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Designing Global Climate Regulation

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Abstract

Designing global climate policy is difficult because global climate change is deeply complex on several dimensions, frustrating simple and hasty regulatory responses. This chapter discusses three kinds of complexity that confront regulatory design for global climate change: causal, spatial, and temporal. Causal complexity refers to the multiple greenhouse gases and their diverse interconnected sources and sinks in multiple economic sectors. Spatial complexity refers to the dispersion of sources and sinks around the planet, the variation in abatement costs and benefits across countries, and the need to design regulatory policies to attract participation efficiently under the voting rule of consent that governs international treaties. Temporal complexity refers to the dynamic character over time of the climate, of human activities and technologies, and of our understanding of these systems. Narrow, uniform, and rigid regulatory policies will be thwarted by these three complexities. Yet innovative designs can construct an effective and efficient global regulatory regime for climate change. The chapter analyzes the merits of a comprehensive approach to address causal complexity, tradeable emissions allowances to address spatial complexity, and optimal time paths and adaptive management to address temporal complexity. In light of these challenges and design innovations, the chapter assesses the actual climate change treaties negotiated at Rio, Kyoto and Bonn.

I. Introduction

As continued scientific research has suggested that global climate change is a serious prospect, political negotiations have sought to establish an international regulatory policy to constrain emissions of greenhouse gases. 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.[ii]

U.S. Supreme Court Justice Stephen Breyer, a scholar of regulatory design, has urged that "mismatches" defeat many well-intentioned regulatory programs, and that regulatory systems should match the social and environmental systems they regulate.[iii] More specifically, regulatory programs should address the full scope of a problem, should foster creativity in achieving solutions, and should 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 refers to the diverse interconnected factors that drive climate change. Multiple greenhouse gases (GHGs) are affected by virtually 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 refers to the great breadth and diversity of GHG sources and sinks in virtually every country around the planet. Regulating a global problem at the global scale 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 of the planet may turn out to 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 is typically imposed by some form of majority vote, at the international level each nation is sovereign and is bound only by those treaties to which it consents. Whereas compliance with national pollution control laws can be compelled, participation in international treaties cannot be compelled and must instead be attracted. Thus, climate regulation must deal with global scale, global diversity, and the global legal framework.

Temporal complexity refers to the dynamic character over time of the climate, of human activities and technologies, and of our understanding of these systems. Climate policy cannot be made once-and-for-all; it must be updated to adapt to changing circumstances and changing 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. Meanwhile, 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. This chapter discusses how. First, it articulates the advantages of a comprehensive approach to regulating the complex causes of climate change. Second, it evaluates the options for regulatory design in the complex spatial terrain of international law – technology requirements, emissions taxes, subsidies for abatement, fixed performance standards, and tradeable emissions allowances – and finds that tradeable allowances have important advantages for the global climate regime. Third, it discusses the challenge of making climate policy adaptive and efficient over time.

II. Causal Complexity and Comprehensive Scope[iv]

A. 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.[v]

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 that confound well-intentioned policies.[vi] 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 (CO_2) emitted from the energy sector, because CO_2 was the most plentiful greenhouse gas, and the energy sector was the largest source of CO_2. The initial negotiating positions of major countries proposed a treaty calling for cuts in energy-sector CO_2.

But at the same time, scientists were demonstrating to policymakers that CO_2 was only one of several important GHGs. First, although the volume of CO_2 emitted far exceeded that of other GHGs, each CO_2 molecule is a relatively weak absorber of infrared radiation (heat). Other GHGs, such as methane (CH_4) and nitrous oxide (N_2O), turned out to be 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 CO_2 at retaining heat in the atmosphere over time. Thus CO_2 was estimated to be responsible for only about one-half[vii] of the global warming potential of anthropogenic GHG emissions in the 1980s.

Second, the relative influence of CH_4 and N_2O was expected to increase in the future. GHGs absorb infrared radiation in wavelengths specific to each gas. As the concentration of CO_2 in the atmosphere has risen, more and more of the infrared radiation at the wavelength blocked by CO_2 molecules is already being absorbed. Because of this "saturation effect," additional emissions of abundant atmospheric gases such as CO_2 will have decreasing marginal impacts relative to those of less abundant gases such as methane. Thus, narrowly targeting the regulatory regime at CO_2 and omitting the other salient GHGs would inhibit the effectiveness of the regulation in averting climate change.

