Designing the Post-Kyoto Climate Regime

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Diverse aspects of human activity around the world result in greenhouse gas (GHG) emissions that contribute to global climate change. Emissions come from coal-fired power plants in the United States, diesel buses in Europe, rice paddies in Asia, and the burning of tropical forests in South America. These emissions will affect the global climate for generations, because most greenhouse gases reside in the atmosphere for decades to centuries. Thus, the impacts of global climate change pose serious, long-term risks.

Global climate change is the ultimate global-commons problem: Because GHGs mix uniformly in the upper atmosphere, damages are completely independent of the location of emissions sources. Thus, a multi-national response is required. To address effectively the risks of climate change, efforts that engage most if not all countries will need to be undertaken. The greatest challenge lies in designing an *international policy architecture* that can guide such efforts. We take "international policy architecture" to refer to the basic nature and structure of an international agreement or other multilateral (or bilateral) climate regime.

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) marked the first meaningful attempt by the community of nations to

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curb GHG emissions. This agreement, though a significant first step, is not sufficient for the longer-term task ahead. Some observers support the policy approach embodied in Kyoto and would like to see it extended—perhaps with modifications—beyond the 2012 end date of the first commitment period. Others maintain that a fundamentally new approach is required, and support the emergence of a pledge-and-review system at the 2009 Copenhagen and 2010 Cancun climate talks. Still others, unsatisfied with these two options, call for new ideas to inform the design of climate policy beyond 2020 under the "Durban Platform for Enhanced Action" agreed to at the 2011 climate talks.

Whether one thinks the Kyoto Protocol was a good first step or a bad first step, everyone agrees that a second step is required. A way forward is needed for the post-Kyoto period. The Harvard Project on Climate Agreements was launched with this imperative in mind. The Project is a global, multi-year, multi-disciplinary effort intended to help identify the key design elements of a scientifically sound, economically rational, and politically pragmatic post-Kyoto international policy architecture for addressing the threat of climate change. This chapter draws extensively on the Project's research, the results of which are described in much greater detail elsewhere (Aldy and Stavins 2009, 2010).

By "scientifically sound" we mean an international agreement that is consistent with achieving the objective of stabilizing atmospheric concentrations of GHGs at levels that avoid dangerous anthropogenic interference with the global climate. By "economically rational" we mean pursuing an approach or set of approaches that are likely to achieve global targets at minimum cost—that is, cost-effectively. And by "politically pragmatic" we mean a post-Kyoto regime that is likely to bring on board the United States and engage key, rapidly-growing developing countries in increasingly meaningful ways over time.

Learning from Experience: The Kyoto Protocol

It is helpful to reflect on the lessons that can be learned from examining the Kyoto Protocol's strengths and weaknesses. Among the Protocol's strengths is its inclusion of several provisions for market-based approaches that hold promise for improving the cost-effectiveness of a global climate regime. We refer, for example, to the well-known flexibility mechanisms, such as Article 17, which provides for emissions trading among the Annex I countries[2] that take on commitments under the Protocol. More specifically, this provision allows the governments of Annex I countries to trade some of the assigned emission allowances that constitute their country-level targets. Second, the Protocol's Joint Implementation provisions allow for project-level trades among the Annex I countries. Finally, the Protocol established the Clean Development Mechanism (CDM), which provides for the use of project-level emission offsets created in non-Annex I countries (the developing countries of the world) to help meet the compliance obligations of Annex I countries.

A second advantage of the Kyoto Protocol is that it provides flexibility for nations to meet their national emission targets—their commitments—in any way they want. In other words, Article 2 of the Protocol recognizes domestic sovereignty by providing for flexibility at the national level. The political importance of this provision in terms of making it possible for a large number of nations to reach agreement on emission commitments

[2] We use Annex I and Annex B interchangeably to represent those industrialized countries that have commitments under the Kyoto Protocol, though we recognize that a few countries are included in one Annex but not the other.

should not be underestimated.

Third, the Kyoto Protocol has the appearance of fairness, in that it focuses on the wealthiest countries and those responsible for a dominant share of the current stock of anthropogenic GHGs in the atmosphere. This is consistent with the principle enunciated in the UNFCCC of "common but differentiated responsibilities and respective capabilities."

Fourth and finally, the fact that the Kyoto Protocol was signed by more than 180 countries and subsequently ratified by a sufficient number of Annex I countries for it to come into force speaks to the political viability of the agreement, if not to the feasibility of all countries actually achieving their targets.

In the realm of public policy, as in our everyday lives, we frequently learn more from our mistakes or failures than from our successes; so, too, in the case of the Kyoto Protocol. Therefore, we also examine some key weaknesses of the Protocol and explore what potentially valuable lessons they may hold for the path forward.

First, it is well known that some of the world's leading GHG emitters are not constrained by the Kyoto Protocol. The United States—until recently the country with the largest share of global emissions—has not ratified the agreement. Also, some of the largest and most rapidly growing economies in the developing world do not have emission targets under the agreement. Importantly, China, India, Brazil, South Africa, Indonesia, Korea, and Mexico are not listed in Annex B of the Kyoto agreement. Rapid rates of economic growth in these countries have produced rapid rates of growth in energy use, and hence carbon dioxide (CO_2) emissions. Together with continued deforestation in tropical countries, the result is that the developing world has overtaken the industrialized world in total GHG emissions. China's industrial CO_2 emissions have already surpassed those of the United

States; moreover, China's emissions are expected to continue growing much faster than US emissions for the foreseeable future (Blanford, *et al*. 2010, 822-856).

