

CHAPTER 5

Designing Global Climate Regulation

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In response to scientific research suggesting that global climate change is a serious prospect, political negotiations have sought to establish an international regulatory policy to constrain greenhouse gas emissions. Major new treaties—the 1992 Framework Convention on Climate Change and the 1997 Kyoto Protocol—have been negotiated. But identifying the problem is not the same as crafting the solution. Climate science is a necessary but not sufficient basis for climate policy. It remains crucial, and often not simple, to design the regulatory system best suited to addressing global climate change.¹

U.S. Supreme Court Justice Stephen Breyer, a scholar of regulatory design, observed two decades ago that “mismatches” defeat many well-intentioned regulatory programs and that regulatory systems should match the social and environmental systems they regulate.² More specifically, regulatory programs should employ cost-effective tools, foster creativity in achieving solutions, and match the scale of the ecosystems and spillover effects they are meant to govern. But actual legal responses have too often created mismatches with social and environmental systems, such as regulatory programs that are unduly narrow and inflexible, resulting in excessive costs or even perverse increases in environmental harm.

Global climate change plainly illustrates this problem. Climate change is complex on many dimensions, frustrating simple and hasty regulatory responses. The challenge is to design a regulatory system that matches these complex realities and thereby accomplishes cost-effective advances in global environmental protection. At least three kinds of complexity confront regulatory design for global climate change: causal complexity, spatial complexity, and temporal complexity.

Causal complexity denotes the diverse interconnected factors that drive climate change. Multiple greenhouse gases (GHGs) are affected by almost every human activity, including industry, transportation, agriculture, and forest management. The sources and sinks of the multiple GHGs are numerous and widespread. Policies aimed at only one of these causal factors, such as one GHG, can unintentionally exacerbate other causal factors. If global climate regulation is to be effective, it must address these complex causal factors comprehensively; it must match the causal scope of the problem. Yet there are persistent pressures to design regulatory regimes narrowly.

Spatial complexity involves the great breadth and diversity of GHG sources and sinks in almost every country. Regulating a global problem is difficult because the institutions of governance are not matched to the spatial scale of the problem. Geographically narrow policies limited to one country or region may induce emitting activities to relocate to other areas. But establishing global environmental regulations is more difficult than instituting national ones; without a global government (in part for some good reasons), global regulations must be made by the cooperation of numerous national governments. Across the planet, countries have diverse economies, social norms, political institutions, and interests. This spatial diversity makes a single uniform regulatory approach unwise and makes global cooperation on coordinated regulatory policies difficult. Furthermore, whereas national law typically is imposed by some form of majority vote, at the international level each nation is sovereign and is bound only by the treaties to which it consents. Compliance with national pollution control laws can be compelled, but participation in international treaties cannot be compelled and must instead be attracted. Effective climate regulation must therefore deal with global scale, global diversity, and the global legal framework.

Temporal complexity refers to the dynamic character over time of the climate, human activities and technologies, and our understanding of these systems. Climate policy cannot be made once and for all; it must be updated to adapt to changing circumstances and knowledge. Yet designing a dynamically adaptive regulatory regime is difficult: We never have full knowledge of the future, investors want predictable rules, early decisions about emissions and investments may endure for many years, and political planning horizons may not match environmental time horizons. And even a climate policy without repeated adaptation must decide how to allocate abatement efforts over time.

Nevertheless, through careful analysis an effective and efficient global regulatory regime for climate change can be constructed. A comprehensive, incentive-based, and adaptive regulatory design can be matched to the casual, spatial and temporal complexities of global climate change.

Causal Complexity and Comprehensive Scope³

The Scope of Environmental Regulation

How comprehensive should environmental regulation be? When faced with a problem, how much of it should we try to tackle? The essence of the environment is its interconnectedness. But the complexities of policymaking often push decision makers toward narrow, piecemeal solutions that address one obvious symptom or cause of an environmental problem. Advocates of narrow solutions claim that limited, incremental steps are easier to accomplish than broader, comprehensive approaches.⁴

Piecemeal regulatory strategies, however, may ignore the full scope of a problem, miss lower-cost options to achieve better results, and produce unintended side effects.⁵ A broader, more comprehensive approach takes into account the complex nature of environmental issues. It attempts to match the regulatory design to the complex environmental system being regulated.

Discussions about global climate change policy in the late 1980s centered on reducing the amount of carbon dioxide (CO₂) emitted from the energy sector because CO₂ was the most plentiful greenhouse gas, and the energy sector was the largest source of CO₂. The initial negotiating positions of major countries proposed a treaty calling for cuts in energy sector CO₂.

But at the same time, scientists were demonstrating to policymakers that CO₂ was only one of several important GHGs. First, although the volume of CO₂ emitted far exceeds that of other GHGs, each CO₂ molecule is a weak absorber of infrared radiation (heat). Other GHGs, such as methane (CH₄) and nitrous oxide (N₂O), are important contributors to global warming potential because despite their smaller volume of emissions, they are roughly 20 and 300 times more potent per unit, respectively, than CO₂ at retaining heat in the atmosphere over time. Thus CO₂ was estimated to be responsible for only about one-half⁶ of the global warming potential of anthropogenic GHG emissions in the 1980s.

Second, the relative influence of CH₄ and N₂O was expected to increase in the future. GHGs absorb infrared radiation in wavelengths specific to each gas. As the concentration of CO₂ in the atmosphere has risen, more and more of the infrared radiation at the wavelength blocked by CO₂ molecules is already being absorbed. Because of this saturation effect, additional emissions of abundant atmospheric gases such as CO₂ will have decreasing marginal impacts relative to those of less abundant gases such as methane. Thus, narrowly targeting CO₂ and omitting the other salient GHGs would limit the effectiveness of the regulatory regime in averting climate change.

Advantages of the Comprehensive Approach to Climate Change

Environmental Advantages

Taking a comprehensive approach to climate policy has several significant advantages. First, it is environmentally superior. Piecemeal approaches ignore important sources of the problem and thus neglect important opportunities to solve it. Moreover, they tend to be self-defeating because efforts to solve one aspect of a problem intensify other, neglected aspects. The history of pollution control in the United States offers an example. Our federal environmental statutes have focused on one medium at a time: separate laws for air, water, and land. Restrictions on one medium have induced disposal into other media.⁷ Like squeezing one end of a balloon, this approach shifts the problems elsewhere and delays attainment of the primary goal: a cleaner environment. An integrated approach would control pollution more comprehensively and effectively.⁸

Similarly, focusing solely on energy sector CO₂ would induce perverse shifts in emissions. For example, controlling energy sector CO₂ alone would invite fuel switching from coal to natural gas because burning coal emits about twice as much CO₂ per unit of energy produced as does natural gas. But natural gas is almost pure methane (CH₄), and methane is roughly 20 times more potent than CO₂ per mass at causing global warming. As little as 6 percent fugitive methane emissions from natural gas systems would be enough to fully offset the CO₂-related benefits of this fuel switching.⁹ In the United States, natural gas systems rarely release more than 2 percent of their methane, but in Europe the methane leakage rate has been much higher, often exceeding 6 percent, especially in Russia, where much of the natural gas to replace European coal would come from. Thus a CO₂-only policy in Europe could yield a net increase in the contribution to global warming.¹⁰

Another example involves replacing fossil fuels with biomass fuels, such as ethanol made from corn. At first glance such a policy seems attractive because it would reduce energy sector CO₂ emissions. The CO₂ emissions from burning the fossil fuels would be reduced or eliminated, and the CO₂ emissions from burning the biomass fuels would, one might presume, be at least partly offset by the sequestration of that same CO₂ from the atmosphere by the corn as it grew. But the story is not that simple. Focusing only on energy sector CO₂ neglects three important emission categories. First, the CO₂ emissions from the ancillary agricultural operations needed to farm the corn, manufacture fertilizer, irrigate the land, and convert the corn into fuel probably would be large.¹¹ Second, growing corn uses large quantities of nitrogen fertilizer, which release nitrous oxide (N₂O), a GHG almost 300 times more potent per mass than CO₂. Third, if the corn is grown on cleared forest lands, the carbon liberated from the forest

ecosystem (trees, plants, and soils) when cleared and the lesser ability of the corn field to sequester carbon as compared to the forest must be counted as well. Together, these three side effects could make biomass fuel much less attractive, and possibly even perverse, as a climate protection strategy.

The solution to these perverse shifts is not to abandon climate protection but to include all the major GHGs (including methane and nitrous oxide, and others, as well as CO₂) and all sectors (including agriculture and forests as well as energy). A comprehensive approach defines performance and measures results in terms of the full impacts of any policy intervention on climate change, thus preventing perverse shifts across GHGs and sectors.

A comprehensive approach would also give sources the incentive to find ways to reduce all of these GHGs in all sectors. For example, under a comprehensive regulatory design, Russia and other countries with leaky natural gas systems would have a greater incentive to invest in closing methane leaks. And sources would invest in conserving and expanding forests to sequester carbon, potentially aiding biodiversity as well as climate protection.¹²

Economic Advantages

There are also economic advantages associated with the comprehensive approach. Allowing a wider array of control options reduces the cost of achieving the overall objective. By allowing countries to choose which GHGs they reduce in which sectors, the comprehensive approach gives them the opportunity to make the most cost-effective reductions. Because there is so much variety in GHG limitation opportunities across nations, the comprehensive approach would yield large cost savings compared with a piecemeal approach that fixes limits for CO₂ alone or for each gas separately. A comprehensive approach would regulate the net CO₂-equivalent emissions from each country, not the specifics of how it was achieved, thereby protecting the climate at lower cost. For example, the U.S. Department of Energy estimated that meeting a U.S. emission target of 20 percent below 1990 levels by the year 2010 by comprehensively addressing all GHGs, instead of just energy sector CO₂ alone, would reduce costs by 75 percent; adding the option of sink enhancement would cost 90 percent less than the energy sector CO₂ policy.¹³ Similarly, a World Bank study found that India could reduce its costs 80 percent by controlling all GHGs instead of energy sector CO₂ alone.¹⁴ The most recent and thorough study confirms these results worldwide. Using an integrated assessment model of the world economy, a research team at the Massachusetts Institute of Technology (MIT) found that a comprehensive approach to all GHGs and sectors reduces the global costs of meeting the Kyoto Protocol targets by at least 60 percent.¹⁵ The MIT study also noted

that the multigas approach could be more effective at protecting the climate than the CO₂-only approach, both because the relative global warming impact of the non-CO₂ gases is expected to increase in the future and because the ability of CO₂ to fertilize plant growth and hence stimulate carbon storage means that CO₂ creates a negative feedback on global warming that the other gases do not. A new study by National Aeronautics and Space Administration (NASA) climate scientist James Hansen and colleagues offers further support for the comprehensive approach, showing that control of non-CO₂ GHGs (including methane and dark soot) would be cost-effective and would yield significant side benefits to human health by reducing local air pollutants.¹⁶

Innovation

By rewarding efforts in a wider array of gases and sectors, the comprehensive approach also provides better incentives for innovation in abatement strategies. Focusing narrowly on a specific sector or gas misses the chance to stimulate new approaches that have not yet been identified. The comprehensive approach also offers the flexibility to change tactics as our understanding of technologies and climate impacts evolves.