B. Advantages of the Comprehensive Approach to Climate Change

1. Environmental advantages. For climate policy, taking a comprehensive approach 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.[viii] Like squeezing one end of a balloon, this approach shifted the problems elsewhere and delayed the attainment of the primary goal – a clean and safe environment. An integrated approach would control pollution more comprehensively and effectively.[ix]

Similarly, focusing solely on energy sector CO_2 would induce perverse shifts in emissions. For example, controlling energy sector CO_2 alone would invite fuel switching from coal to natural gas, because burning coal emits about twice as much CO_2 per unit of energy produced as does natural gas. But natural gas is almost pure methane (CH_4), and methane is roughly 20 times more potent than CO_2 per mass at causing global warming. Hence as little as a 6 percent rate of fugitive methane emissions from natural gas systems would be enough to fully offset the CO_2-related benefits of this fuel switching.[x] In the U.S. , 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 CO_2-only policy in Europe could actually yield a net increase in the contribution to global warming.[xi]

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 CO_2 emissions. The emissions of CO_2 from burning the fossil fuels would be reduced or eliminated, and the emissions of CO_2 from burning the biomass fuels would, one might presume, be at least partly offset by the sequestration of that same CO_2 from the atmosphere by the corn as it grew. But the story is not that simple. Focusing only on energy sector CO_2 neglects three important categories of emissions. First, the CO_2 emissions from the ancillary agricultural operations needed to farm the corn, manufacture fertilizer, irrigate the land, and convert the corn into fuel would likely be large.[xii] Second, growing corn employs large quantities of nitrogen fertilizer, which release nitrous oxide (N_2O) emissions -- a GHG almost 300 times more potent per mass than CO_2. 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 changed ability of the cornfield 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 make it comprehensive so that it encompasses all the major GHGs (including methane and nitrous oxide as well as CO_2) and all sectors (including agriculture and forests as well as energy). Comprehensiveness would define performance and measure 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. Russia and other countries with leaky natural gas systems would now 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.[xiii]

2. 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 the flexibility to choose which GHGs they reduce in which sectors, the comprehensive approach affords 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 as compared to a piecemeal approach that fixes limits for CO_2 alone or for each gas separately. A comprehensive approach would regulate the net CO_2-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 an emissions target for the U.S. of 20% below 1990 levels by the year 2010 by comprehensively addressing all GHGs, instead of just controlling energy sector CO_2 alone, would reduce costs by 75%; adding the option of sink enhancement would reduce costs by 90% compared to the energy sector CO_2 policy.[xiv] Similarly, a World Bank study found that India could reduce its costs 80% by controlling all GHGs instead of energy sector CO_2 alone.[xv] The most recent and thorough study confirms these results. Using an integrated assessment model of the world economy, a research team at 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%.[xvi] The MIT study also noted that the multi-gas approach could actually be more effective at protecting the climate than the CO_2-only approach, both because the relative global warming impact of the non-CO_2 gases is expected to increase in the future, and because the ability of CO_2 to fertilize plant growth and hence stimulate carbon storage means that CO_2 creates a negative feedback on global warming that the other gases do not. A new study by NASA climate scientist James Hansen and colleagues offers further support for the comprehensive approach, showing that control of non-CO2 GHGs would be cost-effective and would yield significant side benefits to human health from the reduction of local air pollutants.[xvii]

3. 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 to climate protection 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.

4. Fairness. The comprehensive approach establishes a more equitable position for all nations at the regulatory negotiations table. Because of the differences across countries in opportunities to control sources and expand sinks, and 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 evenhandedly with countries of widely different internal economic and social configurations.

5. Participation. The cost and fairness advantages of the comprehensive approach have another benefit. As will be discussed in more detail below, attracting participation in international climate policy by a large majority of countries is critical. Since climate change and regulatory actions to address it will 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.

C. 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 sinks as well as sources. The United States proposed the "comprehensive approach" in 1990,[xviii] and that approach was adopted in the Framework Convention on Climate Change 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 classes of GHGs in its quantitative emissions targets: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). It also gives credit for sink expansion. The Kyoto Protocol requires countries to attain levels of net GHG emissions reductions, weighted by the 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 July 2001 Bonn accord on implementing Kyoto reinforced the comprehensive approach in almost all respects, although it 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 Global Warming Potential (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 CO_2) be initially devised and then be 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 social benefits of comprehensiveness vastly outweigh its administrative costs. Second, the intended stepwise expansion would likely 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-CO_2 gases that eventually would be needed to run an effective comprehensive program. Moreover, the comprehensive approach is not impractical.[xix] The measurement of non-CO_2 gases and non-energy sectors, even if initially difficult, would improve in response to policy incentives. And such measurement is necessary even under a CO_2-only policy, if we are to evaluate the true effectiveness of the policy in protecting the climate; ignoring the non-CO_2 gases does not make them go away. The GWP index is not perfect, but it is more accurate than ignoring the non-CO_2 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.