These realities raise the possibility that the Kyoto Protocol is not as fair as originally intended, especially given how dramatically the world has changed since the UNFCCC divided countries into two categories in 1992. For example, approximately fifty non-Annex I countries—that is, developing countries and some others—now have higher per capita incomes than the poorest of the Annex I countries with commitments under the Kyoto Protocol. Likewise, 40 non-Annex I countries ranked higher on the Human Development Index in 2007 than the lowest ranked Annex I country.

A second weakness of the Kyoto Protocol is associated with the relatively small number of countries being asked to take action. This narrow but deep approach may have been well-intended, but one of its effects will be to drive up the costs of producing carbon-intensive goods and services within the coalition of countries taking action. (Indeed, increasing the cost of carbon-intensive activities is the intention of the Protocol and is fully appropriate as a means to create incentives for reducing emissions.) Through the forces of international trade, however, this approach also leads to greater comparative advantage in the production of carbon-intensive goods and services for countries that do not have binding emissions targets under the agreement. The result can be a shift in production and emissions from participating nations to non-participating nations—a phenomenon known as emission "leakage." Since leakage implies a shift of industrial activity and associated economic benefits to emerging economies, there is an additional incentive for non-participants to free-ride on the efforts of those countries that are committed to mitigating their emissions through the Protocol's narrow but deep approach.

This leakage will not be one-for-one (in the sense that increased emissions in non-Annex I countries would be expected to fully negate emission reductions in Annex I countries), but it will reduce the cost-effectiveness and environmental performance of the agreement, and perhaps worst of all, push developing countries onto a more carbon-intensive growth path than they would otherwise have taken, rendering it more difficult for these countries to join the agreement later.

A third concern about the Kyoto Protocol centers on the nature of its emission trading elements. The provision in Article 17 for international emission trading is unlikely to be effective (Hahn and Stavins 1999). The entire theory behind the claim that a cap-and-trade system is likely to be cost-effective depends upon the participants being cost-minimizing entities. In the case of private-sector firms, this is a sensible assumption, because if firms do not seek—and indeed succeed in—minimizing their costs, they will eventually disappear, given the competitive forces of the market. But nation-states can hardly be thought of as simple cost-minimizers; many other objectives affect their decision-making. Furthermore, even if nation-states sought to minimize costs, they do not have sufficient information about marginal abatement costs at the multitude of sources within their borders to carry out cost-effective trades with other countries.

There is also concern regarding the CDM. This is not a cap-and-trade mechanism, but rather an emission-reduction-credit system. That is, when an individual project results in emissions below what they would have been in the absence of the project, a credit, which may be sold to a source within a cap-and-trade system, is generated. This approach creates a challenge: comparing actual emissions with what they would have been otherwise. The baseline—what would have happened had the project not been implemented—is unobserved and fundamentally unobservable. In fact, there is a natural tendency, because of economic incentives, to claim credits precisely for those projects that are most profitable, and that hence would have been most likely to go forward even without the promise of credits. This so-called "additionality problem" is a serious issue.

Fourth, the Kyoto Protocol, with its five-year time horizon (2008 to 2012), represents a relatively short-term approach for what is fundamentally a long-term problem. GHGs have residence times in the atmosphere of decades to centuries. Furthermore, to encourage the magnitude of technological change that will be required to meaningfully address the threat of climate change, it will be necessary to send long-term signals to the private market that stimulate sustained investment and technology innovation (Newell 2010, 403-438).

Finally, the Kyoto Protocol may not provide sufficient incentives for countries to comply (Barrett 2010, 240-272). Some countries' emissions have grown so fast since 1990 that it is difficult to imagine those countries being able to undertake the emission mitigation or muster the political will and resources necessary to purchase enough emission allowances or CDM credits from other countries, so as to comply with their targets under the Protocol. For example, Canada's GHG emissions in 2008 and 2009 exceeded that country's 1990 levels by about 33 percent on average, making it very unlikely that Canada could comply with an emissions target set at 6 percent *below* 1990 levels, averaged over the 2008–2012 commitment period. As a result, Canada formally initiated the process to withdraw from the Kyoto Protocol in 2011, as it is permitted to do under Article 27 of the Protocol. In short, the enforcement mechanism negotiated for the Kyoto Protocol does not appear to induce policy responses consistent with agreed-upon targets.

Alternative Policy Architectures for the Post-Kyoto Period

We characterize potential post-Kyoto international policy architectures as falling within three principal categories: targets and timetables, harmonized national policies, and coordinated and unilateral national policies (Aldy and Stavins 2007).

The first category—targets and timetables—is the most familiar. At its heart is a centralized international agreement, top-down in form. This is the basic architecture underlying the Kyoto Protocol: essentially country-level quantitative emission targets established over specified time frames. An example of an approach that would be within this realm of targets and timetables, but would address some of the perceived deficiencies of the Kyoto Protocol, would be a regime that established emission targets based on formulas rather than specified fixed quantities (Frankel 2010a, 31-87). In lieu of *ad hoc* negotiations over emission caps, this formula approach would establish principles that could be translated into quantitative metrics for determining emission obligations. These formulas could be structured to have some of the appealing properties of indexed growth targets: setting targets as a function of a country's gross domestic product (GDP) per capita, for example (Aldy 2004, 89-118). As countries became wealthier, their targets would become more stringent.[3] Conversely, when and if countries faced difficult economic periods, the stringency of their targets would be automatically reduced.