Fairness

The comprehensive approach establishes a more equitable position for all nations at the regulatory negotiation table. Because of the differences across countries in opportunities to control sources and expand sinks and differences in their economic status, a piecemeal policy inevitably favors some nations while disproportionately burdening others. The comprehensive approach allows each country to choose its best mix of policies, dealing more even-handedly with countries of widely different internal economic and social configurations.

Participation

The cost and fairness advantages of the comprehensive approach have another benefit. As will be discussed in more detail later in this chapter, attracting participation in international climate policy by a large number of countries is critical. Because climate change and regulatory actions to address it affect each nation differently, their own best policy responses will vary. No single, narrow regulatory tactic will be attractive to all of the world's countries; flexible approaches will have wider appeal. Policy instruments that are less costly, individually and collectively, will stand a greater chance of being acceptable to all parties and attracting their participation in the treaty.

Progress on the Comprehensive Approach

The climate treaties have made progress in adopting the comprehensive approach to addressing all major GHGs in all sectors, and including sinks as well as sources. The United States proposed the comprehensive approach in 1990,¹⁷ and that approach was adopted in the Framework Convention on Climate Change (FCCC) signed at the Rio Earth Summit in 1992. Article 3 of the FCCC endorses the comprehensive approach, and Article 4 states that parties shall reduce emissions of all GHGs and enhance GHG sinks.

The Kyoto Protocol, signed in 1997, maintained the comprehensive approach. It specifically included six GHG classes in its quantitative emission targets: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆). It also gives credit for sink expansion. The Kyoto Protocol requires countries to attain levels of net GHG emission reductions, weighted by the Global Warming Potential (GWP) index according to their relative contribution to global warming, and does not specify separate limitations for each gas. This comprehensive approach offers each country the flexibility to reduce the sum of its GHG emissions in the most cost-effective way it chooses while requiring countries to monitor and manage all the salient GHGs. The Bonn and Marrakech accords on implementing Kyoto reinforced the comprehensive approach in almost all respects, although they did impose quantitative ceilings on the use of sinks by each country. These limits may increase the costs of achieving the Kyoto targets.

Concerns have been raised about the administrative practicality of a multi-gas approach, including that emissions of some gases might be difficult to monitor and that the GWP index used to compare the heat-trapping ability of the different GHGs is imperfect. Some critics proposed that a narrow regulatory mechanism (addressing only CO₂) be devised initially and then expanded stepwise into a more comprehensive instrument (addressing multiple GHGs) later on. But this strategy is flawed. First, it would initially forfeit the environmental and economic advantages of the comprehensive approach: It would invite perverse shifts, and it would cost much more. These benefits of comprehensiveness vastly outweigh its administrative costs. Second, the intended stepwise expansion probably would be delayed or thwarted: The countries and interest groups least burdened by the initial narrow design would become entrenched in their favored positions and would resist expansion to a more comprehensive approach later. Third, this piecemeal strategy would fail to provide the incentives for innovation in the monitoring and abatement methods for non-CO₂

gases that eventually would be needed to run an effective comprehensive program. Moreover, the comprehensive approach is not impractical.¹⁸ The measurement of non-CO₂ gases and nonenergy sectors, even if initially difficult, would improve in response to policy incentives. And such measurement is necessary even under a CO₂-only policy if we are to evaluate the true effectiveness of the policy in protecting the climate; ignoring the non-CO₂ gases does not make them go away. The GWP index is not perfect, but it is more accurate than ignoring the non-CO₂ gases (implicitly assigning them an index weight of zero). The treaties expressly contemplate improving the GWP index over time in response to new science. In sum, the comprehensive approach is a practical and advantageous design for effective and efficient climate policy.

Spatial Complexity, Participation, and Instrument Choice¹⁹

GHG emissions could be regulated in several ways, such as technology requirements, emission taxes, subsidies for abatement, maximum emission levels, or tradable emission allowances. This question of instrument choice has long been a central theme of environmental law, policy, and economics. And it has taken center stage in the international negotiations on the FCCC and the Kyoto Protocol (and the 2001 Bonn/Marrakech accord on implementing Kyoto). The FCCC adopted an informal version of allowance trading called joint implementation (JI) (Article 4(2)(a)). The Kyoto Protocol retained JI (Article 6) and added a formal system of tradable allowances (Article 17) as well as a new informal trading system for the sale of emission reduction credits by developing countries, called the Clean Development Mechanism (CDM) (Article 12). Were these the best choices? The answer relates to the spatial complexity of global climate, global economic activity, and global regulation.

Spatial Complexity

Global Impacts

A primary challenge of global environmental problems is that they have global impacts. Each country's GHG emissions create global environmental spillover effects, or externalities.²⁰ The atmosphere is being treated as an open-access commons that anyone can use as a disposal site for GHGs.²¹ Prevention of these global externalities (i.e., climate protection) is a global public good because it is nonexcludable: Once an improved climate is provided, it is impossible to exclude anyone from enjoying its benefits; abatement of emissions at any one location generates benefits enjoyed by people around the world. As a result, any

individual country is likely to receive only a small fraction of the benefits of its own abatement efforts.

If GHG abatement is costly, countries will prefer to avoid the costs of abatement while enjoying the shared benefit of others' efforts, trying to take a free ride on others' abatement.²² Collective abatement action would bring greater net gains to all the participants, but fear of free riding by others can lead each country to hesitate to act. Thus, the global nature of the climate problem means that individual countries will tend to invest in less abatement than would be desirable from a collective global point of view. A central challenge for global regulatory design is to choose instruments that help overcome free riding and facilitate collective action.²³

Global Sources

Overcoming free riding in the provision of public goods is never easy, even at the local level, but doing so in the global context is even more difficult. The sources of GHG emissions are spread all around the planet, so climate policy must have nearly global coverage to be effective. The U.S. and China are the world's top emitters, and developing countries are expected to increase their GHG-emitting activities rapidly over the next few decades.²⁴ A spatially limited policy that covers only industrialized countries, or omits China and the U.S., would omit a major fraction of global emissions and fail to forestall adverse climate change.

Worse, a policy that restricts emissions only in some countries could induce emission sources to shift or "leak" to unregulated countries through both industry relocation and changing world commodity prices. Such leakage has several undesirable consequences. First, it at least partly offsets the environmental effectiveness of the policy. Second, the economies of the initially unregulated nations receiving the leakage become more GHG-intensive as a result of the leakage so that later participation in the regulatory treaty becomes even more costly and unappealing to them.²⁵ Third, even if actual leakage is small, fear of leakage can be a potent political obstacle to treaty participation. For example, in 1997 the U.S. Senate voted 95–0 not to ratify a climate treaty that exempted the developing countries.²⁶

Local Diversity

A further complexity is that sources and impacts vary widely around the world. There is significant local diversity in the costs and benefits of abatement and in social and legal systems. The costs of abatement vary because differences in technology, available substitutes, and economic structures make avoiding future emissions much less (or more) costly in some places than others. One study

found a 50-fold difference in GHG abatement costs just within the membership of the European Union (EU).²⁷ The range of variation in global abatement costs is likely to be even greater than that.

Meanwhile, the benefits of preventing global environmental change also vary. Even though climate protection is a global public good, its benefits would vary regionally. Island nations and countries with low-lying coastal areas are at greater risk from sea level rise and so stand to see greater benefits from averting global warming. Wind and precipitation patterns may change so that some areas will experience drier weather and others wetter weather. Host ranges for vegetation and pests may shift. Poorer countries with agrarian or coastal economies and little social safety net may be physically more vulnerable to these changing patterns than are wealthier countries. But wealthier countries, even if physically less vulnerable to climate change, typically place a higher priority on long-term global environmental protection than do poorer countries for whom more local and more immediate problems—such as hunger and infectious disease—are more pressing. Thus, with the exception of poor island and coastal nations, it is largely the wealthier countries that press for long-term climate protection.²⁸

Some countries, perhaps including China and Russia, might even believe they stand to gain from climate change, on the view that they will enjoy greater agricultural yields in currently cold areas if temperatures rise. A recent synthesis of global climate change impacts on key end points—agriculture, forestry, water resources, energy consumption, sea level rise, ecosystems, and human health—indicates that some initial warming (1°C) and CO₂ fertilization may help agriculture and human health in some areas (including the Organisation for Economic Co-operation and Development [OECD], Russia, and China), for a near-term gain of 1–3 percent of GDP. However, this climate change will have adverse impacts in poorer areas (especially Africa and southeast Asia, which would lose 1–4 percent of GDP), and the impacts of greater warming will become adverse worldwide over the longer term, including losses of 1–2 percent in OECD countries and 4–9 percent in Russia and developing countries (but not in China, which exhibits persistent gains from climate change of about 2 percent of GDP).²⁹ Therefore, China and perhaps Russia (initially) may not just be free riders (players for whom cooperative action is beneficial but who would rather let others bear the cost) but may be “cooperative losers”: players for whom climate change is benign (or not seriously adverse) and for whom cooperative action to prevent climate change is costly and who therefore dislike cooperative prevention efforts.³⁰ Because these countries are also large GHG emitters, successful climate regulation must include these countries. But attracting participation by cooperative losers is even more difficult than overcoming free riding.

