Oxford Review of Economic Policy, Volume 24, Number 2, 2008, pp.239–258

Climate treaties and the imperative of enforcement

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Abstract The emission limits in the Kyoto Protocol are too generous. Simply tightening these limits, however, will not make a new climate treaty any more effective at addressing climate change unless the other problems with Kyoto are also addressed. A new climate treaty arrangement must enforce both participation and compliance. This might be done by applying an enforcement mechanism, such as a trade restriction, to a new treaty styled after Kyoto. Potent trade restrictions, however, may lack credibility and legitimacy. An alternative approach recommended here is to break the problem up, with separate (but linked) agreements addressing individual gases and sectors, using the most appropriate means to enforce each component of the system. In bundling together all sectors and greenhouse gases in a single agreement, Kyoto has aimed to achieve cost-effectiveness at the expense of enforcement, which depends on the treaty's weakest enforcement link. The imperative must be to ensure that any future treaty arrangement can be enforced.

Key words: enforcement, participation, compliance, trade restrictions, Kyoto Protocol, Montreal Protocol
JEL classification: Q54, F51, F53

I. Introduction

Though the Kyoto Protocol entered its implementation phase only this year, attention has already turned to negotiating the next climate agreement. One reason for this is that Kyoto terminates in 2012 and it will take time to negotiate a follow-on agreement, to bring this agreement into force, and for its parties to pass the domestic or EU legislation needed to implement it. The more important reason, however, is that the Kyoto Protocol will have no discernable impact on the climate. More needs to be done.

How much more? There is broad agreement among economists that emissions should be reduced below the 'business as usual' level, today and in the future. There is also broad agreement that greenhouse-gas concentrations should not be allowed to increase without limit.[1] Even 'gradual' climate change will eventually melt Greenland ice, causing sea level

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I am grateful to Christopher Allsopp, Dieter Helm, Cameron Hepburn, Paul Klemperer, and David Victor for comments on a previous draft.

[1] Nicholas Stern (2007) and William Nordhaus (2007) disagree about the level of emission reductions that should be undertaken immediately and the desirable future emissions path.

doi: 10.1093/oxrep/grn015

to rise several metres over many centuries. 'Abrupt and catastrophic' climate change is more uncertain, but would cause greater damage, and is more likely to occur as concentrations climb. So, eventually, concentrations must be capped, and this can only be done if emissions are reduced very substantially.[2]

To stabilize atmospheric concentrations, the amount of carbon dioxide (CO_2) emitted into the atmosphere has to equal the amount that is taken up by the oceans. The balance of CO_2 between the atmosphere and the oceans depends on the rate at which surface waters mix with the deep ocean. Currently, the system is in disequilibrium; the oceans are absorbing CO_2. For the oceans and the atmosphere to approach equilibrium (over a period of a few centuries), (net) emissions to the atmosphere must fall to zero, to equal the rate of uptake by the oceans, which must be zero in equilibrium. I want to stress that this qualitative picture is true for any stabilization target. Eventually, stabilizing concentrations will require a technological revolution.

The important treaty design question is whether this long-run goal can be achieved by merely tightening Kyoto's emission caps, leaving the treaty's basic architecture unchanged, or whether more fundamental change is needed. In this article I explain why fundamental change is needed.

Climate change may or may not be the most important problem the world has ever faced, but it is certainly the greatest challenge for collective action. As I shall explain in this paper, this is true both in theory and in practice. It has certainly been true in practice thus far. In 1988, at a quasi-political conference held in Toronto, participants concluded that global carbon-dioxide (CO_2) emissions should be reduced 20 per cent from the 1988 level by 2005. Through 2004, however, and despite two climate treaties having entered into force, global emissions increased 32 per cent.[3] A gap this big (50 per cent), opening up over a period of just two decades, hints at the magnitude of the collective-action challenge.

The Toronto target is important not only because it was the first target ever proposed but because it was a global target, and only global emissions matter. The problem with global targets, however, is that everyone is responsible for meeting them—meaning, of course, that no one is responsible for meeting them.

What about individual targets? After the Toronto meeting, Austria, Denmark, Italy, and Luxembourg all pledged to meet the Toronto target individually (by reducing their individual emissions 20 per cent from the 1988 level by 2005). In the end, however, none did so.[4] (The Labour Party's 1997 manifesto pledged to reduce Britain's emissions 20 per cent from the 1990 level by 2010, but this target is also expected to be missed.) These (and many other) individual targets were not met because reducing emissions unilaterally is costly and doing so promises little benefit to the country that shoulders this cost. Of course, if every country fails to reduce its emissions, atmospheric concentrations will keep on rising (they have been rising steadily since the first measurements were taken in the late-1950s), and all countries will be worse off (at least in the longer term). Put concisely, this is the collective action problem.

In February 2007, the European Union unilaterally set the goal of reducing emissions 20 per cent from the 1990 level by 2020.[5] The EU pledged to reduce its emissions by

[2] Even if we stabilize concentrations at 1,000 parts per million CO_2-equivalent—and no economist I know is recommending this—emissions would need to peak before the end of this century and then decline after this (IPCC, 2007, p. 15).

[3] See http://cdiac.ornl.gov/ftp/ndp030/global.1751_2004.ems

[4] The targets are summarized in International Energy Agency (1992).

[5] In 2005, EU-27 emissions were almost 8 per cent below the 1990 level; see European Environment Agency, *Annual European Community Greenhouse Gas Inventory 1990–2005 and Inventory Report 2007*, Technical Report No. 7, 2007.

30 per cent (again, from the 1990 level), provided the United States and other industrialized countries agreed to the same target. By making its own (higher) target contingent on other countries, the EU may have been aiming to create an *incentive* for other countries to reduce their emissions; it may have been trying to address the collective action challenge. But will its offer change the behaviour of these other states?

History is not encouraging.[6] According to the *Guardian*, EU officials called the proposal an 'opening bid' for the post-Kyoto negotiations.[7] Over 10 years ago, European officials travelled to Kyoto with another opening bid—a proposal to cut their emissions 15 per cent if the other OECD countries did so, too. That offer was rejected, and Europe eventually agreed to reduce emissions by just 8 per cent. In 1992, the European Community proposed a mix of measures, including a carbon/energy tax, to stabilize EC emissions at the 1990 level. Like the EU's recent proposal, the EC's tax was made contingent on other OECD countries adopting the same tax. The other OECD countries rejected the offer; the EC dropped the tax.

The idea of making obligations contingent is also a feature of the Kyoto Protocol. Its emission limits only become 'binding' (in the legal sense of the word) on each of its parties if the agreement enters into force, and entry into force depends on the ratification decisions of a substantial number of countries. Unfortunately, and as explained later, this mechanism also has done little to change behaviour.

II. Kyoto Protocol

The logic of the Kyoto Protocol goes something like this: The Kyoto Protocol was intended to be a first step. It requires small (about 5 per cent, on average) reductions in the emissions of industrialized (Annex I) countries for a short period of time (2008–12). Kyoto was to be followed by a sequence of other agreements—a second step, a third step, and so on—with each new agreement progressively lowering the limit on the emissions of Annex I countries. It was expected that, in time, the non-Annex I countries would also agree to limit their emissions. Eventually, it was hoped, every country would be subject to an emission cap.