[3] Such a mechanism was proposed by Frankel (2007) and is similar to the graduation mechanism proposed by Michaelowa (2007). As developing countries realize growth in per capita income and per capita emissions on par with Annex I countries, they would be expected to take on binding emission targets.

Such an approach does not divide the world simply into two categories of countries, as in the Kyoto Protocol. Rather, it allows for a continuous differentiation among countries. In this way it reduces, if not eliminates, problems of emission leakage, yet still addresses the key criterion of distributional equity and does so in a more careful, sophisticated manner.

The second category—harmonized domestic policies—focuses more on national policy actions than on goals and is less centralized than the first set of approaches. In this case, countries agree on similar domestic policies. This reflects the view that national governments have much more control over their countries' policies than over their emissions. One example is a set of harmonized national carbon taxes (Cooper 2010, 151-178).[4] With this approach, each participating country sets a domestic tax on the carbon content of fossil fuels, thereby achieving cost-effective control of emissions within its borders. Taxes would be set by nations, and nations would have complete discretion over the revenues they generate. Countries could design their tax policies to be revenue-neutral—for example, by returning the revenues raised to the economy through proportional cuts in other, distortionary taxes, such as those on labor and capital. In order to achieve global cost-effectiveness, carbon taxes would need to be set at the same level in all countries. This would presumably not be acceptable to the poorer countries of the world. Therefore, significant side deals would most likely need to accompany such a system of harmonized carbon taxes to make it distributionally equitable and hence politically feasible. This could take the form of large financial transfers through side payments from the industrialized world to the developing world, or agreements in the trade or

[4] McKibbin and Wilcoxen (2007) advance the idea of parallel, unlinked domestic cap-and-trade programs as a way to move forward in international climate policy.

development agenda that effectively compensate developing countries for implementing carbon taxes.

The third and final category that we have used to classify potential post-Kyoto climate policy architectures is coordinated and unilateral national policies. This category includes the least centralized approaches that we have considered: essentially bottom-up policies that rely on domestic politics to drive incentives for participation and compliance (Pizer 2007, 280-314). Although these approaches are the least centralized, they should not be thought of as necessarily the least effective. One example of a bottom-up approach—linking independent national and regional tradable permit systems—may already be evolving (Jaffe and Stavins 2010, 119-150).

Lessons for the International Policy Community

The nations of the world confront a tremendous challenge in designing and implementing an international policy response to the threat of global climate change that is scientifically sound, economically rational, and politically pragmatic. It is broadly acknowledged that the relatively wealthy, developed countries are responsible for a majority of the anthropogenic greenhouse gases (GHGs) that have already accumulated in the atmosphere, but developing countries will emit more GHGs over this century than the currently industrialized nations if no efforts are taken to alter their course of development. The architecture of a robust international climate change policy will need to take into account the many dimensions and consequences of this issue with respect to the environment, the economy, energy, and development.

We identify a set of principles that our research teams have explicitly or implicitly identified as being important for the design of post-Kyoto international climate policy architecture. We then go on to highlight four potential architectures, each of which is promising in some regards and raises important issues for consideration.

Principles for an International Agreement

These principles constitute the fundamental premises that underlie various proposed policy architectures and design elements; as such they can provide a reasonable point of departure for ongoing international negotiations.[5]

Climate change is a global commons problem, and therefore a cooperative approach involving many nations—whether through a single international agreement or some other regime—will be necessary to address it successfully. Because GHGs mix uniformly in the atmosphere, the location of emissions sources has no effect on the location of impacts, which are dispersed worldwide. Hence, it is virtually never in the economic interest of individual nations to take unilateral actions. This classic free-rider problem means that cooperative approaches are necessary (Aldy and Stavins 2008a).

Since sovereign nations cannot be compelled to act against their wishes, successful treaties should create adequate incentives for compliance, along with incentives for participation. Unfortunately, the Kyoto Protocol seems to lack incentives of both types (Barrett 2010, 240-272; Karp and Zhao 2010, 530-562; and Keohane and Raustiala 2010, 372-402).

[5] Aldy, Barrett, and Stavins (2003) present six criteria for evaluating potential international climate policy architectures that map closely to most of these principles.

Since carbon-intensive economies cannot be replicated throughout the world without causing dangerous anthropogenic interference with the global climate, it will be necessary for all countries to move onto much less carbon-intensive growth paths. Even reducing emissions in the currently industrialized world to zero is insufficient (Blanford, *et al* 2010, 822-856; Bosetti, *et al* 2010, 715-752; Cooper 2010, 151-178; Hall, *et al* 2010, 649-681; and Jacoby, *et al*. 2010, 753-785). With appropriate negotiating rules (Harstad 2010, 273-299), more countries can be brought on board. The rapidly emerging middle class in the developing world seeks to emulate lifestyles that are typical of the industrialized world and may be willing to depart from this goal only if the industrialized world itself moves to a lower-carbon path (Agarwala 2010, 179-200; Schmalensee 2010, 889-898; and Wirth 2010, xxxiii-xxxviii). Moving beyond the current impasse will require that developed countries achieve meaningful near-term emission reductions, with a clear view to medium- and long-term consequences and goals (Agarwala 2010, 179-200; Harstad 2010, 273-299; and Karp and Zhao 2010, 530-562).