Participation and Voting Rules

This spatial complexity would not make so much difference in the choice of regulatory instrument if global regulation could simply be imposed on all emitters worldwide by one rational benevolent dictator. That imaginary world of welfare-maximizing despotism is the dream of some, the nightmare of others, and the routine assumption of most economic models of regulation.³¹

In reality, the voting rule for policy adoption ranges along a spectrum from rule by one (autocracy) to rule by all (unanimity). In autocracy, a single decision maker makes the law, and all are bound regardless of their consent. In democracies, legislation embodies a version of majority rule: A majority of consent is sufficient to adopt a law that then binds all, including those (up to 49 percent) who dissented from the adoption of this law.³² By contrast, the voting rule for international treaties is consent: Treaties bind only those who agree to be bound.³³ Unlike autocracy and majority rule, under the consent voting rule regulation cannot be imposed on dissenters. Note that consent is not quite the same as unanimity. The latter requires the consent of every voter for a law to become binding on any voter, whereas the former does not. Under consent, the law is binding on those who do consent, even if others demur. Under unanimity, each voter can veto the entire law; under consent, each voter can only choose not to participate herself.

In practice, the real international voting rule for global climate treaties is consent,³⁴ tinged with aspects of both coercion and unanimity. Overlaid on the basic rule of consent to treaties are some coercive pressures, such as military force and trade sanctions.³⁵ But military force is rarely used to secure adoption of environmental treaties (although disputes over fisheries have recently come close to naval combat), and the use of trade sanctions to penalize treaty non-participants may be limited by the General Agreement on Tariffs and Trade (GATT) and World Trade Organization (WTO) free trade disciplines. Shaming³⁶ and interest group pressures³⁷ are elements of a country's calculus of whether to consent. Meanwhile, the tradition of seeking consensus in treaty negotiations³⁸ and the need to avoid emission leakage by covering all major players tend to place the consent-based voting rule for international climate treaties fairly near to the unanimity end of the spectrum.

The voting rule of consent has fundamental implications for participation and, in turn, for the choice among regulatory instruments.³⁹ In general, national consent to a treaty requires a positive national net benefit compared to not joining.⁴⁰ Unless a country views joining a treaty as favoring its interests, it is highly unlikely to join. Of course, *net benefit* and *interest* are to be construed broadly,

including considerations of fairness and reputation as well as economic, environmental, social, political, and other concerns. In economic terms, treaties must satisfy not just Kaldor–Hicks efficiency (aggregate net benefits) but also the more stringent test of actual Pareto improvement (individual net benefits for each participant).⁴¹ International treaties thus are adopted by a voting rule much more analogous to marketplace contracts than to national legislation.⁴² And this consent voting rule, together with the problems of free riders, leakage, and cooperative losers, makes collective action more difficult to organize than under coercive voting rules such as majority rule.

Global Instrument Choice

Most analyses of regulation assume autocracy: If one rational person could pick the best regulatory instrument, which would she choose? This section begins by reviewing the analysis under autocracy and then examines how this choice is different when the voting rule is consent.

The Regulator's Toolbox

The instruments available to the regulator include technology requirements, emission taxes, subsidies for abatement, performance standards, and tradable emission allowances. A broad distinction can be drawn between basing regulation on conduct and basing it on outcomes.

Conduct-based instruments specify how firms shall act, in the hope that improved conduct will reduce pollution. For example, a conduct-based instrument might dictate specific technologies that firms must install or specific fuels that firms must use to limit emissions. In contrast, outcome-based instruments (also called incentive-based) seek to achieve a certain degree of environmental protection but allow firms to choose how they will meet that goal. They internalize externalities by “reconstituting” flawed markets, using incentives that motivate firms to adjust their own behavior by taking account of the environmental impacts they had previously neglected.⁴³ Two basic types of incentive-based instruments are price-based and quantity-based.⁴⁴ Price-based instruments set a price for emitting, and firms then decide what quantity of emissions to generate in light of having to pay this price. Price-based instruments include taxes on emissions and subsidies for abatement. Quantity-based instruments set a total quantity of acceptable emissions and then allocate entitlements to emit. Quantity-based instruments include fixed performance standards (i.e., an emission limit for each source) and tradable emission allowances (i.e., emission limits for each source, which sources can buy or sell). Once the total quantity of emissions is chosen and allowances adding up to that total are assigned (or once

an emission tax is set), each source then decides how much to emit in light of having to buy an additional allowance (or pay the tax) and in light of the opportunity to earn the market price to sell an extra allowance.

The Analysis Under Autocracy

There is no universal best regulatory instrument; the choice among them depends on several contextual factors, including their environmental effectiveness and their cost in achieving any given level of protection.⁴⁵ Still, under the standard assumption of autocracy—that the law is imposed by a single rational actor—three presumptions have emerged in the literature on instrument choice. These three presumptions are that incentive instruments are superior to conduct instruments, taxes and tradable allowances are superior to subsidies for abatement, and taxes often are superior to tradable allowances. After briefly describing these presumptions in the world of autocracy, we can examine their validity in a world of consent.

INCENTIVES VERSUS CONDUCT

First, incentive-based instruments such as taxes and tradable allowances generally are more cost-effective than conduct instruments or fixed performance standards. Uniform standards require all firms to do the same thing regardless of cost. If abatement costs vary across sources—as they do for GHGs—then cost-effectiveness can be improved by using a regulatory mechanism that obtains more abatement from the lower-cost abaters. Both emission taxes and tradable allowances achieve overall environmental protection at lower total cost by inducing lower-cost firms to abate more and higher-cost firms to abate less. In the United States, allowance trading programs have proven to be far more cost-effective than conduct rules or fixed performance standards, cutting costs by roughly half.⁴⁶ For example, the SO₂ emission trading system adopted in the 1990 Clean Air Act amendments to reduce acid rain has achieved a dramatic reduction in SO₂ emissions at roughly half the cost of the prior uniform approach.⁴⁷ Because GHG abatement costs vary a great deal across countries, the cost savings for global GHG emission trading (compared with fixed national targets) are predicted to be large (30 to 70 percent).⁴⁸

Second, incentive instruments are more effective in stimulating dynamic innovation. Technology requirements provide no incentive for the firm to invest in improved abatement methods beyond what has been mandated. Performance standards provide a modest incentive for innovation. Taxes and trading give sources the strongest continuous motivation to improve abatement methods, which enables the source to sell allowances or pay lower taxes.⁴⁹

Third, incentive instruments need not involve undue administrative costs.

Technology standards require detailed engineering choices and monitoring of devices installed. Incentive methods must determine the tax rate or number of allowances and monitor actual emissions. Monitoring emissions can be costly (especially for dispersed sources), but monitoring the technology in place at a source does not measure environmental impact. Monitoring actual emissions can be worthwhile if it improves environmental effectiveness. Moreover, the social cost savings and enhanced innovation under incentive instruments would often dwarf their administrative costs.

Fourth, incentive instruments can be designed to promote fairness. There is concern that efficiency-enhancing policies (such as emission trading) might be unfair to poorer communities and developing countries.⁵⁰ Developing countries worry that global environmental law may be a form of eco-imperialism. They want developed countries to take the lead in controlling GHG emissions. It would be unfair to make poorer countries worse off in the effort to correct a problem caused by and of primary concern to wealthier industrialized countries. Technology standards, performance standards, and emission taxes could be regressive. But global tradable allowances could be structured to achieve fairness for poorer societies by giving them valuable headroom in their initial assignment of allowances. This would enable poorer countries to grow economically by emitting somewhat more GHGs (perhaps up to or even over their business-as-usual forecast) or by earning substantial revenues from selling a valuable new asset—the tradable allowances—to wealthier sources facing higher abatement costs. This system would benefit poorer societies by giving them a substantial revenue stream.⁵¹ It would also oblige richer countries to take the lead by financing global emission reductions (in a way that is also cost saving). The basic logic of voluntary exchange (market trading) means that allowance sales would not occur unless both parties felt better off. On the other hand, insisting that industrialized countries control their emissions entirely at home would be unfair to developing countries because it would deprive developing countries of the allowance sale revenue stream. It would be like insisting that rich people must spend their money only in rich neighborhoods.

Fifth, incentive mechanisms do not represent immoral means of achieving environmental protection. Critics worry that translating environmental protection into market prices and commodities may debase its moral value.⁵² But insofar as environmental degradation stems from the failure of markets to take account of environmental impacts, the problem is not that the environment is too important to leave to markets but rather that the environment is too important to leave out of markets. Nor do tradable allowances amount to a special “license to pollute.” Conduct instruments and fixed performance standards amount to a license to pollute for free once the technology has been installed or

the performance standard achieved. Taxes and tradable emission allowances, by contrast, force the source to pay for every unit of emissions, either by paying the tax or by foregoing the revenue from the sale of the allowance. Furthermore, if causing additional pollution is the immoral act and if incentive instruments are more cost-effective and innovation-enhancing, then the moralist who opposes incentive instruments is committing an immoral act.

TAXES AND TRADING VERSUS SUBSIDIES

The second presumption is that subsidies for abatement are inefficient. Subsidies for abatement can act like emission taxes at the margin: For each source, declining to abate means forfeiting the subsidy, which is equivalent to paying a tax of the same amount. But whereas taxes also charge the source for all its unabated emissions and thereby raise the average cost of doing business in that industry, subsidies pay the source for abatement and thereby reduce the average cost of doing business in that industry. This attracts investment to the emitting sector and could increase total emissions even if the subsidy reduced emissions at individual plants.⁵³ The subsidy payment may be seen as insurance against the social cost of the emitting activity and thus lead to its increase.⁵⁴ Sources may also increase pollution to secure larger subsidies for abatement.⁵⁵

TAXES VERSUS TRADING

The third presumption of the standard analysis is that taxes are preferred to tradable allowances. In theory, these instruments can produce identical results. Taxes set the price of emitting and allow the quantity of emissions to vary, whereas allowances set the aggregate quantity of emissions and allow the price of emitting to vary. If the actor adopting these instruments (our assumed rational autocrat) knows firms' costs with certainty, she can use either instrument to achieve the same result: If she issues Q allowances, the market price P for each allowance to emit 1 ton of pollutant will be equal to the tax of P that she would set to achieve the same Q amount of emissions.