Associated with these country-specific caps would be a price on greenhouse-gas emissions. This price would be a 'shadow price' if emissions were regulated domestically. It would be a market price if the caps were implemented by a tradable emission entitlement scheme. It would be a tax rate if countries chose to implement their obligations by means of a carbon tax. However countries sought to reduce their emissions domestically, the treaty's 'flexible mechanisms' would ensure that the price on emissions would be equal internationally, making global abatement cost-effective. As the caps were progressively tightened in future agreements, this world price on greenhouse-gas emissions would increase, stimulating a range of activities from energy conservation to fuel switching. Expectations about its future growth would encourage energy R&D. Eventually the rising price path would lead to substitution of

[6] As well, to call for identical percentage cuts in emissions from the same base year is to ignore differences among countries. The EU-27 includes countries in economic transition. The emissions of these countries are already substantially below the 1990 level for reasons of restructuring. For other OECD countries to meet the same target would not reflect 'equal sacrifice'. This is the 'comparability' problem, discussed later in this paper.

[7] I. Traynor and D. Gow, 'EU Promises 20% Reduction in Carbon Emissions by 2020', the *Guardian*, 21 February 2007.

renewable or nuclear energy for fossil-fuel energy. Alternatively, fossil fuels would continue to be burned but with the emissions captured and stored. Kyoto did not specify the technological means by which emissions would be cut; its purpose was to support a collective end: a limit on atmospheric concentrations. In particular, Kyoto's purpose was to lay a foundation for meeting the goal of the Framework Convention on Climate Change (FCCC)—to ensure that concentrations would be stabilized 'at a level that would prevent dangerous interference with the climate system'.

This is an elegant and audacious construct. Can it work? An effective international agreement for climate-change mitigation must do three things; Kyoto, unfortunately, does none of them.

First, a treaty must attract broad *participation*. This is not only because all countries emit greenhouse gases. It is also because, should only some countries reduce emissions, comparative advantage in the carbon-intensive industries will shift to the other countries, causing *their* emissions to increase—a phenomenon known as 'trade leakage'. Kyoto failed to deter the United States from not participating, partly because of US concerns about leakage. It may seem that the USA is an outlier, but China, India, and the other developing countries only participated in the Kyoto Protocol because the agreement does not require that they reduce their emissions. Similarly, Russia and the economies in transition participated because they were given a surplus of emission entitlements—'hot air' (see Table 1, where the economies in transition are set off in bold). Under Kyoto, very few countries are required to reduce their emissions.

Second, a treaty must create incentives for *compliance*. Canada is a party to the Kyoto Protocol, required to reduce its emissions 6 per cent below the 1990 level through 2008–12. In 2005, however, Canada's emissions were 30 per cent *above* this target, and Canada's current government has given up on the idea of meeting the Kyoto target. It aims instead to reduce the rate of growth in emissions, hoping that Canada's emissions will peak around 2010, the mid-point of Kyoto's implementation period. A government-funded roundtable, however, has concluded that the government's policies will not meet even this modest goal.[8] Canada's previous government—the one that ratified Kyoto but that did not adopt the policies needed to comply with it—predicted that Canada's emissions would exceed the Kyoto target by 45 per cent by 2010 (Government of Canada, 2005). This still remains distinctly possible.[9] Canada's situation is extreme, but it is not the only Kyoto party in jeopardy of non-compliance. As shown in Table 1, the compliance gap is significant for many countries, including New Zealand and Japan. The caps for some members of the European Union also appear challenging. Spain has the largest gap of any country. Denmark is well off its individual target. However, thanks to the European 'bubble,' these countries are not bound by their individual limits so long as the original 15 members of the European Union meet their collective limit. Australia recently ratified the Kyoto Protocol, but as Table 1 shows, after taking land use, land-use change, and forestry (LULUCF) activities into account, Australia is within its Kyoto limit; Australia will have to do very little to comply.[10]

[8] For the relevant section of the roundtable's report, see http://www.nrtee-trnee.ca/eng/publications/c288-response-2007/section4-c288-response-2007-eng.html

[9] The current government's projections are that Canada will exceed Kyoto's limits by around 34 per cent; again, see http://www.nrtee-trnee.ca/eng/publications/c288-response-2007/section4-c288-response-2007-eng.html

[10] LULUCF is normally treated differently because of various accounting and incentive problems. For example, carbon accumulated in forestry may later be released.

Table 1: The Kyoto compliance gap

Annex I country	Kyoto cap from base year	Excluding LULUCF		Including LULUCF	
		Change from base year to 2005	Gap	Change from base year to 2005	Gap
Australia	+8	25.6	17.6	4.5	−3.5
Austria	*−13*	*18.0*	*31.0*	*13.6*	*0.6*
Belgium	*−7.5*	*−1.3*	*6.2*	*−0.6*	*6.9*
Bulgaria	**−8**	**−47.2**	**−39.2**	**−59.3**	**−51.3**
Canada	−6	25.3	31.3	54.2	60.2
Croatia	−5	−3.4	1.6	−10.2	−5.2
Czech Rep.	**−8**	**−25.8**	**−17.8**	**−27.5**	**−19.5**
Denmark	*−21*	*−7.0*	*14.0*	*−9.8*	*11.2*
Estonia	**−8**	**−50.9**	**−42.9**	**−61.4**	**−53.4**
EC	−8	−1.5	6.5	−4.0	4.0
Finland	*0*	*−2.5*	*−2.5*	*−22.8*	*−22.8*
France	*0*	*−1.6*	*−1.6*	*−7.1*	*−7.1*
Germany	*−21*	*−18.4*	*2.6*	*−19.5*	*1.5*
Greece	*+25*	*26.6*	*−1.6*	*25.3*	*0.3*
Hungary	**−6**	**−30.7**	**−24.7**	**−32.7**	**−26.7**
Iceland	+10	10.5	0.5	0.3	−9.7
Ireland	*+13*	*26.3*	*13.3*	*24.9*	*11.9*
Italy	*−6.5*	*12.1*	*18.6*	*7.4*	*13.9*
Japan	−6	6.9	12.9	7.1	13.1
Latvia	**−8**	**−58.9**	**−50.9**	**−161.5**	**−153.5**
Liechtenstein	−8	17.4	25.4	18.4	26.4
Lithuania	**−8**	**−54.1**	**−46.1**	**−64.8**	**−56.8**
Luxembourg	*−28*	*0.4*	*28.4*	*0.4*	*28.4*
Monaco	−8	−3.1	4.9	−3.2	4.8
Netherlands	*−6*	*−0.4*	*5.6*	*−0.4*	*5.6*
New Zealand	0	24.7	24.7	22.7	22.7
Norway	+1	8.8	7.8	−23.1	−24.1
Poland	**−6**	**−32.0**	**−26.0**	**−33.8**	**−27.8**
Portugal	*+27*	*42.8*	*15.8*	*40.3*	*13.3*
Romania	**−8**	**−45.6**	**−37.6**	**−53.5**	**−45.5**
Russia	**0**	**−28.7**	**−28.7**	**−27.7**	**−27.7**
Slovakia	**−8**	**−33.6**	**−25.6**	**−32.5**	**−24.5**
Slovenia	**−8**	**0.4**	**8.4**	**−20.1**	**−12.1**
Spain	*+15*	*53.3*	*38.3*	*59.8*	*44.8*
Sweden	*+4*	*−7.3*	*−11.3*	*−8.2*	*−12.2*
Switzerland	−8	1.7	9.7	4.6	12.6
Ukraine	**0**	**−54.7**	**−54.7**	**−58.7**	**−58.7**
United Kingdom	*−12.5*	*−14.8*	*−2.3*	*−15.4*	*−2.9*
United States	−7	16.3	23.3	16.3	23.3

