has set 40 per cent targets by 2020. At Bali, many were pressing for rich countries to accept 25–40 per cent cuts by 2020. While extremely ambitious, this is nevertheless the appropriate range for 80 per cent cuts by 2050 for rich countries. However, experience with shorter-term targets gives pause for thought—the UK government's impending failure to meet its domestic 20 per cent CO_2 target provides but one example.

Given the scale of the challenge, some have argued that developing countries should also take binding national emission caps in the short term. Yet the only acceptable targets for poor countries at this stage would be very loose, generating 'hot air' and reducing the carbon price on international markets. Moreover, these loose targets might end up determining the baseline for subsequent negotiations. However, by 2020 developing countries will need to take on binding national targets, and current policies should be framed with this objective in mind. Some fast-growing middle-income developing countries may need to take on early sectoral targets, and possibly binding national targets, before 2020.

(iv) Agreement is challenging but feasible

Obtaining an agreement at Copenhagen, or subsequently, will be no easy task. That said, it is notable that the understanding of the challenge is increasingly shared by policy-makers around the world, and the national targets above are consistent with a broader shared goal. Based on this understanding, a framework should emerge that allows all countries to move quickly along what they see to be a responsible path. Building a deal upon a formal WTO structure, where nothing is implemented until everything is agreed, would appear to be a dangerous route. The fundamental challenge, however, is that the negotiations reflect a complex and asymmetric prisoner's dilemma, where, crudely speaking, it is in the interests of each nation to do little other than observe, while other nations bear the costs of reducing their emissions. Nevertheless, there are at least four considerations that suggest that reaching agreement, while difficult, may not be impossible.

First, there is an enormous collective pay-off if agreement is reached and collusion can be maintained. Given the scale of the costs of climate change, the collective prize for overcoming narrow self-interest and reaching a Pareto-efficient coalition is great indeed. Second, the possibility of side agreements on issues other than climate change expands the scope for nation states to reach agreement. Russia joined the Kyoto Protocol in part owing to concessions granted by the EU on WTO membership. Third, while the assumption of self-interested action by nation states is surely the best starting point, it is also clear that nation states are also motivated by other considerations, some reflecting the concerns of their particular leaders, others reflecting important notions of responsibility, capability, national pride, and self respect. Fourth, climate change will redistribute wealth around the world, both within and between nations. If and when the transition to a low-carbon economy occurs, countries which have been slow to move will find that their high-carbon assets are stranded owing to shifts in the full cost of dirty production processes. Indeed, it is not impossible, given the magnitude of the gains from 'winning' in critical low-carbon technologies, that a competitive dynamic will develop where countries race to develop the leading low-carbon technology. Given the significance of coal to the business-as-usual growth path of the global economy, at present carbon capture and sequestration would appear to be one of these critical technologies.

These reasons suggest that hope is far from lost, and agreement may well be reached. But even if it is reached, enforcement of the agreement is another matter. Developing and implementing systems of punishment for nations who fail to meet their targets is difficult. Indeed it seems likely that more than one nation will fail to adhere to its Kyoto target. Unless punishing defection is credible, selfish nation states might be expected to continue emitting at the trigger level of defection.

Public discussion and opinion may serve as one form of enforcement mechanism, even in non-democratic countries such as China, where the Communist Party is increasingly sensitive to popular opinion. The former Prime Minister of Australia was voted out of office in November 2007 in part because of his perceived weakness on climate policy. Politicians recognize the strength, and often breadth, of public interest and demand on this issue from an increasingly vocal civil society. Climate change has become a unifying and defining issue in the structures of Europe. Significant changes in perception in the key countries, the USA, China, and India, have also been observed over the last 12 months.

(v) Anticipating roadblocks

Public opinion

Just as public opinion may have already begun to serve as an enforcement mechanism at the ballot box, so too may it serve as a roadblock to sustained commitment to reduce emissions. When cuts become deeper, and as costs are incurred, country-by-country political support will be necessary in order to sustain climate-mitigation policies over time. This will require a robust and shared public understanding of the science, and agreement that action is warranted, irrespective of short-term economic conditions.