III. Spatial Complexity, Participation, and Instrument Choice[xx]

GHG emissions could be regulated in several ways, such as technology requirements, emissions taxes, subsidies for abatement, maximum emissions levels, or tradeable emissions 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 July 2001 Bonn 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 tradeable allowances (Article 17) as well as a new informal trading system for the sale of emissions 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.

A. Spatial Complexity

1. 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."[xxi] The atmosphere is being treated as an "open-access commons" which anyone can use as a disposal site for GHGs.[xxii] Prevention of these global externalities (i.e., climate protection) is a global "public good" because it is non-excludable: 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.[xxiii] 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.[xxiv]

2. 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 substantially global coverage in order to be environmentally effective. Because developing countries are expected to increase their GHG-emitting activities rapidly over the next few decades,[xxv] a spatially limited policy that covers only industrialized countries could 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 emissions 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 for them to undertake.[xxvi] Third, even if actual leakage would be 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.[xxvii]

3. 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 fifty-fold difference in GHG abatement costs just within the membership of the European Union.[xxviii] 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 dryer 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 who press for long-term climate protection.[xxix]

Some countries, perhaps including China and Russia, might even believe they stand to *gain* from climate change, such as because they will enjoy greater agricultural yields in currently cold areas if temperatures rise. A recent synthesis of global climate change impacts on key endpoints -- agriculture, forestry, water resources, energy consumption, sea level rise, ecosystems, and human health -- indicates that some initial warming (1 degree C) and CO2 fertilization may help agriculture and human health in some areas (including the OECD, Russia and China), for a near term gain of 1 to 3% of GDP; but that this climate change will have adverse impacts in poorer areas (especially Africa and Southeast Asia, which would lose 1 to 4% of GDP); and that the impacts of greater warming will become adverse worldwide over the longer term, including losses of 1 to 2% in OECD countries and 4 to 9% in Russia and developing countries (but not in China, which exhibits persistent gains from climate change of about 2% of GDP).[xxx] Hence 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 net costly, and who therefore dislike cooperative prevention efforts.[xxxi] Because these countries are also large GHG emitters, successful climate regulation will need to include these countries. But attracting participation by cooperative losers is even more difficult than overcoming free riding.

B. Participation and Voting Rules

This spatial complexity would not make so much difference to 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.[xxxii]

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 employs a version of Majority Rule: a majority of consent is sufficient to adopt a law that then binds all, including those (up to 49%) who dissented from the adoption of this law.[xxxiii] By contrast, the voting rule for international treaties is Consent: treaties bind only those who agree to be bound.[xxxiv] 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,[xxxv] 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.[xxxvi] But military force is rarely employed to secure adoption of environmental treaties (though 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 GATT/WTO free trade disciplines. Shaming[xxxvii] and interest group pressures[xxxviii] are elements of a country's calculus of whether to consent. Meanwhile, the tradition of seeking consensus in treaty negotiations,[xxxix] and the need to avoid emissions 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.[xl] In general, national consent to a treaty requires a positive national net benefit compared to not joining.[xli] Unless a country views joining a treaty as on balance favoring its interests, it is highly unlikely to join. Of course, "net benefit" and "interest" are to be construed quite 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 the more stringent test of actual Pareto-improvement (individual net benefits for each participant).[xlii] International treaties are thus adopted by a voting rule much more analogous to marketplace contracts than to national legislation.[xliii] 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.

C. Global Instrument Choice

Most analyses of regulation assume Autocracy: if one rational person could just 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.

1. The Regulator's Toolbox. The instruments available to the regulator include technology requirements, emissions taxes, subsidies for abatement, performance standards, and tradeable emissions 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, in order to limit emissions. Outcome-based instruments (also called incentive-based) seek to achieve a certain degree of environmental protection, but leave firms the flexibility 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.[xliv] Two basic types of incentive-based instruments are price-based and quantity-based.[xlv] *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 to firms. Quantity-based instruments include fixed performance standards (i.e., an emissions limit for each source) and tradeable emissions allowances (i.e., emissions limits for each source, which sources can buy or sell among each other). Once the total quantity of emissions is chosen and allowances adding up to that total are assigned to sources (or once an emissions tax is set), the sources then decide how much to emit in light of having to pay the market price of buying an additional allowance (or paying the tax), and in light of being able to earn the market price to sell an extra allowance.

2. 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.[xlvi] Still, under the standard assumption of Autocracy – that the law is imposed by a single rational actor – three standard presumptions have emerged in the literature on instrument choice. These three presumptions are that: (1) incentive instruments are superior to conduct instruments; (2) taxes and tradeable allowances are superior to subsidies for abatement; and (3) taxes are often superior to tradeable allowances. After briefly describing these presumptions in the world of Autocracy, we can examine their validity in a world of Consent.