Note: The countries in italics were the 15 states covered under the European bubble. The countries in bold are economies in transition. These countries were allowed to choose an alternative base year to 1990.
Source: http://unfccc.int/resource/docs/2007/sbi/eng/30.pdf

Third, a treaty must somehow get countries to participate in and to comply with an agreement in which global emissions are to be reduced substantially. Participation in the FCCC is nearly full (the only non-participants are Andorra, the Holy See, Iraq, and Somalia). Moreover, compliance with this agreement is perfect. However, the Framework Convention does not require that parties reduce their emissions. Kyoto requires that some parties reduce their emissions—but, overall, these requirements are exceedingly modest and short term. Even

if participation in Kyoto were full and compliance perfect, global emissions of greenhouse gases would keep on rising.

These problems with Kyoto are more easily understood by contrasting this agreement with one that works well.

In 2002, the United States imposed tariffs on steel imports. The European Union, supported by other countries, complained to the World Trade Organization (WTO) that the US tariffs were in non-compliance with WTO rules. A WTO panel convened to hear this case agreed. So did an appeals panel. Under WTO rules, the USA was at this time obligated to remove its tariffs. It did not. Also under WTO rules, however, the EU was permitted to 'rebalance' the effect of the US tariffs, given that the USA failed to comply. The EU put together a rebalancing package that targeted politically sensitive products such as citrus fruit from Florida—an astute calculation, since the tariffs were scheduled to be imposed in December 2003, less than a year before the next US presidential election (recall that Florida was a 'battleground' state in the contested 2000 election). As it happens, shortly before the EU tariffs were to be imposed, President George W. Bush lifted the US tariffs on steel imports. In the event, the EU tariffs were never imposed. They did not need to be imposed; the credible threat that they would be imposed was enough to make the USA comply (after a delay) with the WTO ruling.

This is an example of a treaty arrangement that works. The agreement creates an incentive for the EU to punish the USA for not complying, and it creates an incentive for the USA, when facing this punishment, to comply. The agreement also creates incentives for the EU and the USA to participate in the agreement. At no point during this dispute did the USA (or the EU) contemplate withdrawing from the WTO. This incentive to participate is attributable to the very substantial reduction in trade barriers agreed by the WTO—a favourable treatment that could be denied to non-parties.[11]

It is widely acknowledged that Kyoto's emission limits are inadequate, but tightening these limits (as the EU has proposed) will have no effect unless the other two problems with Kyoto (participation and compliance) are also addressed. We have already seen evidence of how the three different requirements play off one another. After the USA announced that it would not ratify Kyoto, Canada and Japan, worried about leakage, insisted upon a generous accounting of their 'sinks' as a condition for their ratification. This renegotiation increased participation at the cost of reducing the overall effect of the agreement. Similarly, compliance can be achieved fairly easily today if countries take advantage of the Protocol's 'flexible mechanisms', thanks again to post-Kyoto negotiations lifting restrictions on emissions trading. But if compliance is achieved by the purchase of 'hot air', global emissions may not fall at all relative to 'business as usual'.

To sum up, a climate treaty must achieve three things. It must get countries to participate; it must get participants to comply; and it must do both of these things even as it requires that parties reduce their emissions substantially. The Kyoto Protocol satisfies none of these conditions. It would be easy to design a treaty that satisfied one or two of the conditions, but success depends on meeting all three of them—no exceptions.

[11] This is not to say that the WTO is flawless. For example, it is a problem that the USA found it in its interests to violate the trading rules in the first place. The incentive for the USA to do so is probably due to the long lag between tariffs between imposed and rebalancing being threatened. As well, while the WTO has reduced trade barriers in manufactured goods, it has not done so for agriculture—the focus of the most recent round of negotiations.

III. Enforcement

Deterring non-participation and non-compliance requires enforcement. As explained previously, trade measures have been used successfully to enforce the WTO; so, why not use trade restrictions to enforce Kyoto? The idea is alluring (Stiglitz, 2006). Would it work?

Trade restrictions in a climate agreement have two justifiable purposes.

First, trade restrictions could be adopted to neutralize leakage. Suppose emissions at home are reduced by means of an economy-wide tradable permit scheme and that emissions abroad are not subject to any controls. Then leakage will be neutralized if exporters are given a rebate at the border, and importers are made to pay a tax at the border, equal to the market price of domestically traded permits times the amount of greenhouse gases emitted in the manufacture of the traded good. Under this arrangement, domestic producers would not be harmed in international markets, and foreign producers would not have an advantage in the home market. By neutralizing leakage, 'border tax adjustments' would also help to promote participation in a treaty aiming to reduce emissions. However, the free-riding problem would remain.

Second, trade restrictions could be designed to deter non-participation directly. If participation were full, and if emissions everywhere were reduced by means of Kyoto's flexible mechanisms, then the price of emissions would be uniform worldwide; there would be no leakage and no need for border tax adjustments; there also would be no free riding.

Which approach is best? Border tax adjustments would need to be comprehensive and based on how products were made.[12] But how to calculate the emissions released in the manufacture of individual products? That would be difficult. Two identical products, manufactured in the same country, might have very different 'carbon footprints' (depending, for example, on how the electricity input had been generated). Cruder calculations might be contemplated, but sector-specific taxes would also be hard to calculate.[13] Crudely designed trade restrictions may also be less effective at reducing leakage (see Oliveira-Martins *et al*., 1992).

Trade restrictions intended to deter free riding can be blunt by design. Their aim, after all, would be to coerce. Ideally, they would not need to be imposed at all; the credible threat to impose them would be sufficient to make every country want to participate. To be effective, however, the restrictions would have to be severe in addition to being credible, and punishments typically become less credible as they become more severe (see Barrett, 2005). Another problem is the legitimacy of such an action. Who should decide what a particular country ought to do? Who should decide the type and severity of punishment that ought to be imposed upon a country that fails to fulfil this obligation? The use of blunt trade restrictions to enforce an unfair climate agreement would lack legitimacy; it may only spur retaliation—a trade war. When Britain decided to debate climate change at the United Nations Security Council, three of the other permanent members (China, Russia, and the United States) responded with indifference, but many countries not represented on the Security Council were angry; they felt that the issue should remain with the General Assembly, where every country has one vote, not the Security Council, where a small number of countries call the shots. At the end of the day's debate, no resolution was presented, no statement issued.

[12] Even if the domestic policy were not economy-wide, there would be general equilibrium effects, and these would need to be taken into account at the border.

[13] For example, Hoel (1996) shows that there is no simple relationship between fossil-fuel intensity and the optimal sector-specific carbon tax.