Recent polls provide conflicting indications as to whether this agreement is present or not. For instance, a majority (56 per cent) of those interviewed by a 2007 IPSOS/Mori poll in the UK agreed that 'many leading experts still question if human activity is contributing to climate change', and more than 40 per cent of Britons and Americans think that warming is not due to human activity (*The Economist*, 29 March 2008, p. 35). Boykoff (2007) argues that confusion persists because the media, at least in the United States, effectively have an incentive to portray conflict rather than coherence in scientific explanations of anthropogenic climate change. However, a BBC World Service poll of 22,000 people in 12 countries in September 2007 found that 'large majorities around the world believe that human activity causes global warming and that strong action must be taken, sooner rather than later, in developing as well as developed countries'.[2] The same poll claims to find majority support (73 per cent on average) in 10 of the 12 countries polled for an agreement in which developing countries would limit their emissions in return for financial assistance and technology from developed countries.

While it is clear that awareness of the problem has been gradually increasing over the last two decades,[3] even the otherwise encouraging BBC World Service poll shows challenges ahead; for instance, only 47 per cent of Indians believe that human activity is a significant cause of climate change. While supportive public opinion is clearly no guarantee of good climate-change policy, it is probably a necessary condition to sustain the move to a low-carbon economy, and in some important instances this condition does not yet seem to be satisfied.

[2] The survey was conducted for the BBC World Service by the international polling firm GlobeScan together with the Program on International Policy Attitudes (PIPA) at the University of Maryland. GlobeScan coordinated fieldwork between 29 May and 26 July 2007.

[3] Nisbet and Myers (2007) sifted through 20 years of polls in the USA, and found that awareness of global warming as a problem has increased steadily from 39 per cent in 1986, to 58 per cent by 1988, 74 per cent by 1990, and reaching 91 per cent in 2006.

Political economy of financial transfers

It was noted in section III(iii) that the currently poor countries must be at the centre of a global deal if it is to be effective. However, the developing countries are neither responsible for creating the problem, nor are they capable of immediately addressing it; they have other urgent priorities for their limited resources. That being so, unless the rich countries provide the finance for the extra costs of reducing carbon, developing countries are extremely unlikely to join the effort on the scale and at the pace required. The developing world rightly argues that they should not be asked to slow their economic growth just at the point when they are beginning to make progress in overcoming poverty. Financing from the rich countries, together with technology demonstration and transfer, will be necessary to convince them to move to a low-carbon growth path.

However, it is very unlikely that the public sector of rich countries will be able to provide the financial flows on the scale required to incentivize appropriate action. The political appetite for flows on the magnitude required—several tens of billions—is low. The challenges in extracting resources for Overseas Development Assistance (ODA) at the level agreed to in the Millennium Development Goals serve as a clear warning against relying upon public financial flows. Furthermore, public aid will be strained still further by the challenge of adaptation, discussed below.

The carbon-trading system is the most feasible model for supporting private financial flows on the scale necessary for the developing world to reduce its emissions on the scale required. Already, as noted below, the CDM is transferring several billions of euros to the developing world, contributing to reducing the costs of compliance in Europe and other developed countries, and reflecting the fact that, given the irrelevance of where reductions occur, firms in rich countries have a strong incentive to finance them in the cheapest location, which is often in the developing world. Carbon trading provides a legitimate and coherent rationale for financial transfers on the scale necessary to shift China, India, and other developing economies on to cleaner growth pathways.

IV. Climate instruments

Implementing the global deal will require the use of a range of different policy instruments at the international, national, and sub-national levels. There are five key components: carbon pricing; support for low-carbon R&D; financial support to reduce deforestation; other domestic instruments; and finance for adaptation.

(i) Carbon pricing

Any satisfactory global deal will place a price on GHG emissions, both to provide an incentive to reduce them and also to minimize the costs of abatement. Indeed, a carbon price would be sufficient to internalize the greenhouse externality in a world without any other imperfections. But, in our imperfect world, a carbon price alone is inadequate, given the urgency of reducing emissions, the inertia in decision-making, and the other market imperfections, including those relating to low-carbon R&D. So a carbon price is a necessary, but not a sufficient, component of the global deal.