But if the decision maker is uncertain about firms' costs, then these instruments diverge. A tax set at P might achieve Q emissions, but if firms' true costs are higher than expected, this tax will yield more than Q emissions (firms will pay the tax rather than abate). Issuing Q allowances might achieve a market price of P for each allowance, but if firms' true costs are higher than expected, this policy will yield a higher price for allowances. Thus the tax prevents cost escalation (firms will not pay more than the tax) but lets emissions vary, whereas the allowance system prevents emission escalation (there is a finite number of allowances) but lets costs vary. Under uncertainty, the choice between these instruments depends on one's relative concern about cost escalation versus

emission escalation (i.e., on the relative steepness of the marginal cost of abatement versus the marginal benefit of abatement).⁵⁶ One study found that, given significant uncertainty about true abatement costs and assuming a very flat marginal benefit curve (i.e., assuming that escalating emissions would have only very gradual impact on the damages from climate change), a GHG tax would yield roughly five times greater net benefits than would a system of tradable emission allowances.⁵⁷

Tax regimes and auctioning allowances also have the advantage of raising revenues that can be used to reduce previously existing taxes. Often, these pre-existing taxes act as a disincentive to something good, such as labor or investment. Revenue-raising GHG abatement policies can also reduce those distortionary taxes, yielding a “double-dividend.”⁵⁸

A system of tradable allowances, like any market, also faces other challenges. One is market power: A few large allowance sellers (e.g., Russia or China) could try to charge excessive monopoly prices.⁵⁹ This is a particularly knotty problem at the international level, where there is no antitrust law. Another problem for a GHG allowance market is transaction costs.⁶⁰ The costs of finding trading partners, negotiating deals, monitoring and enforcing performance, and insuring against nonperformance can hinder efficient transactions. Formal allowance trading seeks to reduce transaction costs by making allowances fungible and fostering risk diversification and market transparency. But informal allowance trading such as JI and the CDM may face high transaction costs.

Taxes, however, face their own difficulties. First, if emission escalation is a more serious concern than cost escalation (the converse of the assumption described earlier), then allowances are superior to taxes under uncertainty.⁶¹ Second, whereas allowance markets can face market power and transaction costs, taxes can face high administrative costs to calculate and collect the tax and to audit and enforce against taxpayers. Third, raising revenue may become more important to tax officials than the environmental purpose of the tax, leading them to set the tax too low to discourage GHG emissions. Fourth, there is the question of which country, countries, or organization would collect GHG taxes and distribute tax revenues, a particularly sensitive issue on the international front. Fifth, as discussed earlier, GHG taxes could be unfairly regressive to poorer countries. Sixth, as discussed below, under the consent voting rule taxes may not attract adequate participation by countries.

The Analysis Under Consent

The foregoing assumes autocracy. As discussed earlier, real global regulation occurs under a voting rule of consent: No country can be bound to a treaty except by its agreement, which in turn depends on its perceived national net

benefit. Basing global instrument choice on the assumption of autocracy may therefore lead to serious errors.

At the international level, participation must be attracted, not coerced. Free riding must be overcome. Cooperative losers (countries that perceive a national net cost from preventing global warming) must be persuaded to participate by some inducement other than global environmental protection itself, such as side payments sufficient to overcome their foregone gains from warming plus their abatement costs.⁶²

PARTICIPATION EFFICIENCY

Attracting participation yields benefits but can be costly. The benefits of participation include greater coverage of globally dispersed emissions, reduced free riding, reduced cross-border emission leakage, and a wider array of abatement opportunities. The costs of securing participation include the out-of-pocket costs of side payments and the perverse incentives of subsidizing abatement (discussed earlier).⁶³ The best regulatory instrument under consent must therefore strive to satisfy a criterion that is not relevant under autocracy: “participation efficiency.”⁶⁴ Participation efficiency is the ability to attract participation at least cost. The most participation-efficient regulatory instrument would minimize the sum of the costs of nonparticipation plus the costs of securing participation. Equivalently, it would maximize the difference between the benefits of securing participation and the costs of securing participation.

The less coercive the voting rule, the more participation efficiency matters in selecting among regulatory instruments. Under majority rule, some participation-efficient inducements are needed to gain the majority needed to adopt a law. After that, coercive power exists over remaining dissenters. Under consent, every important cooperative loser must be paid to play.

COMPARING INSTRUMENTS

Under autocracy, as discussed above, the standard conclusion is that taxes are the superior instrument. But under consent, the relative merits of alternative regulatory instruments depend significantly on their participation efficiency.

First, direct subsidies for abatement, in the form of a cash payment to non-beneficiary countries, would be one way to provide the compensation needed to attract participation.⁶⁵ Unfortunately, subsidies for abatement generate perverse incentives for increased aggregate emissions.⁶⁶ There is also the possibility that some countries would posture as cooperative losers to demand side payments via threatened or actual increases in GHG emissions, potentially decreasing the degree of cooperation enough to result in higher total emissions.⁶⁷

Second, participation might be coerced through threats of trade sanctions.⁶⁸

Loss of trading partners could induce free riders and even cooperative losers to participate because of the fear that noncooperation would be more costly than cooperation.⁶⁹ Although this approach avoids the perverse incentive problem of subsidies, several other problems would arise. Threats of trade sanctions may not be credible because they would impose high costs on both sides of the trade barriers. Trade sanctions may also distort trade, impair global economic efficiency, and spur a retaliatory trade war. Trade sanctions often are ineffective because they strengthen the target government's domestic political case for resistance to foreign meddling.⁷⁰ Trade sanctions can also injure the target country's economy so much that compliance would become more difficult or impossible, thwarting the goal of inducing environmental protection.⁷¹ Finally, trade sanctions imposed by wealthy countries against poorer countries cut against principles of fairness.⁷²

Third, GHG taxes might be used. But because taxes impose the highest costs on sources, they probably will induce the greatest rate of nonparticipation. GHG taxes probably would attract the fewest cooperative losers, leading to significant leakage and a failure to reduce global emissions. Perhaps a tax paired with side payments could succeed. But to attract participation, the side payments would have to be large enough to ensure positive national net benefits, compensating for abatement costs, foregone environmental benefits to cooperative losers, and the burden of the tax on residual unabated emissions. Such a side payment would undercut the ability of the tax to reduce emissions in recipient countries. The side payment could not be a "lump sum" (a single one-time payment unrelated to the country's marginal costs) because the side payment would have to repay the country for every incremental dollar of burden incurred as a result of the tax, or else the policy would not be attractive on net (Pareto improving) to the recipient country and would not attract the country's participation.

Fourth, one could use quantity-based instruments. Fixed-quantity targets (performance standards) for each country, on their own, would incur high nonparticipation costs. Large and growing cooperative losers would simply decline to be bound. This has been the predictable experience under the FCCC and Kyoto Protocol: Large and growing developing countries, including China, India, and Brazil, have declined to adopt quantitative emission limitations.

Coupling fixed quantity targets with a direct payment to cooperative losers could help secure those countries' participation. This was the approach taken in the Montreal Protocol to phase out CFCs: Its Multilateral Fund was created to secure participation by China and India. Such side payments would still generate perverse incentives, but now—in contrast to the cases of direct subsidies and taxes plus side payments—the fixed-quantity limits would constrain the perverse incentives from increasing aggregate emissions. This is a distinct advantage

of quantity limits over taxes under the consent voting rule, where side payments are necessary.

But fixed-quantity limits would not be cost-effective because they would not allow emission reductions to be accomplished wherever abatement costs are lowest. An even better design for quantity-based instruments would be to use tradable allowances, reducing costs dramatically. The side payments could then be embedded in the allowance trading system itself. In this “cap-and-trade” system, poorer countries with large emissions such as Russia, China, India, and Brazil would be assigned extra allowances as a side payment to attract their participation. These headroom allowances would be a new asset that poorer countries could sell to earn profits in the allowance trading market. Wealthier countries would thereby finance abatement (and a lower-GHG economic growth path) in poorer countries by buying headroom allowances. This cap-and-trade system would attract participation through in-kind side payments while constraining the perverse incentives of those side payments by securing the adoption of quantity caps on participating countries.⁷³ This was the strategy used in the Kyoto Protocol to engage Russia’s participation: Russia was assigned headroom allowances in exchange for its agreement to join the treaty. Without these extra allowances, Russia might well have stayed out of the treaty, impairing its effectiveness. This approach might also be used to attract participation by China and other major developing countries.

A critical step in this cap-and-trade approach is the initial allocation of emission allowances. Of course, the negotiations will be difficult, as with any burden-sharing negotiation. Some critics have asserted that negotiating the assignment of GHG emission allowances would be so difficult that the system would never get off the ground.⁷⁴ But this concern applies to any regulatory instrument because all forms of regulation impose varying burdens on those regulated and because all forms of regulation under the consent voting rule entail a burden-sharing negotiation. The real question is the relative difficulty of negotiating the initial assignment using the alternative instruments, given the consent framework.⁷⁵ In that context, tradable allowances would ease the problem of initial negotiations. As Coase taught, the lower the impediments to subsequent reallocations of entitlements among the parties, the less the initial assignment binds.⁷⁶ Technology standards, fixed quantity limits, and taxes provide no flexibility for subsequent reallocations of entitlements. But allowance trading makes postagreement reallocations possible, thereby reducing the initial assignment impasse.

To summarize, under the voting rule of consent that governs global climate treaties, participation efficiency is crucial. A way must be found to pay reluctant sources to participate while also inhibiting the perverse incentives that these pay-

ments create. The best instrument for achieving this result is a system of international tradable emission allowances, with headroom allowances allocated to cooperative losers. It secures broad participation and enables cost-effective flexibility in the spatial location of abatement but caps total emissions and thereby constrains the perverse environmental effects of subsidizing abatement.

Compliance

Compliance is a general problem of any regulatory system. But it figures prominently in criticisms of international environmental regulation because it is more troublesome under the consent voting rule, where countries—even after agreeing to participate—cannot be compelled to comply but must be attracted by the continuing desirability of participation. Critics often charge that ensuring compliance with international emission trading would be difficult. Yet the problem of compliance is not unique to allowance trading; all regulatory instruments require monitoring and enforcement. The key question is the relative ability of the instruments to maintain compliance, given the voting rule of consent. The criticisms of weak enforcement systems are really criticisms of the weak ability of the international system to deal with any nation-states' noncompliance with any treaty obligations.