A credible global climate change agreement must be equitable. If past or present high levels of emissions become the basis for all future entitlements, the developing world is unlikely to participate (Agarwala 2010, 179-200). Developed countries are responsible for more than 50 percent of the accumulated stock of anthropogenic GHGs in the atmosphere today, and their share of near-term global mitigation efforts should reflect this responsibility (Agarwala 2010, 179-200). In the long term, nations should assume the same or similar burdens on an equalized per capita basis (Agarwala 2010, 179-200; Cao 2010, 563-598; and Frankel 2010a, 31-87). However, if the goal is a more equitable distribution of wealth, approaches based on metrics other than per capita emissions can be better

(Jacoby, *et al*. 2010, 753-785; and Posner and Sunstein 2010, 343-371). It is also important to recognize and acknowledge that in the short term, developing countries may value their economic growth more than future, global environmental conditions (Victor 2010, 618-649).

Developing countries face domestic imperatives for economic growth and political development. More and better research is needed to identify policies that promote both mitigation and adaptation, while accommodating development. At the same time, developing countries should not "hide behind the poor" (Agarwala 2010, 179-200): the burgeoning middle class in the developing world is on a path to exceed the population of developed countries and, as we have already noted, its lifestyle and per capita emissions are similar to those in much of the developed world. While not exclusively a problem of developing countries, tropical forests, in particular, are one important dimension of the larger interplay between development and climate change policy. Because of the enormous impacts that natural and anthropogenic changes in forests have on the global carbon cycle, it is important to provide a meaningful, cost-effective, and equitable approach to promoting forest carbon sequestration in an international agreement (Plantinga and Richards 2010, 682-714).

A credible global climate change agreement must be cost-effective. That means it should minimize the global welfare loss associated with reducing emissions (Aldy and Stavins 2008b; Ellerman 2010, 88-118; and Jaffe and Stavins 2010, 119-150), and also minimize the risks of corruption in meeting targets (Agarwala 2010, 179-200; Somanathan 2010, 599-617).

A credible global climate change agreement must bring about significant technological change. Given the magnitude of the problem and the high costs that will be involved, it will be essential to reduce mitigation costs over time through massive technological invention, innovation, diffusion, and utilization (Blanford, *et al*. 2010, 822-856; Bosetti, *et al*. 2010, 715-752; Clarke, *et al*. 2010, 786-821; Newell 2010, 403-438; Somanathan 2010, 599-617; Wirth 2010, xxxiii-xxxviii; and Aldy and Stavins 2008c). Rapid technology transfer from the developed to the developing world will be needed (see Hall, *et al*. 2010, 649-681; Keeler and Thompson 2010, 439-468; Newell 2010, 403-438; Somanathan 2010, 599-617; Teng, *et al*. 2010, 469-492; and Wirth 2010, xxxiii-xxxviii).

Governments should work through a variety of channels to achieve a credible global climate change agreement that uses multiple ways to mitigate climate change risks. Although a post-2012 agreement under the UNFCCC may be part of a post-Kyoto regime, other venues—whether bilateral treaties, or G20 accords, or under the Montreal Protocol—should continue to be explored, as additional agreements and arrangements may be necessary (Hall, *et al*. 2010, 649-681; and Schmalensee 2010, 889-898).

An effective global climate change agreement must be consistent with the international trade regime. A global climate agreement can lead to conflicts with international trade law, but it can also be structured to be mutually supportive of global trade objectives (Frankel 2010b, 493-529; Harstad 2010, 273-299).

A credible global climate change agreement must be practical, realistic, and verifiable. That means it needs institutional mechanisms for effective implementation (Agarwala 2010, 179-200). Because tremendous start-up costs are usually incurred in creating new institutions, consideration should be given, whenever appropriate, to maintaining existing institutions, such as the Clean Development Mechanism, and improving them rather than abandoning them (Hall, *et al.* 2010, 649-681; Karp and Zhao 2010, 530-562; Keeler and Thompson 2010, 439-468; and Teng, *et al*. 2010, 469-492). In addition, it should be recognized that most parts of the industrialized world have signaled their preference for the use of cap-and-trade mechanisms to meet their domestic emissions commitments (Jaffe and Stavins 2010, 119-150), and it would be *politically* practical to build upon these institutional and policy preferences. Whatever institutions or mechanisms are used to implement policy commitments, they should promote emission abatement consistent with realistic technological innovation to avoid risking costly and ineffective outcomes (Agarwala 2010, 179-200; Blanford, *et al*. 2010, 822-856; Bosetti, *et al*. 2010, 715-752; and Jacoby, *et al*. 2010, 753-785). The best agreements will be robust in the face of inevitable global economic downturns (McKibbin, *et al*. 2010, 857-888). Finally, various metrics can be employed to judge the equity and integrity of national commitments, including measures of emissions performance, reductions, or cost (Fischer and Morgenstern 2010, 300-342). An international surveillance institution could provide credible, third-party assessments of participating countries' efforts.

Promising International Climate Policy Architectures

We highlight four potential architectures—each with advantages as well as disadvantages—because each is promising in some regards, raises key issues for consideration, and to a considerable extent is exemplary of the types of architectures we consider.

One architecture follows a targets and timetables structure, using formulas to set dynamic national emissions targets for all countries. Two fall within the category of harmonized domestic policies: a portfolio of international treaties and harmonized national carbon taxes. The fourth architecture summarized below is based on a set of coordinated, unilateral national policies and involves linking national and regional tradable permit systems.