Putting a price on GHG emissions can be done in three main ways: carbon taxes; carbon trading; and implicit pricing via regulations and standards. Each of the three approaches has different advantages and disadvantages, and all three are likely to be used in some form at some level of government. For instance, a great deal of research indicates that the uptake of energy efficiency by individual consumers is relatively insensitive to energy prices (Oxera, 2006). Carbon pricing would, therefore, be expected to do little to increase the uptake of domestic energy efficiency measures. In contrast, behavioural change is likely to be better stimulated by policies that provide information, reduce cognitive costs, hassle costs, and transactions costs. Pricing will do little to overcome these hidden costs and information imperfections. This is not to say that explicit carbon pricing via taxes or trading is not necessary—it is clearly a core part of appropriate climate policy—but rather that it is not sufficient to capture all economic reduction opportunities.[4]

Taxes and trading are ‘dual’ instruments: they provide identical results under idealized conditions with no uncertainty. Where there is uncertainty, taxes fix the carbon price but leave the quantity of emissions uncertain, such that, for instance, setting taxes too low would lead emissions to overshoot their target. The science makes clear that overshooting on emissions is dangerous. In contrast, carbon trading can guarantee that a particular emissions target is achieved. The European Union Emissions Trading Scheme (EU ETS) covers around one-half of European emissions with relatively low administrative burdens by focusing on major emitting industries. However, an implication of carbon trading is price uncertainty and volatility, and firms would ideally prefer clear and simple signals for decision-making and investment, which a tax provides. With learning and readjustment of policy the difference in effects between carbon taxes and carbon trading can be reduced. However, continual policy readjustment creates further uncertainty for firms that increases the cost of capital for low-carbon investments.

Carbon trading has been selected as the instrument of choice because of its appealing political characteristics. By starting with allocations which are not paid for, and moving to auctions, trading schemes have been accepted by industry because they allow for a less dramatic adjustment than a carbon tax. Free allocations based on historical emissions have significant drawbacks. First, they create a perverse incentive for firms to increase emissions in order to get more permits. Second, they lead to a sluggish management response since there are no immediate balance-sheet pressures. Third, they can give competitive advantages to incumbent firms, who may succeed in getting large quota allocations, and thus reduce competition and promote rent-seeking (indeed, intensive lobbying occurred in Europe, and windfall profits as a result of allocation hand-outs were observed). Finally, they lose public revenue. Thus moving to auctioning over time has strong advantages and should be a clear and transparent policy (Hepburn *et al*., 2006).

A further feature of carbon trading is its role in international efficiency and collaboration. International trading reduces costs, from the usual gains from trade, and provides an incentive for poor countries to participate in the global deal. The importance of these arguments, on cost and collaboration, is a central reason why there should be a very substantial element of carbon trading in policy in rich countries, with openness to international trade, backed by strong rich-country targets for reductions, in order to maintain prices at levels which will give incentives both for reduction at home and purchase abroad.

Price volatility is also a potential problem with carbon trading, when the market rules are unclear and when trading is narrow and thin, rather than broad and deep. The first phase of the EU ETS (2005–7) is sometimes cited as an example, but in fact the primary problem

[4] See Hepburn (2006) for an overview of the advantages and disadvantages of taxes and trading.

in that scheme was that too many allowances were allocated, resulting inevitably in a price collapse. Prices in the second phase (2008–12) of the EU ETS have so far been more stable, and are currently over €20 per tonne. Greater trading across sectors, periods, and countries should also reduce volatility.

Difficulties may arise in trading emissions with countries with low price ceilings or with overly generous allocations and correspondingly lower carbon prices. Linking of different trading schemes will need to address these issues, and ensure consistency of definitions and units of account. Further difficulties may arise when trading goods with countries which have not adopted strong measures against climate change. There is, in principle, a case for levying appropriate border taxes, or requiring the purchase and retirement of carbon allowances, on goods from such countries which do not otherwise embody a carbon price. A system analogous to the operation of the border procedures for VAT could be envisaged. However, this is a second-best alternative and care would be necessary to ensure that border adjustments did not generate a round of protectionist policy.