Noncompliance is a partial version of free riding. Once free riding is overcome—once countries are attracted to participate by the net gains they perceive from joining the treaty—then “compliance comes free of charge.”⁷⁷ Therefore, there are good reasons to expect allowance trading to be superior to alternative regulatory instruments at inducing compliance. First, the improved cost-effectiveness (30–70 percent lower abatement costs) under allowance trading makes participation less costly and thus lowers the incentive to free ride or cheat. Second, the assignment of headroom allowances attracts participation by erstwhile noncooperators, and the prospect of continuing to sell allowances over time provides a strong disincentive to cheat. Third, a system of allowance trading furnishes useful enforcement tools, including the ability to debit a violator's allowance account and to exclude the violator from the allowance market. Fourth, a tradable allowance system is likely to nurture domestic political constituencies—allowance sellers, allowance buyers, abatement investors, brokers, and environmentalists—who would pressure their governments to comply with emission limits so as not to have their allowances devalued or their market access hindered.⁷⁸

Meanwhile, the actual effectiveness of internationally agreed GHG taxes or technology standards would be extremely difficult to ensure. In response to a GHG tax or technology standard, countries would have strong incentives to adjust their internal tax and subsidy policies to counteract the effect of the inter-

national policy on domestic industries. This “fiscal cushioning” would undermine the effect of the tax or technology standard on actual emissions.⁷⁹ Thus, a country could be in technical compliance with the tax or technology standard, but its fiscal cushioning countermoves could vitiate the environmental effectiveness of these instruments. It would be difficult for international authorities to detect and block these detailed domestic fiscal games. By contrast, the effectiveness of international allowance trading would be simpler to monitor. Under a quantity instrument, participants need not monitor all the domestic tactics being practiced in each country. Instead, they need only monitor the nation’s aggregate emissions and compare them with the country’s allowed total (its cap or allowance holdings). This real environmental effectiveness—as opposed to apparent compliance—would be easier to monitor than would the intricacies of domestic implementation under a global tax or technology standard.

Assessing the Kyoto Protocol

In terms of spatial complexity and participation efficiency, the Kyoto Protocol gets things about half right. On the bright side, it adopts a quantity constraint on emissions, eschewing technology standards and emission taxes, and it authorizes emission trading (in Article 17) to enhance cost-effectiveness rather than adopting fixed performance standards. Moreover, it makes some use of allowance allocations to secure participation. It allocates the burden of emission reductions among nations roughly in proportion to national wealth, which as discussed earlier is a rough proxy for national perceived benefits of climate protection. And it assigns headroom allowances to Russia—a move that some observers have criticized as ineptitude and dubbed “hot air” but can be better understood as a very rational and necessary form of compensation to secure Russia’s participation in the treaty. Russia’s agreement to emission controls was by no means guaranteed, and without headroom allowances it might well have stayed out of the treaty, squandering many low-cost abatement options and inviting significant leakage.

But this cap-and-trade regime is only a half-step in the right direction because the Kyoto Protocol omits the developing countries from this regime. China, India, Brazil, Indonesia, and other developing countries have no obligations to limit their emissions under the treaty. Their growing emissions will render the treaty increasingly ineffective. The prospects for emission leakage from capped industrialized countries to uncapped developing countries are serious. Under the consent voting rule (and also for reasons of distributional fairness), side payments will be needed to attract their participation.

The Kyoto Protocol tries to address developing country abatement by intro-

ducing a new and well-intentioned device—the Clean Development Mechanism (CDM) created in Article 12—through which industrialized country sources could purchase emission reduction credits from developing countries. The CDM does promise significant abatement at low cost and the possibility of introducing lower-emitting technologies into developing countries before they become dependent on high-emission growth paths. These are important advantages.

But the CDM could have a perverse impact on global emissions and could undermine future efforts to bring developing countries into the cap-and-trade regime. First, because CDM seller countries are not subject to national quantity caps, the CDM transactions amount to pure subsidies for abatement. As discussed earlier, this regulatory instrument is disfavored because it induces perverse increases in the total size of the emitting sector. By reducing the relative cost of operating emitting enterprises in developing countries, the CDM will attract investment to those industries (accelerate leakage) and thus could be of limited effectiveness or even expand total emissions. (Moreover, because there are no national quantity caps on developing countries, CDM abatement investments might be offset by unseen increases in emissions elsewhere in the same country.)

Second, the opportunity to sell CDM credits could discourage uncapped developing countries from joining the cap regime. Recall that it is the prospect of selling headroom allowances that provides the pivotal incentive for developing countries to participate in the cap-and-trade system. But if those countries can earn just as much by selling CDM credits without a cap, why should they accept caps? And if they don't join the cap regime, increased net leakage may render the entire treaty futile or worse. One way to address this problem would be to discount CDM credits (or "certify" them at less than the claimed tons of abatement) to reflect their lesser effectiveness in achieving global abatement. This would lower their attractiveness and push more countries toward agreeing to caps to take advantage of more lucrative formal trading.⁸⁰

Third, the CDM may be a battleground for political and market power. It is constituted under Article 12 as a discrete entity governed by an executive board. This apparently centralized organization could exert control over the market in CDM credits.

Thus, the Kyoto Protocol makes some progress in the use of allowance trading to secure efficient participation but fails to engage developing countries in the cap-and-trade system. For that reason the U.S. Senate announced its unanimous opposition to the treaty, and the Clinton administration never submitted the treaty to the Senate for ratification. In 2001 the Bush administration

announced that it would not pursue the Kyoto Protocol but did not propose an alternative.

The accords reached at Bonn and Marrakech in 2001 to implement Kyoto omitted both the developing countries and the United States, portending limited effectiveness in reducing global emissions. They also retained some restrictions on emission trading, including a “reserve” requirement to limit allowance selling and quantitative limits on credit for sink expansion. The cost savings expected from emission trading in theory must be reestimated with the actual Bonn/Marrakech restrictions in place. To be environmentally effective (as well as less costly), the accords should be revised to include major developing countries in a fully flexible cap-and-trade system on terms beneficial to all through the assignment of headroom allowances.

Although the events of 2001 seemed to sacrifice broad participation, they might set the stage for an even better result: joint accession by both the United States and China.⁸¹ Politically the United States will not join targets without China (as made clear by the Bush administration and by the Senate’s 95–0 vote against joining a climate treaty that omits the major developing countries). And China will not join targets without the United States (because it will not act unless the wealthy industrialized countries act first). So both will have to join for either to join. Moreover, the current parties to Kyoto will want the United States and China to join simultaneously. If one joins without the other, it will distort allowance prices in the emission trading market: Prices will go way up if the United States (a large net demander) joins alone and way down if China (a large net supplier) joins alone. The EU and Japan will not want prices to rise sharply, and Russia will not want prices to fall sharply.

Thus, perhaps unintentionally, the initially awkward result in 2001 may pave the way for joint accession by the United States and China. If not, the Kyoto accord will amount to very little. Without the world’s largest emitters participating, it will not affect global emissions or concentrations much at all. Thus joint accession by the United States and China may be the only plausible future for the climate treaties. And this reality in turn gives the United States and China significant leverage to negotiate for a sound global regime that improves on Marrakech, Bonn, and Kyoto through full global emissions trading. The real difficulty in this scenario will not be the United States; it will be China. The United States faces both costs and benefits from joining. But China may well perceive only costs because many forecasts of the impacts of global warming, as noted earlier, suggest that China would on balance benefit from a warmer world. China will have to be paid to play. The best way to compensate China for joining the abatement regime will be through assignments of headroom allowances that China can then sell, as was done in Kyoto to engage Russia.

Temporal Complexity and Dynamic Adaptation

Perhaps the most vexing form of complexity confronting climate policy is temporal: Things change over time. The environment changes, so climate change may turn out to be more or less serious (or different in kind) than we now envision. The economy changes in ways that may ease or exacerbate abatement costs. Temporal complexity implies two challenges: optimally allocating abatement efforts over time and adapting climate policy as conditions and knowledge evolve. Compared with causal and spatial complexity, temporal complexity has received the least attention in the actual climate change treaty negotiations.

Optimal Allocation of Abatement over Time

Any given level of climate protection may be achieved with different allocations of abatement over time. These different time paths of emission reduction will imply different costs and benefits. Earlier reductions may protect the climate more because they prevent the buildup of gases that would reside in the atmosphere for decades thereafter. But later reductions may cost less because they ease the turnover of capital investments, allow the development of new technologies, and spend scarce resources later rather than sooner.

One strategy to optimize abatement over time is to set emission targets not for single years but for multiyear aggregates such as 10-year emission budgets for each country. Such multiyear targets (or extended commitment periods) give each country flexibility in the timing of abatement, thereby reducing the costs of compliance because different countries may have different expectations for the turnover of capital stock, acquisition of new technologies, and social discount rates. Temporal flexibility through multiyear budgets is conceptually similar to the spatial flexibility afforded by tradable allowances: Because abatement costs vary across the relevant dimension (temporal or spatial), flexibility improves cost-effectiveness. A more embracing version of temporal flexibility would authorize banking of extra early emission reductions for application to subsequent emission limitations, and perhaps borrowing against later limitations by promising to achieve extra abatement later to make up for earlier excess emissions. (If the climate benefits more from emission reductions achieved earlier than later, then banking should earn and borrowing should be charged an “interest rate” that renders equivalent the abatement occurring at the different times.)

Second, targets could be announced at least 10 years in advance of their effective dates, or take effect 10 years after the treaty enters into force. Major investments in capital and innovation often take longer than 5 years to turn

over, so a longer time horizon would provide early signals that enable more cost-effective changes in technology. Targets set too close to the present will be harder to achieve, perhaps impossible, and will invite repeated deferral in a process that makes the initial targets lack credibility and inculcates public cynicism about the regulatory regime. A similar cycle of unrealistic targets followed by deferral and cynicism has characterized several major U.S. environmental laws, such as the national ambient air quality standards (NAAQS) under the Clean Air Act amendments of 1970, 1977, and 1990 and the best technology standards under the Clean Water Act amendments of 1972, 1977, and 1987. On the other hand, a downside of setting targets for many years hence is that they may fail to motivate changes in businesses' investments, and they may lack credibility because there is so much time available to debate and revise them. Perhaps a middle course is to set not a single target for one out-year or period but a continuous schedule of emission limits, beginning with small or no reductions and tightening over time. This approach was successful in the lead phasedown from the 1970s through late 1980s and was approximated in the acid rain title of the 1990 Clean Air Act and the Montreal Protocol on ozone-depleting substances.