Targets and Timetables: Formulas for Evolving Emission Targets for All Countries[6]

This targets-and-timetables proposal offers a framework of formulas that yield numerical emissions targets for all countries through the end of this century (Frankel 2010a, 31-87). National and regional cap-and-trade systems for greenhouse gases would be linked in a way that allows trading across firms and sources (Jaffe and Stavins 2010, 119-150), not among nations *per se* (as in Article 17 of the Kyoto Protocol). Such a global trading system would be roughly analogous to the system already established in the European Union, where sources rather than nations engage in trading (Ellerman 2010, 88-118).[7]

The formulas are based on what is possible politically, given that many of the usual science- and economics-based proposals for future emission paths are not dynamically consistent; that is, future governments will not necessarily abide by commitments made by

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[6] This proposed architecture was developed by Frankel (2010a), supplemented by Aldy and Stavins (2008b), Harstad (2010), Cao (2010), Ellerman (2010), and Jacoby, *et al*. (2010). Bossetti, *et al*. (2010) provide an economic analysis of this and several other potential architectures.
[7] For an examination of the possible role and design of cap-and-trade and other tradable permit systems as part of an international policy architecture, see Aldy and Stavins (2008b).

today's leaders.[8] Several researchers have observed that when participants in the policy process discuss climate targets, they typically pay little attention to the difficulty of finding mutually acceptable ways to share the economic burden of emission reductions (Bosetti, *et al*. 2010, 715-752; Jacoby, *et al*. 2010, 753-785).

This formula-based architecture is premised on four important political realities. First, the United States may not commit to quantitative emission targets if China and other major developing countries do not commit to quantitative targets at the same time. This reflects concerns about economic competitiveness and carbon leakage. Second, China and other developing countries are unlikely to make sacrifices different in character from those made by richer countries that have gone before them. Third, in the long run, no country can be rewarded for having "ramped up" its emissions well above 1990 levels. Fourth, no country will agree to bear excessive cost. (Harstad adds that use of formulas can render negotiations more efficient [2010, 273-299].)

The proposal calls for an international agreement to establish a global cap-and-trade system, where emission caps are set using formulas that assign quantitative emissions limits to countries in every year through 2100. The formula incorporates three elements: a progressivity factor, a latecomer catch-up factor, and a gradual equalization factor. The progressivity factor requires richer countries to make more severe cuts relative to their business-as-usual emissions. The latecomer catch-up factor requires nations that did not agree to binding targets under the Kyoto Protocol to make gradual reductions to

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8 It is worth nothing that Harstad's (2010) game-theoretic analysis supports the efficacy of using formulas to calculate national obligations or contributions. This is because if the distribution of contributions or obligations is determined by a formula it is fundamentally more difficult for a country to renegotiate its own share of the burden. Enhancing its bargaining position is then less useful, and investments in research and development increase.

account for their additional emissions since 1990. This factor prevents latecomers from being rewarded with higher targets, and is designed to avoid creating incentives for countries to ramp up their emissions before signing on to the agreement. Finally, the gradual equalization factor addresses the complaint that rich countries are responsible for a majority of the accumulated anthropogenic GHGs currently in the atmosphere. In the second half of the century, this factor moves national per capita emissions in the direction of the global average of per capita emissions.[9]

The caps set for rich nations would require them to undertake immediate abatement measures. Developing countries would not bear any cost in the early years, nor would they be expected to make any sacrifice that is different from the sacrifices of industrialized countries, accounting for differences in income. Developing countries would be subject to binding emission targets that would follow their business-as-usual (BAU) emissions in the next several decades.[10] National emission targets for developed and developing countries alike should not cost more than one percent of GDP in present value terms, or more than five percent of GDP in any given year.

Every country under this proposal is given reason to feel that it is only doing its fair share. Importantly, without a self-reinforcing framework for allocating the abatement burden, announcements of distant future goals may not be credible and so may not have desired effects on investment. The basic architecture of this proposal—a decade-by-decade

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[9] This is similar to Cao's (2010) "global development rights" (GDR) burden-sharing formula and is consistent with calls for movement toward per capita responsibility by Agarwala (2010). On the other hand, it contrasts with the analyses of Jacoby, *et al*. (2010) and Posner and Sunstein (2010). Under Cao's GDR formula, the lion's share of the abatement burden would fall on the industrialized world in the short term, with developing countries initially accepting a small but increasing share over time, such that, by 2020, fast-growing economies such as China and India would take on significant burdens.

10 Somanathan (2010) would argue against including developing countries in the short term, even with targets equivalent to BAU, as recommended in this proposal. We discuss alternative burden-sharing arrangements below.

sequence of emission targets determined by a few principles and formulas—is also flexible enough that it can accommodate major changes in circumstances during the course of the century.

Harmonized Domestic Policies: A Portfolio of International Treaties[11]

The second proposal we highlight is for a very different sort of architecture than that of the Kyoto Protocol. Rather than attempting to address all sectors and all types of GHGs under one unified regime, this approach envisions a system of linked international agreements that separately address various sectors and gases; as well as key issues, including adaptation and technology research and development (R&D); plus last-resort remedies, such as geoengineering and air capture of greenhouse gases.