Another problem with trade restrictions of either type is that they would need to apply to countries that failed to comply as well as those that failed to participate. Otherwise, participation would become a route for avoiding having to reduce emissions. Climate negotiators actually agreed to adopt a compliance mechanism in 2001. But according to Article 18 of the Kyoto Protocol, any compliance mechanism 'entailing binding consequences' must be approved by amendment. An amendment is akin to a new agreement. It would only be binding on the parties that ratified it, provided at least three-quarters of the parties to the Kyoto Protocol also ratified it. So far, no such amendment has been adopted. The mechanism agreed in 2001 is thus non-binding.

Even if the mechanism were binding, it would have no effect. The main component of the mechanism is a 30 per cent penalty. A country that emits, say, 100 tonnes more than the treaty allows in the first 'commitment period' (2008–12) must make up for this by reducing its emissions by an additional 130 tonnes in the next period. This reduction is 'additional' relative to this country's next-period cap. This cap, however, is subject to the approval of the country having to pay the penalty. That country can, therefore, insist on a generous cap as a condition for joining, and so get away with paying a 'phantom' penalty. Alternatively, it could ratify the new treaty and then fail to comply again—the current arrangement essentially carries forward the penalty indefinitely. The reason this penalty system cannot deter non-compliance is that its punishments must be self-inflicted. This is to be contrasted with the WTO enforcement mechanism described previously. The WTO compliance mechanism works by enabling an injured party to impose rebalancing tariffs against a party found to have violated the rules. It was the threat by the EU to impose tariffs against the USA that impelled the USA to drop its illegal steel tariffs.

The Kyoto compliance mechanism just mentioned does allow one non-self-inflicted punishment. It permits other parties to the Kyoto Protocol to suspend the trading privileges of a country found to be in non-compliance. Would other countries impose this punishment? There is good reason to believe they would not, at least in some important cases (Kallbekken and Hovi, 2007). If a large seller of permits were in non-compliance, withdrawal of its trading privileges would push up international permit prices, harming net importers; the latter countries may therefore be unwilling to impose the punishment. If a large buyer of permits were punished in this same way, international permit prices would fall, harming net exporters; *these* countries may therefore also be unwilling to impose the punishment. In short, the threat to punish may not be credible. Of course, in each of the cases I just mentioned, some countries would gain by imposing the punishments (net exporters in the first instance, net importers in the second). But with some countries gaining and some losing, activation of the sanction could spark conflict among the countries that had complied. This is in contrast to the WTO punishment mentioned previously, in which the retaliatory trade restriction harms only the target country.[14]

Another point: it cannot be assumed that every other aspect of a treaty will remain unchanged should an effective enforcement mechanism be adopted. Adding enforcement penalties, for example, may make parties want to water down the agreement, to ensure that the punishments are not imposed. As I said before, to be effective a treaty must not only deter non-participation and non-compliance; it must do both of these things even as it gets countries to change their behaviour significantly. Usually an attempt to address one of these

[14] The essential difference between enforcing a trade agreement and a climate agreement is that trade is a bilateral activity whereas climate-change mitigation is a global public good. Bilateral agreements are easy to enforce; multilateral agreements seeking to supply a global public good are much harder to enforce.

dimensions only displaces the free-rider problem, putting pressure on one or both of the other dimensions.

To sum up, should the focus of negotiations be on setting even tougher targets and timetables without addressing the underlying enforcement challenge, the outcome is likely to be more of the same—meaning, little if any success in reducing global emissions. Should the focus be on strengthening the enforcement mechanism—by allowing trade restrictions, for example—different challenges will emerge. We cannot be sure that the outcome will be any more satisfactory.

IV. The Montreal Protocol as a climate-change treaty

While efforts to address climate change directly have failed, we have succeeded in addressing climate change indirectly—almost without anyone noticing.

The relationship between stratospheric ozone depletion and climate change is complex. Ozone in the stratosphere is a greenhouse gas (protecting the ozone layer will thus add to climate change), but so are the chemicals that deplete stratospheric ozone (reducing these emissions will thus help mitigate climate change). Making matters more complicated, some of the substitutes for these ozone-destroying gases are also greenhouse gases. The Montreal Protocol on Substances that Deplete the Ozone Layer, which aims to protect stratospheric ozone by banning ozone-depleting gases, could thus dampen or aggravate global climate change.

What is the net effect? A recent study has done the accounting and shown that the overall effect of the Montreal Protocol is helpful to the climate (Velders *et al*., 2007). Indeed, the study calculates that the Montreal Protocol has been, and will continue to be, much more helpful in addressing climate change than the Kyoto Protocol, even assuming that Kyoto is implemented perfectly and with full participation. Already, this study estimates, the Montreal Protocol has reduced greenhouse-gas emissions four times as much as the Kyoto Protocol aspired to do.

In September 2007, on the Montreal Protocol's 20th anniversary, the parties to this extraordinary treaty met again in Montreal to accelerate and expand the phase-out of hydrochlorofluorocarbons (HCFCs), an ozone-depleting substance that happens also to be a greenhouse gas. HCFCs are especially important because the manufacture of these compounds produces hydrofluorocarbons (HFCs) as a byproduct. HFCs do not deplete the ozone layer, and so they cannot be regulated directly by the Montreal Protocol; but they are a very potent greenhouse gas, covered under the Kyoto Protocol. By one estimate, the adjustment negotiated in Montreal in September 2007 will have about the same impact on the climate as the Kyoto Protocol was designed to achieve (Kaniaru *et al*., 2007, p. 4).[15] I stress that this is on top of the larger effect Montreal has already had in reducing the concentration of greenhouse gases.

[15] The example of reducing HFCs exposes another flaw in the Kyoto Protocol. It turns out that most emission reductions under the treaty's Clean Development Mechanism (CDM) have involved HFCs. This would not matter except that too much is being paid for the reductions. One consequence of this is that less is being achieved than could be achieved for the same money. According to Michael Wara (2007, p. 596), HFCs could be phased out for less than €100 m, saving €4.6 billion 'in CDM credits that could be spent on other climate-protecting uses'. Wara (2007, p. 596) also notes an allied problem—'HFC-23 emitters can earn almost twice as much from CDM credits as they can from selling refrigerant gases—by any measure a major distortion of the market.' The distortion creates incentives for production of HCFCs to expand so that the manufacturers can earn CDM credits for cutting back on their emission of HFCs.

V. Why Montreal works

Why has the Montreal Protocol succeeded where the Kyoto Protocol has failed? Part of the reason is that the environmental problems are very different.[16] However, the treaty itself also made a huge difference. It is really only in hindsight that protecting the ozone layer appears easy.

First, the Montreal Protocol limits not only the production of chlorofluorocarbons (CFCs) and related chemicals; it also limits the consumption of these substances (defined by Montreal as production plus imports minus exports). We speak of 'Britain's carbon emissions' and 'China's carbon emissions' but when Britain imports energy-intensive products from China, which country is responsible for the emissions released in the manufacture of these products, China or Britain? If participation were universal, the distinction would not matter. When participation is incomplete, limiting consumption as well as production helps to reduce leakage. For that reason, it also promotes participation.