Third, the time path of emission limitations can be optimized in light of the benefits and costs of climate protection. The FCCC states in Article 2 that its objective is the stabilization of atmospheric GHG concentrations at a level that will avoid dangerous anthropogenic interference with the climate. (No such level has yet been defined or agreed upon.) Such a stabilization objective can be achieved through many different time paths of abatement, some of which are much less costly than others. In particular, delaying abatement for several decades and then reducing emissions more sharply can significantly reduce the cost of stabilization by allowing for capital turnover, new technologies, and discounting.⁸² On the other hand, if one takes account of the damages resulting from climate change as it occurs (instead of pegging a single level at which to stabilize concentrations), then the optimal time path of abatement is different. Hammitt⁸³ compares the emission reductions implied by the least-cost path to stabilize atmospheric GHG concentrations at designated levels with the emission reductions implied by the optimal (net benefits maximizing) path to prevent climate change (based on several assumptions about benefits and costs). He finds that the optimal path involves more stringent near-term emission reductions below the business as usual (BAU) emission forecast than does the least-cost path to stabilize atmospheric GHG concentrations at 750, 650, or even 550 ppm by the period 2100–2150.⁸⁴ The reason is that the optimal path takes into account the damages from near-term emissions, whereas the least-cost path to stabilize concentrations does not. Thus the optimal path in Hammitt's analysis calls for some near-term emission reductions—roughly 3 percent below BAU by

2010, 5 percent below BAU by 2025, and 20 percent below BAU by 2100—whereas the least-cost stabilization path for hitting 750, 650, or 550 ppm calls for near-term emissions essentially unchanged from BAU until around 2070, 2050, and 2010, respectively, and then much steeper declines in emissions thereafter (beginning about 2025 in the case of the 550 ppm target, for example). The optimal path exhibits a more smoothly but slowly rising emission profile that is about 2–5 percent below the least-cost stabilization profile in the near term (through about 2025) but eventually exceeds the least-cost stabilization emission profile after 2107, 2069, and 2024, respectively, for stabilization at 750, 650, and 550 ppm.⁸⁵ Hammitt’s approach, which minimizes overall costs (both economic and environmental), is conceptually preferable to the least-cost stabilization strategy, which minimizes only economic costs to achieve an arbitrarily chosen stabilization level.⁸⁶

As Hammitt notes, one would need to start building the institutional structure for climate policy some time before the dates at which emission reductions would be expected, in order to send credible policy signals that will in turn stimulate the needed shifts in investments, practices, and technologies. To achieve Hammitt’s optimal path of 3 percent below BAU in 2010, 5 percent below BAU in 2025, and 20 percent below BAU in 2100, one would need to begin constructing and implementing the institutional design well before 2010—that is, roughly, now.

Adaptation of Policy over Time

Temporal complexity also means that the level of protection initially set may later seem erroneous and need to be updated as conditions and knowledge have changed. The direction of our likely errors is highly debatable: Are we acting too hastily or not fast enough? Some say that temporal complexity counsels against adopting quantity limits on emissions and in favor of more gradual institution building and research;⁸⁷ others say that temporal complexity counsels in favor of adopting more stringent limits now to prevent even greater harms than we now foresee.⁸⁸

A central lesson of temporal complexity is the value of adaptation over time. “Adaptive management” has become a popular idea but an elusive reality. Designing an adaptive regulatory regime is difficult because knowledge is always changing, but investors want predictable rules, and the establishment of rules itself invites investments that entrench opposition to subsequent changes in those rules. The challenge is to design regulatory institutions that are able to evolve as conditions and understandings change yet are not so mercurial that they upset investors’ expectations and undermine their own credibility.

Several steps toward an adaptive approach are desirable. First, governments should continue investing in scientific and economic research as regulations are imposed and reassess regulations regularly in light of the latest expert advice. The role of the Intergovernmental Panel on Climate Change (IPCC) and of national research programs therefore will continue to be crucial. All regulatory institutions, at every scale, need to be geared toward learning and updating.

Second, the iterative negotiating sessions held under the FCCC and Kyoto Protocol—roughly one or two Conferences of the Parties each year—can be seen as fostering the regime’s adaptive capacity. Through this process, parties debate new emission targets every few years, keeping options open rather than trying to adopt a permanent set of emission limits once and for all. On the other hand, this process of sequential decisions creates uncertainty about future targets and may be at odds with the objective of setting a schedule of continuous emission limitations over many years so that investments respond accordingly and cost-effectively. Sequential target-setting should be undertaken transparently so that investors have advance signals of likely next steps.⁸⁹

Third, policy should be based on an evaluation of multiple plausible scenarios rather than the choice of a single best scenario. Adaptive management is particularly valuable in cases such as climate change that involve fundamental uncertainty about how the system works.⁹⁰ Our current forecasts may not only be off a bit but may rely on models that do not even describe reality. One hedge against this uncertainty is to base policy on a collage of several plausible but conceptually different models and to update this collage over time, with predictions weighted by experts’ relative confidence in the different models.

Fourth, in the face of such uncertainty, policy should at least begin by instituting measures that would be desirable under all of these scenarios. These could include reducing subsidies for energy use, reforming incentives for forest clearing, supporting basic research into low-GHG energy systems, improving the capacity for technology diffusion and application in developing countries, reducing emissions of air pollutants in ways that both protect human health and help prevent climate change, and making social and environmental systems more resilient against climate changes. At the same time, some measures will be warranted on grounds of climate protection alone, even in the face of significant uncertainty.

Assessing the Kyoto Protocol

The FCCC and Kyoto Protocol have done little to address temporal complexity. Kyoto allowed some temporal flexibility by setting targets as average emissions over a 5-year commitment period, 2008–2012. But even greater temporal

efficiencies could have been achieved through a longer commitment period (such as 10 years) and through expressly authorizing both banking of early reductions and borrowing against later limitations (with an interest rate reflecting the time value of abatement). Kyoto did not give any credit for emission reductions before 2008 (except, oddly, for CDM projects) and did not allow borrowing. Banking and borrowing make the most sense as early departures below and above a continuous emission reduction schedule, whereas Kyoto set a single commitment period target, and negotiations on a second commitment period target have not yet begun.

Regarding the time to achieve targets, Kyoto announced its targets in 1997 for an effective date beginning 11 years into the future. Eleven years might seem like a long time, but the practical realities of treaty negotiations and energy system investments suggest that a longer time between announcement and effective date could have been prudent. By the time the Kyoto process neared even initial ratification it was already 2001, with entry into force expected no earlier than late 2002, making the 2008 effective date seem too near to achieve substantial emission cuts without major costs.

Kyoto also set targets that depart significantly from both the least-cost stabilization path and Hammitt's illustrative optimal path. The Kyoto Protocol called for emission reductions by industrialized countries of about 5 percent below 1990 levels by 2012, which corresponds to a U.S. reduction of about 30 percent below BAU in 2012 and a reduction in all industrialized countries' emissions of roughly 15–20 percent below BAU by 2012. Thus the Kyoto Protocol appears to require (at least for industrialized countries) much sharper near-term emission reductions than those required by either Hammitt's optimal path (which requires global emissions to be 3 percent below BAU by 2010, 5 percent below BAU by 2025, and 20 percent below BAU by 2100) or the least-cost path to stabilizing concentrations at 750, 650, or 550 ppm (all of which require essentially zero reduction below BAU through 2025 but steeper reductions later).⁹¹ More fundamentally, Hammitt's analysis suggests that the stabilization objective enshrined in the FCCC is not the best goal for climate policy, even if achieved at least cost, because it neglects the continuous impacts of GHG accumulation over time. Analyses of optimal climate policy must do a better job of accounting for damages over time and nonlinear climatic effects.⁹²

As to adaptive management, the Kyoto process involves iterated negotiation of targets, with regular scientific input from the IPCC. This sequential process of adjustment could be helpful in adapting to new information. But the IPCC has not done enough to advise the treaty negotiators on the optimal time path

of abatement. The Kyoto process may well result in repeated updating of its emission targets, but those updates may not reflect a considered evaluation of the optimal temporal path for abatement.

Conclusion

Global climate policy is deeply complex. This chapter has examined three kinds of complexity—causal, spatial, and temporal—and three corresponding innovations in the design of the regulatory regime for climate change. First, the comprehensive approach would protect the environment more effectively (avoiding perverse cross-gas shifts) and at perhaps 60 percent lower cost than a piecemeal approach. Second, international allowance trading would cost perhaps 70 percent less than fixed national caps, and, under the consent voting rule that prevails at the global level, would be more participation-efficient than alternative regulatory instruments. Participation is crucial to global success; it has been neglected in the Kyoto and Bonn/Marrakech agreements, but well-designed global allowance trading holds the promise of engaging both the United States and China in the future. Third, optimal time paths and adaptive management would enable climate policy to be flexible as technologies, environmental conditions, and our knowledge all change over time.

This is not to say that these approaches are perfect, nor that other regulatory approaches do not have their strengths in other contexts. The administrative costs of the comprehensive approach could become unreasonable if its scope were expanded indefinitely. The presumptive advantage of tradable allowances could diminish if cooperative losers were unimportant to global emissions or if abatement cost uncertainties were so large that containing those costs through taxes (or through a price ceiling on allowances) became a higher priority than participation efficiency and containing climate damages. Optimal temporal policies could raise questions about the credibility of long-term commitments by governments. Nonetheless, the advantages of these three policy designs appear to far outweigh their administrative difficulties.

The phenomena of causal, spatial, and temporal complexity will continue to challenge and intrigue those who design global climate policy. The Kyoto Protocol and the Bonn/Marrakech accord have made good progress on comprehensive coverage and on emission trading among industrialized countries, but they have limited sinks, have made meager headway in the effort to secure broad global participation, and have only begun to address optimal temporal policy design. Thus there is much work remaining in the design of successful global climate policy.

Acknowledgments

The author thanks John Barton, Aimee Christensen, James Hammitt, John O. Niles, Stephen Schneider, and Richard Stewart for comments on prior drafts and David Haling for editorial assistance.