One further advantage of carbon trading, when conducted over relatively long time periods, is that the market establishes a forward price for allowances. Investors buy or sell forward emissions allowances until a forward price curve emerges that causes the expected return from holding an allowance to equal that on alternative investments, as reflected by the opportunity cost of capital. The whole price curve—the spot price, and all of the forward prices, together—embodies the market's expectations on what will be necessary to comply with the future pathway of agreed emission reductions. The forward price curve provides stability to the market, with opportunities for hedging price risks and adjusting quickly to new information.

Trading over longer periods also provides firms with 'when' flexibility as well as 'where' flexibility—firms can use their carbon allowances at the point when they have greatest value. Many of the low-carbon investments that are needed now, to avoid high-carbon lock in, are long lived. A market that provides long-term certainty of a reward for low-carbon investment will reduce the cost of capital for these investments.

(ii) Reforming the CDM

The current system for trading between rich and poor countries, the Clean Development Mechanism (CDM), was established by Kyoto and operates at the level of a project in a poor country (so-called 'non-Annex 1' country in the Kyoto Protocol). If a firm in a rich country (an 'Annex 1' country) is part of a trading scheme (such as the EU ETS) which recognizes the CDM, then that firm can buy an emissions reduction achieved by the project, provided the project employs approaches and technologies from an admissible list, amounting to the requirement that the project would not have occurred in the absence of the funds from the CDM. The amount of the notional reduction is determined by comparing the project with a counterfactual, or baseline, which sets out what might otherwise have happened. Approval of a project goes through the rich and poor country authorities and the CDM Executive Board in Bonn.

In some respects, the CDM has been the success story of carbon trading to date. It has delivered emissions reductions from thousands of projects and generated billions of euros of investment in a short space of time, producing emission reductions at relatively low cost. It has also provided an important platform for engaging the developing world in efforts to mitigate climate change. As a market, the CDM is functioning as one would expect it to. Despite relatively high transaction costs and bureaucratic barriers, the private sector has developed a wide range of methodologies to reduce emissions, which have been submitted for approval to the CDM Executive Board, and efforts have focused on picking the 'low hanging fruit', or the cheapest emission reductions. In short, the CDM market has directed private-sector efforts to the short-term efficient outcome.

The short-term efficient outcome, however, involves emission-reduction projects being concentrated in relatively few countries, particularly China and India, and further being focused on gases other than CO_2 in relatively few industry sectors—in particular, on HFC-23 from refrigerant manufacturing. As such, the CDM is doing relatively little to address the crucial long-term need to reduce CO_2 emissions from the energy sector at a time when high-carbon capital assets are being locked in. For instance, the CDM has done little to stop China from rapidly increasing coal-fired power-generating capacity, most of which is likely still to be operating in several decades, and most of which may be costly to retrofit with carbon capture and sequestration (CCS) technology. Second, it is contributing very little to sustainable development in the poorest countries, which was one of the original objectives of the mechanism. In particular, projects in Africa constitute a tiny percentage of the total.