Second, the Montreal Protocol requires *all* countries, rich and poor alike, to cut back on their production and consumption of CFCs. Developing countries were given easier, initial limits, but they were expected to get to the same final end-points as the rich countries (an early example of rich and poor countries having 'common but differentiated responsibilities'). Under the Kyoto Protocol, the emissions of developing countries are unconstrained—a bizarre situation when you consider that China has added more coal-fired electricity capacity in a single year than Britain's entire installed capacity.

Third, Montreal's cuts are permanent whereas Kyoto's last only 5 years. Five-year targets are entirely unsuited to bringing about lasting change. The coal plants being built today will last 40 or 50 years. The energy and transportation infrastructure being built now will last even longer. Because of path-dependence, the effects of these investments may endure longer still. An effective climate agreement must impose obligations that can be ratcheted up, and that are immune to backsliding.

Fourth, the Montreal Protocol, as amended in 1990, creates positive incentives for developing countries to participate. Essentially, Montreal compensates developing countries for their compliance costs. These costs are paid out of the Multilateral Fund, which is financed by rich countries according to the United Nations scale of assessments.[17] Kyoto's Clean Development Mechanism offers limited incentives for developing countries to reduce their emissions. However, CDM 'offsets', being project-based, are burdened by high transactions costs. Their quantity is also too small to be transformational.[18] The Montreal Protocol used financing to get developing countries on to an ozone-friendly development path. An effective climate agreement needs to get poor countries, especially the fast-growing poor countries, on to a climate-friendly (carbon-free) development path.

[16] For example, ozone depletion harms all countries. Catastrophic climate change (such as a break-up of the West Antarctic Ice Sheet) would similarly harm most states, but 'gradual' climate change would create winners as well as losers. As well, the damages from ozone depletion are substantial (primarily owing to increased deaths from skin cancer) and the costs of substituting for ozone-depleting substances modest, whereas for climate change the benefit–cost comparison is less attractive (Barrett, 2007). Finally, it also happened that the companies manufacturing ozone-destroying chemicals were best placed for developing and manufacturing their replacements, and the treaty deftly opened new markets for the substitutes as it shut the old markets down. Altogether, the 'initial conditions' for addressing ozone depletion were unusually favourable.

[17] As of July 2007, $2.27 billion has been contributed; see http://www.multilateralfund.org. See Barrett (2007) for a discussion of the United Nations scale.

[18] See also the comments in footnote 15.

Finally, Montreal created strong incentives for countries to participate and to comply. The main incentive is a trade restriction: Montreal bans trade between parties and non-parties in ozone-depleting substances and products containing these substances. Originally, the treaty also intended to ban trade in products made using these same substances, but experts determined that this was impracticable, and this last ban was never adopted. Fortunately, it was not needed. (As explained previously, trade restrictions based on how products are made would be needed to enforce a climate treaty, if their purpose was to limit leakage.) Importantly, Montreal's trade restrictions have not been imposed. The threat to impose them, made credible by the leakage that would be avoided by the restrictions, has sufficed to change behaviour.[19] As explained previously, it is not obvious that climate-related trade restrictions, at least if applied across-the-board, would work as conveniently.

VI. Montreal's lessons

Like the Kyoto Protocol, Montreal establishes targets and timetables. In Montreal's case, however, these instruments served as a means, not an end. Their purpose was not to reduce emissions by an exact amount on a particular date. Their purpose was to effect a technological transformation. An effective climate treaty system must do the same thing.

The Kyoto Protocol limits more than the emissions of CO_2; it also caps the emissions of methane (CH_4), nitrous oxide (N_2O), and three industrial gases—HFCs, perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). Economists have celebrated Kyoto's 'comprehensive' design. By throwing all these gases in the same basket, as it were, Kyoto has facilitated cost-effective abatement (that is, it has allowed the marginal cost of reducing concentrations, after adjusting for each gas's contribution to climate change, to be equal for every gas). The problem is that cost-effectiveness has been achieved at the cost of lowering the emission reductions that Kyoto is able to sustain. Montreal has shown that emissions could have been cut more if the different gases included in Kyoto had been treated separately. It seems very possible that the three industrial gases mentioned above could have been controlled more effectively by a separate agreement styled after Montreal rather than being lumped together with all the other gases in the Kyoto Protocol.

In 1998, 11 years after Montreal was first negotiated, the agreement was not only well into its implementation phase; it had already been adjusted and amended seven times. In 2008, eleven years after Kyoto was negotiated, that agreement has only just entered its implementation phase. In 1998, it was clear that the ozone layer would be protected, and nearly to the maximum extent achievable. The agreement would be amended one more time (in 1999) and adjusted twice more (in 1999 and, as mentioned before, in 2007), but by 1998 the main work of the Montreal Protocol had already been accomplished; certainly an effective architecture was firmly in place. In 2008, by contrast, the future of the climate regime remains very uncertain. Kyoto expires in 2012 and we don't know what kind of regime will succeed it. The current plan is to negotiate a successor by late 2009, but this is an ambitious timetable, particularly as the US negotiating team will be replaced midway through this process, and a new regime, if it is to be effective, must include the USA as a key and enthusiastic party.

[19] This makes Montreal's punishment mechanism better than the WTO's, which has needed to be imposed, as explained previously. See also footnote 11.

At the same time, delays in negotiating a successor to Kyoto will put more pressure on the existing agreement; compliance with Kyoto may suffer further.

Where to go from here? The parties to the Framework Convention mapped out a plan—a 'roadmap'—in Bali in December 2007. I turn to this next.

VII. Bali

In Bali, the European Union urged rich countries to accept 'binding commitments' for reductions in greenhouse gases—a plan that would retain Kyoto's essential structure. Specifically, the EU pushed for rich countries to cut their emissions 25–40 per cent by 2020 (a higher level than the EU had recommended before; see the introduction to this paper). This proposal is consistent with the view that Kyoto's only problem is that its caps are too generous. Kyoto's caps are too generous, but as I have explained, simply tightening Kyoto's existing caps while leaving the rest of the agreement unchanged will not increase the treaty's effectiveness—indeed, it is likely to make no difference at all. Incentives must also be created for developing countries to reduce their emissions. Most importantly, the obligations of the new agreement need to be enforced.

The Bali Action Plan admits a wider range of possibilities. In particular, it identifies five key areas: (*a*) 'a shared vision for long-term cooperative action, including a long-term global goal for emission reductions'; (*b*) 'enhanced . . . action on mitigation'; (*c*) 'enhanced action on adaptation'; (*d*) 'enhanced action on technology development and transfer to support action on mitigation and adaptation'; and (*e*) 'enhanced action on the provision of financial resources and investment to support action on mitigation and adaptation and technology cooperation'. This agenda is broader than Kyoto's. It also provides an opportunity to address many of Kyoto's failings. I discuss each of these five issues in turn below.

(i) Long-term goal

What should be the long-term global goal? In 1996, the Council of the European Union decided that the goal should be to ensure that mean global temperature increase does not exceed 2°C. Why this level? The Council reasoned that, 'once global warming exceeds 2°C, climate impacts on food production, water supply and ecosystems are projected to increase significantly and irreversible catastrophic events may occur'.[20] The Council's rationale is significant. The FCCC says that the world should avoid 'dangerous anthropogenic interference with the climate system', and do so 'within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner'. The EU goal of limiting climate change to 2°C was meant to quantify the agreed qualitative goal.