Notes

1. This chapter examines the design of the regulatory mechanism, not its goals; that is, it discusses the means or instruments of protection, not the ends or level of protection that should be sought. Although the two questions ultimately are interrelated, deciding how to reduce emissions can usefully be analyzed as a distinct matter from deciding how much to reduce emissions. See Bohm, P. and C. S. Russell, 1995: "Comparative analysis of alternative policy instruments," in A. V. Kneese and J. L. Sweeney (eds.) *Handbook of Natural Resource and Energy Economics* (New York: North-Holland/Elsevier), 395, 397 ("Choice of policy goal and choice of instrument or implementation system are essentially separable problems.").
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9. Rodhe, H., 1990: "A comparison of the contribution of various gases to the greenhouse effect," *Science*, 248 (June 8): 1217–1219.
10. Wiener, 1995, pp. 209–212.
11. Schlesinger, W. H., 1999: "Carbon sequestration in soils," *Science*, 284 (June 25): 2095.
12. "Potentially" because, although conserving forests would protect biodiversity, new afforestation projects to sequester carbon might replace biodiverse mature forests

- with monoculture plantation forests. See Wiener, 1995, 218–219. Meanwhile, some GHG emissions could aid forests: CO₂ emissions help fertilize plant photosynthesis, a beneficial effect that the other GHGs do not offer. See Wiener, 1995, 214–218; DeLucia, E. H., et al., “Net primary production of a forest ecosystem with experimental CO₂ enrichment,” *Science*, 284 (May 14): 1177–1179. Thus, to be fully environmentally comprehensive, a climate policy would need to be broadened or accompanied by biodiversity protections and by a gas comparison index reflecting GHGs’ full ecosystem impacts. See Stewart and Wiener, 1990, 1992.
13. Bradley, R., E. Watts, and E. Williams, 1991: *Limiting Net Greenhouse Emissions in the United States*, Volume II: *Energy Responses* 8.10–8.12 (Washington, DC: U.S. Department of Energy, Office of Environmental Analysis).
 14. World Bank, 1992: *World Development Report 1992: Development and the Environment*, Box 8.6 (Washington, DC: The World Bank).
 15. Reilly, J., R. Prinn, J. Harnisch, J. Fitzmaurice, H. Jacoby, D. Kicklighter, J. Melillo, P. Stone, A. Sokolov, and C. Wang, 1999: “Multi-gas assessment of the Kyoto Protocol,” *Nature*, 401 (October 7): 549–555.
 16. Hansen, J., M. Sato, R. Ruedy, A. Lacis, and V. Oinas, 2000: “Global warming in the twenty-first century: an alternative scenario,” *Proceedings of the National Academy of Sciences*, 97: 9875.
 17. Stewart and Wiener, 1990, 1992. The comprehensive approach was staunchly advocated by the United States through both the Bush and Clinton administrations. See Revken, A. C., 2000: “Study proposes new strategy to stem global warming,” *New York Times*, Aug. 19, p. A13 (reporting that the White House supports the comprehensive approach embodied in the Kyoto Protocol as the “best approach to slowing warming” because it addressed “all of the greenhouse gases . . . largely because of the insistence by American negotiators.”).
 18. For further discussion see Stewart and Wiener, 1992.
 19. This section draws on Wiener, J. B., 1999: “Global environmental regulation: instrument choice in legal context,” *Yale Law Journal*, 108: 677–800.
 20. Externalities are the effects of an economic transaction not faced by the parties to the transaction. Economists view externalities as a source of inefficiency because the actors involved in the transaction are making decisions without considering their full social consequences. Economists therefore seek ways to internalize externalities into market decisions, such as through regulatory instruments. Because regulations themselves can pose costs, the presence of an externality is a necessary but not sufficient condition for regulating.
 21. Hardin, G., 1968: “The tragedy of the commons,” *Science*, 162: 1243.
 22. Axelrod, R., 1984: *The Evolution of Cooperation* (New York: Basic Books) pp. 7–9.
 23. Keohane, R. O., 1984: *After Hegemony* (Princeton: Princeton University Press).
 24. Council of Economic Advisors, 1998: *Economic Report of the President* (Washington, DC: Government Printing Office) pp. 170–172 (forecasting that GHG emissions from developing countries will exceed those from industrialized countries by the year 2030). To be sure, such forecasts are uncertain. See U.S. Energy Information Administration, 2001: *International Energy Outlook* (Washington, DC: U.S. Department of Energy) (forecasting China’s energy sector CO₂ emissions to grow

- from roughly 650 million tons of carbon in 1999 to somewhere between 1,115 and 2,059 million tons in 2020).
25. Schmalensee, R., 1998: "Greenhouse policy architectures and institutions," in W. D. Nordhaus (ed.), *Economics and Policy Issues in Climate Change* (Washington, DC: Resources for the Future), pp. 137, 146.
 26. S. Res. 98, 143 *Congressional Record* S8113-05 (July 25, 1997). The Clinton administration decided not even to submit the Kyoto Protocol to the Senate for ratification until "meaningful participation" by developing countries had been secured.
 27. Barrett, S., 1992: "Reaching a CO₂ emission limitation agreement for the community: implications for equity and cost-effectiveness," *European Economics*, 1:3, 16.
 28. Baumol, W. J., 1974: "Environmental protection and income distribution," in H. H. Hochman and G. E. Peterson (eds.), *Redistribution Through Public Choice* (New York: Columbia University Press), p. 93 (observing that the demand for environmental protection typically rises with income).
 29. Tol, R., 2001a: "Estimates of the damage costs of climate change, part I: benchmark estimates," *Environment & Resource Economics* (Dordrecht: Kluwer Academic Publishers); Tol, R., 2001b: "Estimates of the damage costs of climate change, part II: dynamic estimates," *Environment & Resource Economics* (Dordrecht: Kluwer Academic Publishers). Tol's synthesis does not account for other adverse impacts, such as fishery losses, extreme weather events, and the possibility of catastrophic changes in ocean currents or other critical natural systems.
 30. Aronson, A. L., 1993: "From 'cooperator's loss' to cooperative gain: negotiating greenhouse gas abatement," *Yale Law Journal*, 102: 2143, 2150–2151.
 31. Wiener, "Global environmental regulation," 1999, pp. 701–704 (showing the ubiquity of the assumption of coercive fiat in discussions of regulatory instrument choice). As James Buchanan put it in his Nobel Prize address, economists have long been "proffering advice as if they were employed by a benevolent despot." Buchanan, J. N., 1987: "The constitution of economic policy," *American Economic Review*, 77: 243.
 32. This is an approximation. Real national law in the United States involves majority or super-majority votes in more than one legislative chamber, plus signature by the executive and review by the courts. And majority rule can be limited, for example, by constitutional protection of free speech or compensation to those from whom the majority takes property.
 33. A classic statement is Lord McNair, 1961: *The Law of Treaties* (Oxford: Clarendon Press), p. 162: "No State can be bound by any treaty provisions unless it has given its assent."
 34. Hoel, M. and K. Schneider, 1997: "Incentives to participate in an international environmental agreement," *Environmental & Resource Economics*, 9: 153, 165–167.
 35. Cameron, J., 1994: "The GATT and the environment," in P. Sands (ed.), *Greening International Law* (New York: New Press), pp. 106–116.
 36. Chayes, A. and A. Handler Chayes, 1995: *The New Sovereignty* (Cambridge: Harvard University Press), p. 27.
 37. Keohane, R. O. and J. Nye, 1972: *Transnational Relations and International Governance* (Boston: Little Brown and Company); Lee, H., 1995: *Shaping National*

- Responses to Climate Change* (Washington, DC: Island Press), p. 14 (“de facto transnational coalitions” often have “enormous influence” on international diplomacy).
38. Humphreys, D., 1996: *Forest Politics* (London: Earthscan), p. 162.
 39. In this discussion I take the voting rules as given and make no normative comment on their relative desirability. Cf. Wiener, J. B., 1999: “On the political economy of global environmental regulation,” *Georgetown Law Journal*, 87: 749 (discussing normative implications of alternative voting rules for international environmental law).
 40. Keohane, 1984, p. 104; Wiener, “Global environmental regulation,” 1999, pp. 735–747. The question for each country is whether joining would be better than not joining. A country need not view the entire treaty as a net gain compared with the complete absence of any treaty (the situation before anyone had joined the treaty). The fact that some countries have already formed the treaty could impose net costs on the remaining countries. See Gruber, L., 2000: *Ruling the World* (Princeton: Princeton University Press). Even if a country would prefer a world with no treaty at all, it may still prefer joining the treaty to staying out if there are further costs to staying out (such as trade sanctions) or new benefits to joining (such as side payments).
 41. Wiener, “Global environmental regulation,” 1999, pp. 743–755.
 42. Buchanan, J. and G. Tullock, 1962: *The Calculus of Consent* (Ann Arbor: University of Michigan Press), p. 113 (analogizing consent voting rules to contracts); Keohane, R. O., 1983: “The demand for international regimes,” in S. D. Krasner (ed.), *International Regimes* (Ithaca, NY: Cornell University Press), pp. 141, 146–149, 152 (arguing that “international regimes . . . are more like contracts. . . . In general, we expect states to join those regimes in which they expect the benefits of membership to outweigh the costs”).
 43. Stewart, R. B., 1986: “Reconstitutive law,” *Maryland Law Review*, 46: 86, 92.
 44. Hahn, R. W. and R. N. Stavins, 1991: “Incentive-based environmental regulation: a new era from an old idea?” *Ecology Law Quarterly*, 18: 1. A third type of incentive instrument is information disclosure.
 45. Stavins, R. N., 2000: “Introduction,” in P. R. Portney and R. N. Stavins (eds.), *Public Policies for Environmental Protection*, 2nd ed (Washington, DC: Resources for the Future). Improving cost-effectiveness is valuable because it saves resources that can be used for other important social goals, including greater investments in environmental protection. See Baumol, W. J. and W. E. Oates, 1988: *The Theory of Environmental Policy*, 2nd ed. (Cambridge, England: Cambridge University Press).
 46. Hahn, R. W. and G. L. Hester, 1989: “Marketable permits: lessons for theory and practice,” *Ecology Law Quarterly*, 16: 387.
 47. Joskow, P. L., R. Schmalensee, and E. Baily. 1998: “The market for sulfur dioxide emissions,” *American Economic Review*, 88: 669.
 48. See Manne, A. S. and R. G. Richels, 2000: “The Kyoto Protocol: A Cost effective strategy for meeting environmental objectives?” in C. Carraro (ed.), *Efficiency and Equity in Climate Change* (Amsterdam: Kluwer Academic Publishers), p. 59; Weyant, J. P. and J. Hill, 1999: “Introduction and overview,” *The Energy Journal*, Special Issue vii; Bohm, P., 1997: “Joint implementation as emission quota trade:

- an experiment among four Nordic countries,” *Nord*, 1997: 4, Nordic Council of Ministers, Copenhagen; Manne, A. and R. Richels, 1996: “The Berlin mandate: the costs of meeting post-2000 targets and timetables,” *Energy Policy*, 24: 205; Burniaux, J.-M., J. P. Martin, G. Nicoletti, and J. Oliveira-Martins. 1992: “The costs of reducing CO₂ emissions: evidence from GREEN,” OECD Economic Department Working Paper No. 115.
49. Jaffe, A. and R. N. Stavins, 1995: “Dynamic incentives of environmental regulation: the effects of alternative policy instruments on technology diffusion,” *Journal of Environmental Economics and Management*, 29: S-43.
 50. See Okun, A. M., 1975: *Equality and Efficiency: The Big Tradeoff* (Washington, DC: The Brookings Institution); Kelman, S., 1981: *What Price Incentives? Economists and the Environment* (Boston: Auburn Publishing Co.), pp. 84–86. A related concern is that trading allowances of toxic emissions might yield local hotspots, but this concern is minimal in the case of CO₂ and other GHGs with few or no local health impacts.
 51. Oliveira-Martins, J., J. M. Burniaux, J. P. Martin, and G. Nicoletti. 1992: “The costs of reducing CO₂ emissions: a comparison of carbon tax curves with GREEN,” OECD Economics Department Working Paper No. 118 (estimating developing country revenues at \$10 billion per year initially and increasing over several decades to \$100 billion per year under global emission trading).
 52. Sandel, M. J., 1997: “It’s immoral to buy the right to pollute,” *New York Times*, December 15, p. A23 (op-ed).
 53. See Baumol and Oates, 1988, pp. 211–222; Oates, W. E. 1990: “Economics, economists, and environmental policy,” *Eastern Economic Journal*, 16: 289, 290; Kohn, R. E., 1992: “When subsidies for pollution abatement increase total emissions,” *Southern Economic Journal*, 58: 77.
 54. Posner, R. A., 1992: *Economic Analysis of Law*, 4th ed. (Boston: Little Brown) p. 64.
 55. Hoel and Schneider, 1997.
 56. Weitzman, M. L., 1974: “Prices vs. quantities,” *Review of Economic Studies*, 41: 477.
 57. Pizer, W. A., 1997: “Prices vs. quantities revisited: the case of climate change,” Resources for the Future, Discussion Paper No. 98-02.
 58. See Goulder, L. H., 1995: “Environmental taxation and the ‘double dividend’: a reader’s guide,” *International Tax and Public Finance*, 2: 157.
 59. Hahn, R. W., 1984: “Market power and transferable property rights,” *Quarterly Journal of Economics*, 99: 753. Alternatively, a few large buyers could try to exercise monopsony power, depressing allowance prices.
 60. Dudek, D. J. and J. B. Wiener, 1996: “Joint implementation, transaction costs, and climate change,” OECD/GD (96) 173, pp. 20–21.
 61. In addition, recent research suggests that under more realistic models with imperfect enforcement policies, quantity instruments are preferable to price instruments. See Montero, J. P., 1999: “Prices versus quantities under imperfect enforcement,” MIT CEEPR Working Paper.
 62. Cf. Merrill, T. W., 1997: “Golden rules for transboundary protection,” *Duke Law Journal*, 46: 981.
 63. Wiener, “Global environmental regulations,” 1999, pp. 748 & n.266, 761 & n.311.

64. This concept is advanced and discussed in Wiener, "Global environmental regulation," 1999, pp. 742–770.
65. Baumol and Oates, 1988, pp. 279–281.
66. *Ibid.*, p. 281. Negotiators might limit the perverse incentive effect by constraining the availability of the subsidy to certain countries or circumstances, but that might undercut the ability of the subsidy to attract participation.
67. Hoel and Schneider, 1997, p. 165.
68. Chang, H. F., 1995: "An economic analysis of trade measures to protect the global environment," *Georgetown Law Journal*, 83: 2131.
69. Barrett, S., 1996: "Building property rights for transboundary resources," in S. S. Hanna, C. Folke, and K. G. Mäler (eds.), *Rights to Nature* (Washington, DC: Island Press), pp. 265, 280–282.
70. Haass, R. N., 1997: "Sanctioning madness," *Foreign Affairs*, November–December: 74, 77–80.
71. Jacobson, H. K. and E. B. Weiss, 1997: "Compliance with international environmental accords: achievements and strategies," in M. Rolen, H. Sjöberg, and U. Svedin (eds.), *International Governance on Environmental Issues* (Dordrecht: Kluwer Academic Publishers), pp. 78, 109.
72. Hurrell, A. and B. Kingsbury, 1992: "The international politics of the environment: an introduction," in A. Hurrell and B. Kingsbury (eds.), *The International Politics of the Environment* (Oxford: Clarendon Press), pp. 7–8.
73. And by delivering the side payments through market trades rather than official government aid, this system would yield abatement investments that are less impeded by bureaucratic costs, more cost-effective, and more innovation-enhancing. See Burtraw, D. and M. A. Toman, 1992: "Equity and international agreements for CO₂ containment," *Journal of Energy Engineering*, 118: 122, 131–132. Ironically, the reduced role of the bureaucracy in allowance trading (as compared with official government aid) could lead government representatives in both industrialized and developing countries to oppose allowance trading. This domestic power struggle is one possible reason for the opposition to allowance trading by government officials whose national economies would benefit greatly from trading. See Wiener, "On the political economy of global environmental regulation," 1999, pp. 780–781.
74. Victor, D., 2001: *The Collapse of the Kyoto Protocol* (Princeton: Princeton University Press); Cooper, R., 1998: "Toward a real global warming treaty," *Foreign Affairs*, March–April: 66, 70–72, 74, 78.
75. Hahn, R. W., 1998: *The Economics & Politics of Climate Change* (Washington, DC: American Enterprise Institute), p. 43.
76. Coase, R., 1960: "The problem of social cost," *Journal of Law & Economics*, 3:1. The Coase theorem holds that in a world of zero transaction costs, the initial assignment is irrelevant to efficiency and to the ultimate allocation after bargaining. To be sure, distributional impacts would still matter. The point here is that the more a regime is designed to reduce the transaction costs of postassignment contractual reallocations, the easier it will be to negotiate that regime initially.
77. Barrett, S., 1998: "A theory of international cooperation," Fondazione Eni Enrico Mattei Working Paper No. 43-98, p. 7.

78. Stewart, R. B., J. B. Wiener, and P. Sands, 1996: *Legal Issues Presented by a Pilot International Greenhouse Gas Trading System* (Geneva: UNCTAD), p. 45.
79. Wiener, "Global environmental regulation," 1999, pp. 785–787.
80. In any case, the higher transaction costs of project-based CDM credits may ensure that they trade at a lower price than formal allowances would. See Dudek and Wiener, 1996. And rules for buyer liability under Article 12 (but not under Article 17, where emission limits are enforced through national emission inventories) could also make CDM credits less attractive to buyers than formal allowances. These steps would help distinguish CDM credits from the more environmentally dependable commodity of formal allowances and also encourage developing countries to join the formal cap-and-trade system (with headroom allowances).
81. This suggestion is advanced and elaborated in Stewart, R. B. and J. B. Wiener, 2002: *Reconstructing Climate Policy* (Washington, DC: American Enterprise Institute).
82. Wigley, T., R. Richels, and J. Edmonds, 1996: "Economic and environmental choices in the stabilization of atmospheric CO₂ concentrations," *Nature*, 379: 240–243. Cf. Schneider, S. H. and L. H. Goulder, 1997: "Achieving low-cost emissions targets," *Nature*, 189: 13–14.
83. Hammitt, J. K., 1999: "Evaluation endpoints and climate policy: atmospheric stabilization, benefit–cost analysis, and near-term greenhouse-gas emissions," *Climatic Change*, 41: 447–468.
84. The atmospheric CO₂ concentration in the year 2000 was about 375 ppm.
85. In Hammitt's model, the marginal abatement costs associated with the optimal path are \$10/ton of carbon in 2000, \$40 in 2050, \$110 in 2100, and \$190 in 2150. The marginal abatement costs associated with the least-cost stabilization paths are close to zero through 2070, 2050, and 2010 for stabilization at 750, 650, and 550 ppm, respectively, and then rise steeply from zero to more than \$300 per ton of carbon within about 50 years after those dates to accomplish stabilization.
86. Hammitt finds that several alternative assumptions—a higher climate sensitivity (4.5°C increase in temperature caused by a doubling in GHG concentrations, rather than 2.5°C), a higher damage function (15 percent of world GDP rather than 2 percent loss caused by a warming of 2.5°C), a damage function related to the rate of climate change rather than the level of climate change, and earlier technological innovations that significantly reduce abatement costs—each call for even greater near-term emission reductions to achieve the optimal path. With high climate sensitivity, Hammitt's optimal path requires an 8 percent reduction in emissions below BAU in 2010 yet remains 40 percent above 1990 levels through 2100 before declining. Marginal abatement costs in the high-sensitivity case are \$25 per ton of carbon in 2000, \$90 in 2050, and \$230 in 2100. With high damages, Hammitt's optimal path requires emissions equal to 1990 levels through 2050 and then declining. Marginal abatement costs in the high-damages case are \$70 per ton of carbon in 2000, \$220 in 2050, and \$500 in 2100.
87. Hahn, 1998; Schmalensee, 1998; Council of Economic Advisers, Economic Report of the President 2002 (Washington, DC: Government Printing Office).

88. See Oppenheimer, M. and R. H. Boyle, 1990: *Dead Heat* (New York: Basic Books). This is also the implication drawn by advocates of the “precautionary principle.”
89. Hammitt, J. K., R. J. Lempert, and M. E. Schlesinger, 1992: “A sequential decision strategy for abating climate change,” *Nature*, 357: 315–318.
90. Lempert, R. J. and M. E. Schlesinger, 2001: “Adaptive strategies for climate change,” in *Innovative Energy Strategies for CO₂ Stabilization* (Cambridge, England: Cambridge University Press).
91. The Kyoto target of 5 percent below the 1990 level for industrialized countries (roughly 15 percent below BAU) by 2012 appears to lie somewhere between Hammitt’s high-damages case and his case of both high climate sensitivity and high damages (which requires about a 20 percent reduction below 1990 levels through 2020). In Hammitt’s model, marginal abatement costs in the case of both high sensitivity and high damages are \$170 per ton of carbon in 2000, \$400 in 2050, and \$500 in 2100.
92. Schneider, S. H., 1997: “Integrated assessment modeling of global climate change: transparent rational tool for policymaking or opaque screen hiding value-laden assumptions?” *Environmental Modeling and Assessment*, 2: 229–248.