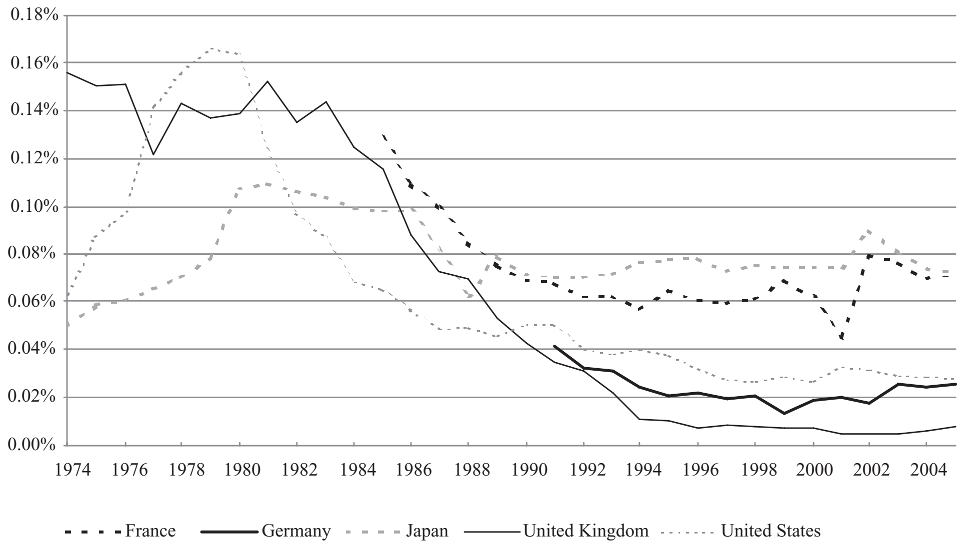
Another significant problem arises because of the reliance upon defining a baseline, or counterfactual, to determine whether the project would have happened anyway. Here, the mechanism faces difficult challenges of asymmetric and uncertain information. Firms applying for carbon credits under the CDM, called 'certified emission reductions' (CERs), have more information about this hypothetical baseline than the regulator, because they are more likely to know what they would have done if the CDM had not existed. Unsurprisingly, these problems of asymmetric information have generated opportunities for gaming, coupled with classic symptoms of moral hazard and adverse selection. The net result is that a small proportion of CERs have been issued to projects which probably would have happened without the CDM.

The CDM also created some perverse incentives. Governments have an incentive not to impose regulations on emissions if this means that lucrative CDM projects are incorporated into the baseline. In other words, the CDM reduces the incentives of developing-country governments to enact policies reducing emissions. Project participants have an incentive to design their projects so that they just, at the margin, fail to be economically sensible without the support of carbon finance through the CDM.

The two key objectives of CDM reform are to scale up the mechanism, so that it can deliver significantly greater finance and emission reductions, and to ensure the integrity of the mechanism, by reducing information problems and perverse incentives. Scaling up will require a much simpler, 'wholesale' CDM. Wholesale measures might include sectoral benchmarks, so that firms would receive credits for achieving a stipulated emissions intensity per unit output, or technological benchmarks, such as employing CCS (which is currently excluded from CDM). Standardized emissions-intensity factors for specific sectors would improve upon the relatively slow and costly case-by-case nature of the current CDM. Because the mechanism would remain one-sided, providing a 'no-lose' mechanism for participating countries, so that there are benefits for reducing emissions but no penalties for business-as-usual, these benchmarks could be set very ambitiously.

Defining benchmarks is complicated, however, by the need to recognize specific local circumstances. For instance, local factor prices of labour and natural capital, including energy endowments (e.g. wind, water, geothermal, etc.), will strongly determine the feasibility of achieving particular benchmarks. In some industries, the entire supply chain may have to be

Figure 2: Public energy R&D investments as a share of GDP



Source: Stern (2007, p. 401).

covered to ensure that carbon-intensive activities are not simply outsourced. Data availability may also prove to be problematic if companies and countries prove unwilling to share data for commercial reasons.

Sectors where benchmarks might work include most emissions- and energy-intensive industries, including electric power, refining, pulp and paper, metals, and cement. In sectors that are particularly subject to international competition, such as aluminium and steel, the benchmarks would probably mirror the efficiency levels expected from firms in industrialized countries (for example, those used in the allocation of allowances in an emissions-trading scheme). In some sectors this might take the form of global sector agreements. Standardized benchmarks would help to reduce the risk of carbon leakage, alleviate competitiveness concerns, and thereby help to preserve free trade in these sectors.