Will other countries accept it? There are a number of problems with this goal; three are especially important. First, because of 'climate uncertainty', there is a probability distribution of concentration levels associated with meeting any particular temperature target. This means that, given our present knowledge, we have to ask with what degree of certainty we should aim

[20] 'Questions and Answers on the Commission Communication, *Limiting Global Climate Change to 2°C*', Memo/07/17.

to limit temperature rise to 2°C. With probability equal to one? That would require reducing concentrations below the current level. With probability one-half? Two-thirds? (Allied to this question is a related one: Should this concentration level be an upper bound or a long-run target? Should 'overshooting' be allowed?) Second, the goal seems to have been determined without considering the consequences of having to meet it.[21] Would it matter if the goal were met by a massive expansion in nuclear power? Nuclear power would have consequences for very long-term waste storage and proliferation; not every country agrees that nuclear power should be expanded. What about carbon capture and deep ocean storage on a massive scale? This may introduce new risks to the marine environment. Would countries agree that these risks are worth taking to avoid the risk of greater climate change? Meeting the goal will also be costly. Will countries agree that the cost is worthwhile? Will some developing countries argue that development deserves a higher priority? Will they say that the target for temperature increase needs to be determined jointly with arrangements for adaptation assistance?

Finally, this goal can only be met by the collective actions of all countries. Will agreeing on a collective goal help? It would if the following were feasible. Having agreed on a maximum allowable temperature change, having agreed on the concentration level needed to avoid exceeding this temperature target (with some probability), and having determined the best emission trajectory for reaching this concentration level (where 'best' might be the cost-effective emissions path), all the countries of the world are also able to agree how to allocate annual emission limits among them such that the sum of all their limits equals the required global total precisely (this division, you will notice, is a zero-sum game; it assumes that countries can 'solve' the participation problem). Then, provided each country stayed within its emission limit (that is, that the treaty also 'solves' the compliance problem), the temperature-change goal would be met (again, with some probability). But will countries stay within these limits? Will they consent to this arrangement? Will they be able to reach agreement? There have been numerous proposals for a programme like the one just outlined.[22] But the logic underpinning these proposals presumes a degree of global solidarity and a capability to enforce individual behaviour that simply does not exist.[23]

Choosing a long-run goal only helps if there is a reasonable prospect of the goal being met. As I noted earlier, the world has set collective goals before (recall the Toronto target from 1988) and missed them by a mile. Agreeing on a goal only helps if it is also possible to enforce the actions needed to ensure that the goal is actually met. This, in my view, should be the focus of negotiations.

Interestingly, the Vienna Convention for the Protection of the Ozone Layer (ozone's equivalent to the FCCC) does not specify a collective goal, even in qualitative terms. Instead, it enjoins countries 'to take appropriate measures . . . to protect human health and the environment against adverse effects resulting or likely to result from human activities which modify or are

[21] This need to account for the consequences of acting or not acting to address the threat of global climate change underlies the analyses of both Stern (2007) and Nordhaus (2007). I noted in footnote 1 that these economists agree that emissions need to be reduced now and that they need to be reduced very substantially later. They disagree as to whether 2°C is the 'right' target.

[22] The most recent is by Barnes *et al*. (2008).

[23] There is one exception to the situation described here. Imagine that damages (benefits) were discontinuous at the global target: should the world cross this threshold, the consequence would be truly catastrophic for every country. Then avoiding the threshold would be sustainable; it would be a Nash equilibrium. This situation resembles the challenge of averting a certain catastrophic asteroid strike; see Barrett (2007). Unfortunately (or fortunately!), global climate-change damages do not, so far as we know, have this feature. They are not catastrophic in the same sense.

likely to modify the ozone layer'. This is what a climate regime needs to do. It needs to focus the world's attention on the need to take appropriate measures: to take action rather than to set goals. This is why the other four elements of the Bali roadmap are important. They all focus on the taking of actions. I turn to these next.

(ii) Enhanced mitigation: the merit in sectoral approaches

According to the Bali roadmap, 'enhanced mitigation' is to include 'measurable, reportable and verifiable nationally appropriate mitigation commitments or actions, including quantified emission limitation and reduction objectives, by all developed country Parties, while ensuring the comparability of efforts among them, taking into account differences in their national circumstances.' Developing countries are now also expected to contribute. They are to undertake 'nationally appropriate mitigation actions. . . in the context of sustainable development, supported and enabled by technology financing and capacity-building, in a measurable, reportable and verifiable manner'. Importantly, the mitigation actions of all countries may include 'cooperative sectoral approaches and sector-specific actions'.

Bali thus permits a range of treaty designs.[24] It could lead to negotiation of a Kyoto look-alike treaty. It could allow some countries to adopt targets and timetables even as others chose a different approach—tradable permits with a price escape valve, perhaps, or a carbon tax, or technology standards. Though the type of action can vary, the actions adopted by different developed countries must be comparable. The Kyoto emission caps only had the illusion of comparability. They were calculated relative to an atypical base year (making matters worse, the economies in transition were able to choose their preferred base year). The gaps identified in Table 1 do not reflect different efforts to reduce emissions so much as different initial conditions. They are meaningless as an indicator of 'comparability'. So, Bali was right to draw attention to comparability, though it will be difficult for countries to define what the term means.

While the emphasis of Kyoto was on economy-wide emission reductions, it is not a fully comprehensive agreement. It excludes emissions from aviation, marine transport, and deforestation. Of course, it also fails to impose emission obligations on developing countries. Various proposals have been made for integrating these omitted areas in a new agreement. Doing so would aid cost-effectiveness. However, it may also compromise enforcement. With all gases and sectors bundled together, enforcement of the system as a whole may depend on its weakest links.

An alternative approach would address the parts and not—or not only—the whole. My suggestion earlier that the three industrial gases be treated separately is an example of this approach. For the main greenhouse gas, CO_2, this approach would commend a focus on sector-level actions.[25]

Implementation of Kyoto has so far been sectoral by choice. No country has a single, economy-wide policy for meeting its Kyoto obligations. The European Emissions Trading Scheme (EU ETS) covers less than half of EU emissions. Sweden arguably has the most well-developed climate-change policy of any country, and its approach involves both 'sector integration' (every sector plays a part towards meeting the overall goal) and 'sector

[24] A number of alternative approaches have been proposed. For a particularly good collection and analysis, see Aldy and Stavins (2007).

[25] After the Bali meeting, Japan proposed a sectoral approach.

responsibility' (different sectors play different parts). Even Sweden's economy-wide policies differentiate by sector. Its carbon tax, for example, offers relief for energy-intensive industrial operations (Ministry of Sustainable Development, 2005). The reason, of course, is fear of trade leakage.

In not requiring that developing countries reduce emissions, Kyoto has created incentives for its emissions-constrained parties either to offer preferential treatment to the trade-sensitive sectors or to adopt trade restrictions. Preferential treatment undermines the objective of cost-effectiveness—the main reason for adopting an economy-wide approach in the first place. Economy-wide trade restrictions, as noted previously, are likely to introduce new tensions (the legitimacy problem). They may also fail (the credibility problem).