First, nations would negotiate sector-level agreements that would establish global standards for specific sectors or categories of GHG sources. Developing countries would not be exempted from these standards, but would receive financial aid from developed countries to help them comply. Trade sanctions would be available to enforce agreements governing trade-sensitive sectors. Such a sectoral approach could have the advantage that it protects against cross-contamination: if policies designed for a given sector prove ineffective, their failure need not drag down the entire enterprise. Similar arguments can be made for separate approaches to different types of GHGs.

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[11] This proposed architecture was developed by Barrett (2010) and supplemented by Newell (2010) on research and development policies, by Sawa (2010) on sectoral approaches, and by economic modeling from Bosetti, *et al*. (2010).

In general, sectoral approaches in a future climate agreement can offer some advantages (Sawa 2010, 201-239). First, sectoral approaches could encourage the involvement of a wider range of countries, since incentives could be targeted at specific industries in those countries. Second, sectoral approaches can directly address concerns about international competitiveness and leakage: if industries make cross-border commitments to equitable targets this would presumably mitigate concerns about unfair competition in energy-intensive industries. Third, sectoral approaches could be designed to promote technology development and transfer. It should also be recognized, however, that sectoral approaches have some significant problems (Sawa 2010, 201-239). First, it may be difficult to negotiate an international agreement using this approach if negotiators are reluctant to accept the large transaction costs associated with collecting information and negotiating at the sector level. Countries that are already participating in emission trading schemes may tend to avoid any approach that creates uncertainty about their existing investments. Second, a sectoral approach would reduce cost-effectiveness relative to an economy-wide cap-and-trade system or emission tax. Finally, it is difficult for a sectoral approach to achieve high levels of environmental effectiveness, because it does not induce mitigation actions by all sectors.

Recognizing the technology challenge implicit in successfully addressing climate change, a second component of this suite of international agreements could focus on research and development. Specifically, it could require participants to adopt a portfolio of strategies for reducing barriers and increasing incentives for innovation in ways that maximize the impact of scarce public resources and effectively engage the capacities of the private sector (Newell 2010, 403-438).[12] R&D obligations could be linked with emission reduction policies. For example, an agreement could require all new coal-fired power stations to have certain minimum thermal efficiency, and ready capacity to incorporate carbon capture and storage, as the latter becomes technically and financially feasible, with these obligations binding on individual countries as long as the treaty's minimum participation conditions were met. Such an agreement would reduce incentives for free-riding and could directly spur R&D investments in areas where countries and firms might otherwise be likely to under-invest.

Third, an international agreement should address adaptation assistance for developing countries. All nations have strong incentives to adapt, but only rich countries have the resources and capabilities to insure against climate change risks. Rich countries may substitute investments in adaptation—the benefits of which can be appropriated locally—for investments in mitigation, the benefits of which are distributed globally. If so, this would leave developing countries even more exposed to climate risks and widen existing disparities. Critical areas for investment include agriculture and tropical medicine. Policy design to leverage such investment can improve developing countries' resilience to climate shocks while facilitating their economic development.

A fourth set of agreements would govern the research, development, and deployment of geoengineering and air capture technologies.[13] Geoengineering could serve

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[12] In the section below on key design issues, we focus on technology transfer as a key design issue for any international climate policy architecture. Bosetti, *et al*. (2010) analyze the costs and effectiveness of R&D strategies compared with alternative architectures.

[13] Geoengineering strategies attempt to limit warming by reducing the amount of solar radiation that reaches the Earth's surface—the most commonly discussed approach in this category involves throwing particles into the atmosphere to scatter sunlight. Air capture refers to strategies for removing carbon from the atmosphere. Possible options include fertilizing iron-limited regions of the oceans to stimulate phytoplankton blooms or using a chemical sorbent to directly remove carbon from the air.

as an insurance policy in case refinements in climate science over the next several decades suggest that climate change is much worse than currently believed and that atmospheric concentrations may have already passed important thresholds for triggering abrupt and catastrophic impacts. Geoengineering may turn out to be cheap, relative to transforming the fossil-fuel foundation of industrial economies. While no one country can adequately address climate change through emissions abatement, individual nations may be able to implement geoengineering options. The challenge may lie in preventing nations from resorting to it too quickly or over other countries' objections.

This portfolio approach to international agreements could avoid the enforcement problems of a Kyoto-style targets-and-timetables structure, while providing the means to prevent climate change (through standards that lower emissions), become accustomed to climate change (through adaptation), and fix it (through geoengineering). By avoiding the enforcement problems of an aggregate approach and by taking a broader view of risk reduction, the portfolio approach could provide a more effective and flexible response to the long-term challenge posed by climate change.

Harmonized Domestic Policies: A System of National Carbon Taxes[14]

This architecture consists of harmonized domestic taxes on GHG emissions from all sources. The charge would be internationally adjusted from time to time, and each country would collect and keep the revenues it generates (Cooper 2010, 151-178). Since decisions

[14] This proposed architecture was developed by Cooper (2010) and supplemented by Fischer and Morgenstern (2010) on measurement issues, McKibbin, *et al*. (2010) on a hybrid of this approach, and economic modeling by Bosetti, *et al*. (2010).

to consume goods and services that require the use of fossil fuels are made on a daily basis by more than a billion households and firms around the world, the most effective way to reach all these decision makers is by changing the prices they pay for these goods and services. Levying a charge on CO_2 emissions does that directly.