(iii) Research and development

Public support for R&D in energy has fallen dramatically since the early 1980s, as Figure 2 illustrates. This trend needs to be rapidly reversed in order to stimulate a portfolio of new technology options that are ready for deployment to reduce emissions from 2030 and in the longer term. Large-scale contributions from the public finances will be necessary to ensure the optimal levels of investment, because research has public-good characteristics. The fruits of research into low-carbon technologies will not necessarily be fully protected by the patent regime, and each country's public efforts to support low carbon R&D will benefit other countries, leading to inadequate financing in the absence of an international agreement. Furthermore, private- and public-sector R&D spending on energy have been closely correlated in the recent past, so partnerships where the public and private sectors each bear different risks may enhance both private and social returns.

In addition to support for fundamental research, the commercial demonstration and sharing of existing technologies is urgent. Demonstration of CCS for coal is particularly urgent given the abundance and low cost of coal reserves (Helm, 2008, this issue). While there are a couple of dozen demonstration plants at different levels of maturity, there are no current commercial plants using CCS for coal. Stern (2008) argues that, from 2015 or 2020, most new coal-fired generation globally will need to be fitted with CCS for there to be any chance of realizing the 2050 targets. He argues that feed-in subsidies, world-wide, of around $5 billion p.a. could support over 30 plants over the next 7 or 8 years across a portfolio of specific technologies and countries. Note that this does not require every individual country to run its own CCS portfolio, and individual countries might aim to develop expertise in specific CCS technologies. Certainly, we need to know soon whether CCS will be relatively cheap or expensive on the necessary scale, so that alternative cost-effective strategies can be developed if necessary.

Other technologies should also be supported, with a variety of policies as set out by Stern (2008). One of the most significant challenges will be to avoid a low-carbon technology pork-barrel. The last few years have seen several potentially promising developments, including new materials and technologies for solar photovoltaics (other than silicon), various biotechnologies to sequester carbon, along with industrial carbon-capture processes. But governments have a poor record at picking the winning technologies and, indeed, the crucial low-carbon technology may yet to be invented. To the extent possible, technology-neutral mechanisms need to be employed, including prizes, tournaments, auctions, and distribution of grants through university channels.

Financial resources must be rapidly committed, and institutional arrangements designed to ensure those resources are delivered. Garnaut (2007) proposes that countries above a given threshold of GDP *per capita* should spend a fraction of their GDP above that threshold on public support for 'research, development and commercialization of new technologies relevant to the transition to a low-emissions economy'. Much of this funding might be raised through hypothecation of revenues from auctioning national emission allowances.[5] Each government would determine which specific technologies it would support, subject to meeting agreed criteria for the public-good or global-benefit nature of the spending on technological development.

(iv) Deforestation

Emissions from global land-use change probably amount to 5–8 Gt CO_2e per annum, implying that up to 20 per cent of current emissions are from this category, primarily deforestation in Brazil and Indonesia. Deforestation occurs because the value of the logged timber, coupled with the value of converting the forest to agriculture (including for production of commodities such as soy and palm oil), is greater than the value of the standing forests. Reducing these emissions requires a framework that accounts for the full opportunity costs of land and provides the institutional, administrative, and enforcement measures necessary.

Stern (2008) estimated that emissions from deforestation could be roughly halved for around $5 per tonne of CO_2, at a total of $15 billion per annum. The opportunity-cost

[5] Hypothecation may not be considered credible when 'new' revenues are, in fact, merely allocated to pre-existing programmes, with the funds for the pre-existing programmes returning to the general budget. Here, however, the new financial flows from allowance auctions would significantly exceed existing flows to low-carbon R&D, thereby guaranteeing a net R&D increase.

component of these estimates ranged from $3 billion (Grieg-Gran, 2006) to $33 billion (Obersteiner, 2006) annually. These estimates will now be much higher, given recent increases in agricultural commodity prices. Implementation of a scheme to reduce emission from deforestation and degradation (REDD) will be challenging. Property rights need to be strengthened, as do democratic institutions which are needed to protect the poor and to resolve and arbitrate between competing usage claims. This is extremely important, because an estimated 1.6 billion people depend on forests for their livelihoods (World Bank, 2004). Administrative costs of delivering funds through a national payment scheme, one of the possible alternatives, may be up to $1 billion annually (Grieg-Gran, 2006). Institutions, such as the World Bank's Forest Carbon Partnership Facility, will be needed to support capacity in rainforest nations, to develop national deforestation strategies, and to put in place monitoring systems to ensure objectives are met. The private sector, which currently provides 90 per cent of the total forest finance (Tomaselli, 2006), also has a major role to play in reducing deforestation rates, potentially through the voluntary and, in the longer term, the compliance-based carbon markets.