Sectoral agreements would need to be inclusive; developing countries would be expected to participate in these agreements, to meet the same industry standards, but they would also be offered financial assistance, to aid their compliance. This arrangement would recognize that rich and poor countries alike have common but differentiated responsibilities. Sectoral agreements would also need to be enforced—by trade restrictions. Trade restrictions in this context would be legitimate, since developing countries would be compensated for participating and the aim of the restrictions would be to enforce an agreement establishing a 'level playing field' for a global industry. Trade restrictions applied to sector-specific agreements are also more likely to be credible. Parties to a sectoral agreement would not want non-parties to have an 'unfair' advantage in international trade. Moreover, by definition, these sectors would be especially vulnerable to leakage. Applying trade restrictions to non-parties would reduce leakage, and thus help to make credible the threat to apply the restrictions. Enforcement would be further helped if the treaty's obligations were expressed in terms of consumption and not only production.

The aluminium sector is a prime candidate for a separate agreement.[26] It is a concentrated industry: 12 countries account for 82 per cent of global production; ten companies produce more than half of world output. The industry employs just two smelting technologies, and emissions can be reduced substantially by re-melting aluminium scrap (the former is 95 per cent less greenhouse-gas-intensive than primary aluminium production). Finally, 26 companies, making up 80 per cent of world output, belong to the International Aluminium Institute, which has already adopted voluntary intensity targets. There exists a basis here for negotiating new global standards for the industry, backed by international enforcement. Other candidates for sectoral agreements include steel and cement.[27]

Emissions from the power sector must be cut substantially. Electricity is rarely traded internationally; it is not trade-sensitive in the same way as are the aluminium, steel, and cement sectors. Indeed, that is why many countries have already adopted, or are now in the process of adopting, policies to reduce emissions from the power sector. Control of the emissions of the trade-sensitive sectors in separate global agreements should help these efforts (aluminium production, for example, is very electricity-intensive), while at the same time lessening incentives to adopt across-the-board trade restrictions (since the sectoral agreements would be enforced using trade restrictions). The industrialized countries should continue to focus on reducing emissions from electricity production domestically. They should do this by relying on domestic enforcement and international comparability, not international enforcement.

[26] I am drawing here from the excellent study by Bradley *et al.* (2007), especially pp. 37–8.
[27] Again, see Bradley *et al.* (2007).

Beyond this, international cooperation is needed for R&D into, and the demonstration of, new electricity-generation technologies. I discuss this challenge in section VII(iv).

Transportation is another sector that may benefit from separate treatment, but for a different reason than aluminium and electricity. I discuss it also in section VII(iv).

The Kyoto Protocol enables parties to generate credits for afforestation and reforestation, but subject to substantial restrictions. No credits are allowed for avoided deforestation. The latter category, however, is responsible for around 18 per cent of global emissions of greenhouse gases (Bradley *et al*., 2007, p. 44), and there is wide agreement that the deforestation 'loophole' needs to be closed. However, there are good reasons why avoided deforestation was left out of the Kyoto Protocol. Forest loss is sometimes beyond the control of individual parties (forest fires), the potential for leakage is huge, the benefits of avoided deforestation are reversible, and establishing a baseline for agreement is a tricky business. Policies to reduce deforestation will be imperfect. One reason for addressing deforestation in a separate agreement is to ensure that such policies do not drag down efforts to reduce emissions from other sectors.

(iii) Adaptation

The climate will change, no matter how successful we are at reducing emissions. Countries will therefore need to adapt.

Countries have exceptionally strong incentives to adapt. In contrast to mitigation, the benefits of adaptation are excludable. Much adaptation will be done 'automatically' by the market. Much of the rest will require the supply of local public goods (augmenting the Thames Barrier is an example), the benefits of which will be largely internal to the countries that supply them.

Unfortunately, many poor countries lack the capability to adapt. Adaptation requires the same institutions as development. Poor countries have weaker market institutions, and their governments routinely undersupply basic local public goods. Poor countries are also less accustomed to cooperating with each other to address cross-border challenges such as malaria, which may spread (largely to higher altitudes) with climate change. The failure to supply regional public goods is especially important for adaptation in Africa (see the paper by Collier *et al*. (2008), in this issue), a highly fragmented continent.

Mitigation will depend mostly on the efforts of the richest countries (not only as regards their own abatement but also their financing of abatement by other countries). However, these countries are also more able to adapt. The rich countries may, therefore, substitute the local public good of adaptation for the global public good of mitigation, leaving poor countries more vulnerable still. Climate change thus has the potential to widen existing inequalities. I discuss this challenge further in section VII(v).

(iv) Technology R&D and diffusion

Emissions can be reduced significantly using existing technologies. Reducing emissions very, very substantially, however, will require fundamentally new technologies (Hoffert *et al*., 2002).

Kyoto provides a modest 'pull' incentive for innovation. By constraining emissions, Kyoto makes emissions costly, stimulating demand for technologies that can allow users to avoid this cost. This demand in turn creates an incentive for innovation. As already mentioned, however,

Kyoto is unable to raise the price on emissions significantly. The incentives it creates for innovation are exceedingly weak.

Kyoto also fails to create a 'push' incentive for innovation. The discovery, development, and demonstration of 'breakthrough' technologies (such as carbon capture and storage, space solar power, and nuclear fusion) require basic research—the fruits of which cannot be patented. Like mitigation, the knowledge arising from basic research is a global public good.

The incentives to undertake basic research are mixed. We know the incentives to conduct research into nuclear fusion are strong, because countries have already invested in this research.[28] Fusion power, however, would yield national benefits quite apart from the benefits for climate-change mitigation. The incentives to undertake R&D into carbon capture and storage are much weaker. They depend on the prospects of the knowledge emerging from this research being embodied in new technologies that are actually diffused, and these depend on the incentives for countries to cut their emissions (Barrett, 2006). As noted previously, these incentives are weak unless a way can be found to address the enforcement challenge.[29]

Intriguingly, some technologies have features that can aid enforcement. The incentives for new technologies to spread depend on more than their cost of production (relative to the alternatives). They depend also on whether use of these technologies entails network effects. Suppose that there are two technologies, A and B. The current technology, A, is cheaper; the alternative technology, B, is more expensive but results in zero emissions. Full cooperation requires that the world switch from A to B (the benefits of reducing emissions exceed the costs of switching). But there are two obstacles. The first is the usual one: the incentive for countries to free ride (perhaps exacerbated by trade leakage). The second is that, due to network effects, the cost to any country of switching to B is exorbitantly high when few if any other countries switch to B. This double penalty will prevent any country from switching to B unilaterally. However, should 'enough' countries switch to B, and should network effects be very strong, it may pay all the remaining countries to switch to B, despite free-rider incentives (Barrett, 2006).