Carbon taxes could have several advantages over a cap-and-trade system. First, the allocation of valuable emission allowances to domestic firms or residents under a cap-and-trade scheme could foster corruption in some countries. A carbon tax would avoid such problematic transfers. Likewise, a carbon tax minimizes bureaucratic intervention and the necessity for a financial trading infrastructure (Agarwala 2010, 179-200). Second, a carbon charge would generate significant revenues that could be used to increase government spending, reduce other taxes, or finance climate-relevant research and development, though it should be noted that the same is true of a cap-and-trade system that auctions allowances. Third, a carbon tax may be less objectionable to developing nations than an emission cap because it does not imply a hard constraint on growth (Pan 2007).[15] Fourth, any international climate regime requires some means for evaluating national commitments and performance (Fischer and Morgenstern 2010). A carbon tax system provides a straightforward and useful metric, since the marginal cost of abatement activities is always equivalent to the tax rate itself.

Since several economies, most notably the European Union, have embarked on a cap-and-trade system, Cooper (2010, 151-178) investigates whether cap-and-trade

[15] China's 2007 National Program on Climate Change indicated that any near-term emissions reductions in that country will be accomplished using domestic policies designed to address energy efficiency, renewable and nuclear energy, and energy security. The document also indicated that in the longer term, China might be willing to place a price on carbon emissions using more direct mechanisms such as an emissions tax or cap-and-trade system (Jiang 2008). This policy approach is reinforced in Part III of China's October 2008 White Paper on climate change (Information Office of the State Council 2008).

systems and tax systems can co-exist. He concludes that the answer is "yes," provided that several conditions are met. First, allowance prices under the cap-and-trade system should average no less than the internationally agreed carbon tax. Second, if the allowance price fell below the agreed global tax for more than a certain period of time, trading partners should be allowed to levy countervailing duties on imports from countries with a low permit trading price. Third, countries could not provide tax rebates on their exports, and cap-and-trade systems would have to auction all of their allowances.

The tax should cover all the significant GHGs, insofar as is practical. The initial scheme need not cover all countries, but it should cover the countries that account for the vast majority of world emissions. All but the poorest nations should have sufficient administrative capacity to administer the tax at upstream points in the energy supply chain—that is, on the carbon content of fossil fuels.[16] The level of the tax would be set by international agreement and could be subject to periodic review every five or ten years.[17]

A carbon tax treaty would need to include monitoring and enforcement measures. The International Monetary Fund could assess whether signatory nations have passed required legislation and set up the appropriate administrative machinery to implement the tax (Agarwala 2010). If a country were significantly and persistently out of compliance, its exports could be subject to countervailing duties in importing countries. Non-signatory countries could also be subject to countervailing duties. This possibility would provide a potent incentive for most countries to comply with the agreement, whether or not they were formal signatories.

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[16] For example, the carbon content of oil should be taxed at refineries, natural gas should be taxed at major pipeline collection points, and coal should be taxed at mine heads or rail or barge collection points.

[17] For a thorough economic assessment of the implications of a system of harmonized domestic carbon taxes, see Bosetti, *et al*. (2010).

Cost-effective implementation at a global level would require the tax to be set at the same level in all countries. The abatement costs incurred by key developing countries would likely exceed by a considerable margin the maximum burden they would be willing to accept under an international agreement, at least in the near term. This could be addressed through transfers (side payments) from industrialized countries to developing countries, thereby enhancing both cost-effectiveness and distributional equity. These transfers would be from one government to another, raising concerns about possible corruption, as well as political acceptability in the industrialized world. Alternatively, distributional equity could be achieved by pairing the carbon tax agreement with a deal on trade or development that benefits these emerging economies.

Coordinated National Policies: Linkage of National and Regional Tradable Permit Systems[18]

A new international policy architecture may be evolving on its own, based on the reality that tradable permit systems, such as cap-and-trade systems, are emerging worldwide as the favored national and regional approach. Prominent examples include the European Union's Emission Trading Scheme (EU ETS); the Regional Greenhouse Gas Initiative in the northeastern United States; AB32 cap-and-trade in California; a hybrid form of carbon pricing in Australia; and systems in Norway, Switzerland, New Zealand, and other nations; plus the existing global emission-reduction-credit system, the CDM.

The proliferation of cap-and-trade systems and emission-reduction-credit systems around the world has generated increased attention and increased pressure—both from governments and from the business community—to link these systems. By linkage, we refer to direct or indirect connections between and among tradable permit systems through the unilateral or bilateral recognition of allowances or permits.[19]

Linkage produces cost savings in the same way that a cap-and-trade system reduces costs compared to a system that separately regulates individual emission sources; it substantially broadens the pool of lower-cost compliance options available to regulated entities. In addition, linking tradable permit systems at the country level reduces overall

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[18] This proposed architecture was developed by Jaffe and Stavins (2010), and supplemented by Ellerman (2010) on the European approach as a potential global model, Keohane and Raustiala (2010) on buyer liability, Hall, *et al*. (2010) and Victor (2010) on the importance of domestic institutions, and by economic modeling from Bosetti, *et al*. (2010).
[19] As Ellerman (2010) explains, to some degree the EU ETS can serve as a prototype for linked national systems.

transaction costs, reduces market power (which can be a problem in such systems), and reduces overall price volatility.

There are also some legitimate concerns about linkage. Most important is the automatic propagation of program elements that are designed to contain costs, such as banking, borrowing, and safety valve mechanisms. If a cap-and-trade system with a safety valve is directly linked to another system that does not have a safety valve, the result will be that both systems now share the safety valve. Given that the European Union has opposed a safety valve in its emission trading scheme, and given that a safety valve could be included in a future U.S. emission trading system, this concern about the automatic propagation of cost-containment design elements is a serious one.