Cost will be as low as possible when programmes are coordinated internationally and are as large-scale as possible; this reduces the risk that reduced deforestation in one country is simply displaced into deforestation activities in another country. Developing alternative sources of supply for existing demand that drives deforestation is critical. Given capital requirements, public-sector funds will need to be combined with private-sector flows, with a view to ultimately working towards the trading of credits earned through preserving forests.

As with the political economy considerations of international financial transfers more generally (see section III(v)), large payments for avoided deforestation could become unpopular in the countries buying permits if the funds are not directed towards achieving clear development goals. As such, a development framework to support payments for avoided deforestation would need to be agreed as an important component of a global deal on reduced emissions from deforestation and degradation.

(v) Adaptation finance

Even if the ambitious global emission reduction targets to 2050 are achieved, Earth will warm by another 1–2°C, and it will be necessary for humans to adapt to a changing climate. This will be particularly difficult for poor countries, which lack the resources to prepare for and respond to these changes. The UNDP Human Development Report has estimated additional costs for developing countries of around $86 billion annually by 2015 (UNDP, 2007), while the UN FCCC (2007) estimates adaptation costs to be $28–67 billion annually by 2030.

Delivering this level of adaptation finance will be difficult. Indeed, it is already proving difficult to achieve the official development assistance (ODA) promises of the UN Financing for Development conference in Monterrey in 2002, in connection with the Millennium Development Goals. If, as many have promised, the OECD countries move to providing 0.7 per cent GDP in ODA by 2015, this would generate $150–200 billion in additional development finance annually. However, the Millennium Development Goals did not adequately address climate change. If support for climate adaptation is added, then delivering ODA of 0.7 per cent GDP would only barely meet the responsibilities of the rich nations to the poor. Beyond 2015, assessments of the appropriate level of development assistance should account for the likely additional costs from climate change. Much more detailed risk and impacts information will be necessary to ensure development proceeds in a fashion that is resilient to climate changes.

It is important that financial assistance for climate adaptation be integrated into development spending more generally. Countries with good governance and successful diversified economies are less vulnerable to shocks of all kinds, including those related to climate impacts. Spending should be directed to developing broader social resilience to environmental changes, rather than being earmarked for climate-specific adaptation projects, which may not yield social returns as high as other development priorities.

V. Conclusion

Reaching a new climate agreement is both urgent and important, and will be exceptionally challenging. Many of the trends are adverse (Helm, 2008), but a new global deal on climate is nevertheless possible and, indeed, necessary. The international community now has a broadly shared understanding of the objective, with the basic outlines coming into focus. A new global deal should seek to stabilize atmospheric concentrations of GHGs at around 500 ppm CO_2e, or place an equivalent limit on cumulative emissions of CO_2e. Achieving that broadly requires setting a pathway to reduce global emissions by 50 per cent in 2050, with rich countries reducing their emissions by at least 75 per cent.

The instruments required to achieve this are feasible. Global emissions trading, built by linking existing and new emissions-trading schemes, will establish a shared global carbon price to reduce costs. The reform of the CDM is crucial to both scale up emission reductions on a sectoral or benchmark level, and to deliver the necessary finance to the developing world. Similarly, a dramatic scaling up of R&D funding for low-carbon energy is necessary to ensure that new technologies have been invented and are in place by the time they are needed from 2030 and beyond. In the shorter term, an agreement on deforestation is important to capture large-scale emission reductions at relatively low cost. Finally, in the longer term, the demands for finance to adapt to inevitable climatic changes will continue to grow, irrespective of the success or otherwise in agreeing a new global deal.

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