Though emissions from international marine transport are excluded from Kyoto, this sector may be an attractive candidate for switching to hydrogen fuel (Farrell *et al*., 2003). One reason for this is that ports are often close to refinery operations, where hydrogen is already produced and where cargo vessels already refuel. Helped by network effects, ocean shipping has already been transformed. For example, the standard for oil tankers has evolved—first, by requiring separate oil and ballast water tanks; and, second, by requiring double hulls (Barrett, 2007). Parties to the International Maritime Organisation could establish a new standard for hydrogen-powered container ships. This would require that ports make the fuel available and that individual governments ban ships (above a certain size) that were not powered by hydrogen. As more countries imposed this standard, the incentives for others to impose it would increase. Moreover, should hydrogen become viable for this one sector, further network effects may help to spread the technology to other forms of transportation (Farrell *et al*., 2003).

[28] The International Thermonuclear Experimental Reactor, being built now in France, is a cooperative endeavour, supported by the European Union, China, India, Japan, South Korea, Russia, and the United States—the same countries that will need to cooperate in addressing climate change.

[29] The United States had planned to build a 'clean coal' pilot project called FutureGen. The plant was to produce hydrogen and electricity from coal while using carbon capture and storage to sequester the CO_2 underground. The initiative was launched in 2003. In December 2007, a site was selected. A month later, the project was cancelled, ostensibly because the cost had risen from $1 billion to $1.8 billion. See M. L. Wald, 'Higher Costs Cited as US Shuts Down Coal Project', *New York Times*, 31 January 2008; available at http://www.nytimes.com/2008/01/31/business/31coal.html?ref=environment&pagewanted=all

The economics of hydrogen for automobile transportation are less attractive, but this sector also exhibits strong network effects, particularly as regards refuelling. Moreover, substituting an alternative fuel for petrol may yield local environmental benefits—a further inducement for spread. The current high price of petrol makes the economics of substitution more attractive still. Currently, the electric vehicle seems to be a particularly attractive option, with the plug-in hybrid possibly acting as a kind of bridge to a full-electric future. Network effects would include the availability of electrical outlets for recharging and of replacement batteries for long-haul travel. Of course, a switch to electric vehicles makes it even more imperative that emissions from electricity generation be cut very substantially.

(v) Financing

Financing for mitigation actions undertaken in developing (non-Annex-I) countries is already available under the Clean Development Mechanism (recall that the CDM allows rich countries to fulfil their emission-reduction obligations by obtaining credit for the emission reductions they finance in poor countries). As noted previously, however, there are a number of problems with this means of financing. Most importantly, the effectiveness of this mechanism depends on Kyoto's emission limits being enforced and, as I have explained, Kyoto's enforcement arrangements are very weak. Canada, for example, has no plans to comply with Kyoto by purchasing CDM credits. To stabilize concentrations, it is imperative that fast-growing developing countries such as China be put on to a different kind of development path. Doing so, however, will require financing. Since this financing is just another means of supplying the global public good of mitigation, its provision will depend on an agreement to finance mitigation in such countries being enforced.

It is typically assumed that industrialized countries must transfer their technologies to developing countries. However, developing countries may require different kinds of technology than rich countries. The ecological, economic, and social context in developing countries is different. So is the installed base of infrastructure. At the very least, developing countries must be able to determine the technologies they need, whether the technologies available from rich countries have to be adapted to suit local circumstances, and how these technologies should be deployed and used. All of this requires a degree of technical and scientific capability that many developing countries currently lack. Assistance is needed to help developing countries obtain this capability.[30]

Rich countries have already accepted that they are obligated to assist poor countries to adapt. Article 3 of the FCCC says that rich-country parties to the convention shall 'assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation to those adverse effects'. The Kyoto Protocol makes a first attempt to implement this obligation. It established an adaptation fund, financed by a levy on CDM transactions. However, this arrangement is inadequate. The amounts of money that will be needed for adaptation bear no relation at all to the amounts raised by CDM transactions. Moreover, taxing CDM transactions penalizes efforts to reduce emissions. Finally, since the United States is not a party to this treaty, its obligation to assist developing

[30] The International Task Force on Global Public Goods and, more recently, the Club of Madrid have proposed creating a Consultative Group on Clean Energy Research for this purpose. The proposal was inspired by the successful Consultative Group on International Agricultural Research, which gave rise to the 'green revolution'. See http://www.gpgtaskforce.org/uploads/files/227.pdf and http://www.unfoundation.org/files/pdf/2007/GLCA_Framework2007.pdf

countries, accepted under the Framework Convention, cannot be fulfilled by this mechanism. Here again, a different approach is needed.

The Bali roadmap underlines 'the urgent and immediate needs of developing countries that are particularly vulnerable to the adverse effects of climate change, especially the least developed countries and small island developing States'. It allows a new approach to be prepared but it does not mention how much money ought to be provided or the basis for determining this amount or for assessing contributions. Unfortunately, while a strong moral argument can be made for international assistance (the rich countries, after all, are largely responsible for the accumulation of greenhouse gases in the atmosphere), the direct incentives rich countries have to provide assistance are weak. Adaptation assistance is likely to become an increasing source of friction in international relations, particularly if mitigation efforts continue to stumble.

VIII. Conclusions

Climate change is arguably the greatest collective-action problem the world has ever faced. We should not be surprised that we have failed to address it thus far. Climate change emerged as a major global challenge soon after the Montreal Protocol was negotiated. Understandably, many people believed at that time that climate change could be addressed as easily as stratospheric ozone depletion. They were wrong. Climate change is a much harder problem.

A more instructive exemplar may be the efforts taken to address pollution of the world's oceans by oil dumping.[31] The first international conference on this issue was held in 1926. An agreement was reached but never signed. In 1935a new agreement was negotiated, but it also never entered into force. In 1954, the world tried again. This time a treaty to protect the oceans entered into force. However, it had no effect; it failed to address the enforcement challenge. The agreement was amended in 1962 and again in 1969, but these changes also made little difference because the amendments, like the underlying treaty, could not be enforced. Finally, in the 1970s, a different approach was tried. Instead of trying to reduce oil dumping by means of performance standards, countries negotiated technical standards, which were much easier to enforce. These agreements entered into force in 1983 and have been a great success. Climate change is a much harder problem than oil dumping, but it need not take us 50 years to discover how to address it. The lesson of the history of oil dumping is not that effective agreements take decades to negotiate. It is that, should one approach to addressing a problem fail, we should be open to trying another.

The European Union has proposed styling a post-Kyoto agreement after the original agreement, the key difference being that the EU wants the emission limits in the new agreement to be more ambitious. Greater cuts in emissions are needed, but, as I have explained in this paper, tighter caps will not help unless the treaty also creates incentives for participation and compliance. President Sarkozy, among others, has suggested that trade restrictions be imposed against non-participants. Such measures may not work as intended. They are also likely to introduce new tensions.

As explained here, a superior strategy may be to break the problem up, relying on separate agreements to address different gases and sectors. Kyoto lumps everything together—an approach that helps ensure cost-effectiveness but that also ensures that enforcement is only as effective as the agreement's weakest individual component. By breaking the problem

[31] See Barrett (2005), especially ch. 9.

up, different pressure points can be exploited—trade restrictions coupled with financial assistance for developing countries for the trade-sensitive sectors, technical standards, again with financial assistance for developing countries, for sectors characterized by network effects, and so on. This alternative strategy will not sustain a first best. Given the nature of this challenge, however, a first best is unattainable. The motivation for recommending separate agreements is that it would be superior to the approach tried thus far.

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