More broadly, linkage will reduce individual nations' control over allowance prices, emission impacts, and other consequences of their systems. This loss of control over domestic prices and other effects of a cap-and-trade policy is simply a special case of the general proposition that nations, by engaging in international trade through an open economy, lose some degree of control over domestic prices, but do so voluntarily because of the large economic gains from trade.

Importantly, there are ways to gain the benefits of linkage without the downside of having to harmonize systems in advance. If two cap-and-trade systems both link with the same emission-reduction-credit system, such as the CDM, then the two cap-and-trade systems are indirectly linked with one another. All of the benefits of linkage occur: the cost-effectiveness of both cap-and-trade systems is improved and both gain from more liquid markets that reduce transaction costs, market power, and price volatility. At the same time, the automatic propagation of key design elements from one cap-and-trade system to another is much weaker when the systems are only indirectly linked through an emission-reduction-credit system.

Such indirect linkage through the CDM is already occurring, because virtually all cap-and-trade systems that are in place, as well those that are planned or contemplated, allow for CDM offsets to be used (at least to some degree) to meet domestic obligations. Thus, indirectly linked, country- or region-based cap-and-trade systems may already be evolving into the *de facto*, if not the *de jure*, post-Kyoto international climate policy architecture.

Of course, reliance on CDM offsets also gives rise to concerns, especially as regards the environmental integrity of some of those offsets. Some have recommended that a system of buyer liability (rather than seller or hybrid liability) would endogenously generate market arrangements—such as reliable ratings agencies and variations in the price of offsets according to perceived risks—that would help to address these concerns, as well as broader issues of compliance (Keohane and Raustiala 2010). These features would in turn create incentives for compliance without resorting to ineffective inter-state punishments. In addition, a system of buyer liability gives sellers strong incentives to maintain permit quality so as to maximize the monetary value of these tradable assets.

While in the near term, linkage may continue to grow in importance as a core element of a bottom-up, *de facto* international policy architecture, in the longer term, linkage could play several roles. A set of linkages, combined with unilateral emissions reduction commitments by many nations, could function as a stand-alone climate architecture. Such a system would be cost-effective, but might lack the coordinating mechanisms necessary to achieve meaningful long-term environmental results. Another possibility is that a collection of bottom-up links may eventually evolve into a comprehensive, top-down agreement. In this scenario, linkages would provide short-term cost savings while serving as a natural starting point for negotiations leading to a top-down agreement.[20] The top-down agreement might continue use of linked cap-and-trade programs to reduce abatement costs and improve market liquidity.

A post-Kyoto international climate agreement could include several elements that would facilitate future linkages among cap-and-trade and emission-reduction-credit systems. For example, it could establish an agreed trajectory of emissions caps (Frankel 2010a, 31-87) or allowance prices, specify harmonized cost-containment measures, and establish a process for making future adjustments to key design elements. It could also create an international clearinghouse for transaction records and allowance auctions, provide for the ongoing operation of the CDM, and build capacity in developing countries. If the aim is to facilitate linkage, a future agreement should also avoid imposing "supplementarity" restrictions that require countries to achieve some specified percentage of emission reductions domestically.

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[20] Carraro (2007) and Victor (2007) also describe the potential for trading to emerge organically as a result of linking a small set of domestic trading programs. This evolution would be analogous to the experience in international trade in goods and services, in which a small number of countries initially reached agreement on trade rules governing a small set of goods. As trust built on these initial experiences, trading expanded to cover more countries and more goods, a process that eventually provided the foundation for a top-down authority in the form of the World Trade Organization.

Conclusion

Great challenges confront the community of nations seeking to establish an effective and meaningful international climate regime for the post-Kyoto period, but we have identified some key principles and promising policy architectures.

Climate change is a global commons problem, and therefore a cooperative approach involving many nations will be necessary to address it successfully. Since sovereign nations cannot be compelled to act against their wishes, successful treaties must create adequate internal incentives for compliance, along with external incentives for participation. A credible global climate change agreement must be: (1) equitable; (2) cost-effective; (3) able to facilitate significant technological change and technology transfer; (4) consistent with the international trade regime; (5) practical, in the sense that it builds where possible on existing institutions and practices; (6) attentive to short-term achievements, as well as medium-term consequences and long-term goals; and (7) realistic. Because no single approach guarantees a sure path to ultimate success, the best strategy may be to pursue a variety of approaches simultaneously.

We have highlighted in this chapter four potential frameworks for a post-Kyoto agreement, each of which is promising in some regards and raises important issues for consideration. One calls for emissions caps established using a set of formulas that assign quantitative emissions limits to countries through 2100. These caps would be implemented through a global system of linked national and regional cap-and-trade programs that would allow for trading among firms and sources. A second potential framework would instead rely on a system of linked international agreements that separately address mitigation in various sectors and gases, along with issues like adaptation, technology research and development, and geoengineering. A third architecture would consist of harmonized domestic taxes on emissions of GHGs from all sources, where the tax or charge would be internationally adjusted from time to time, and each country would collect and keep the revenues it generates. Fourth, we discussed an architecture that, at least in the short term, links national and regional tradable permit systems only indirectly, through the global CDM. We highlight this option less as a recommendation and more by way of recognizing the structure that may already be evolving as part of the *de facto* post-Kyoto international climate policy architecture.

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