(A) Incentives versus Conduct. First, incentive-based instruments such as taxes and tradeable allowances are generally 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 emissions taxes and tradeable 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 U.S., allowance trading programs have proven to be far more cost-effective than conduct rules or fixed performance standards, cutting costs by roughly half.[xlvii] For example, the SO2 emissions trading system adopted in the 1990 Clean Air Act amendments to reduce acid rain has been a dramatic success, achieving a dramatic reduction

in SO2 emissions at roughly half the cost of the prior uniform approach.[xlviii] Because GHG abatement costs vary a great deal across countries, the cost savings for global GHG emissions trading (compared to fixed national targets) are predicted to be quite large -- on the order of 30 to 70 percent.[xlix]

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.[l]

Third, incentive instruments need not involve undue administrative costs. Technology standards require detailed engineering choices and monitoring of devices installed. Incentive methods need to determine the tax rate or number of allowances and monitor actual emissions. Monitoring actual emissions can be costly (especially for dispersed sources), but monitoring the technology in place at a source does not measure actual 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 promote fairness. There is concern that efficiency-enhancing policies (such as emissions trading) might be unfair to poorer communities and developing countries.[li] 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 emissions taxes could be regressive, but global tradeable 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 their business-as-usual forecast), or by earning substantial revenues from selling a valuable new asset – the tradeable allowances – to wealthier sources facing higher abatement costs. This system would benefit poorer societies by giving them a substantial revenue stream.[lii] It would also oblige richer countries to "take the lead" by financing global emissions 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 must control their emissions entirely at home would actually be *unfair* to developing countries, because it would deprive developing countries of the allowance-sale revenue stream from selling headroom allowances. It would be like insisting that rich people must only spend their money 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.[liii] 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 tradeable 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 tradeable emissions allowances, by contrast, force the source to pay for *every* unit of GHG emissions, either by paying the tax or by foregoing the revenue from the sale of the allowance. Further, if the immoral act is to cause additional pollution, and if incentive instruments are more cost-effective and innovation-enhancing, then the moralist who opposes incentive instruments is herself committing her immoral act.

(B) Taxes & Trading versus Subsidies. The second presumption is that subsidies for abatement are inefficient. Subsidies for abatement can act like emissions 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 thus 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.[liv] The subsidy payment may be seen as insurance against the social cost of the emitting activity and thus lead to its increase.[lv] Sources may also increase pollution in order to secure larger subsidies for abatement.[lvi]

(C) Taxes versus Trading. The third presumption of the standard analysis is that taxes are preferred to tradeable allowances. In theory, these instruments can produce identical results. Taxes set the price of emitting and allow the quantity of emissions to vary, while 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 one 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, while the allowance system prevents emissions escalation (there is a finite number of allowances) but lets costs vary. The choice between these instruments under uncertainty depends on one's relative concern about cost escalation versus emissions escalation (that is, on the relative steepness of the marginal cost of abatement versus the marginal benefit of abatement).[lvii] One study found that, given significant uncertainty about true abatement costs and, crucially, assuming a very flat marginal benefits curve (that is, 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 tradeable emissions allowances.[lviii]

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."[lix]

A system of tradeable 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.[lx] 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.[lxi] The costs of finding trading partners, negotiating deals, monitoring and enforcing performance, and insuring against non-performance 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 emissions escalation is a more serious concern than cost escalation (the converse of the assumption described above), then allowances are superior to taxes under uncertainty.[lxii] 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 a more important purpose 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 succeed at attracting adequate participation by countries.

3. The Analysis under Consent. The foregoing assumes Autocracy. As discussed above, 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 who 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.[lxiii]

(A) Participation Efficiency. Attracting participation yields benefits but can be costly. The best regulatory instrument under Consent must therefore strive to satisfy a criterion that is not relevant under Autocracy: "participation efficiency."[lxiv] 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 non-participation 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 benefits of participation include greater coverage of globally dispersed emissions, reduced free riding, reduced cross-border emissions 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 above).[lxv]

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 in order to gain the fifty percent-plus-one needed to adopt a law. After that, coercive power exists over remaining dissenters. Under Consent, every important cooperative loser must be paid to play.

(B) 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.[lxvi] Unfortunately, subsidies for abatement generate perverse incentives for increased aggregate emissions.[lxvii] There is also the possibility that some countries would posture as cooperative losers in order 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.[lxviii]

Second, participation might be coerced through threats of trade sanctions.[lxix] Loss of trading partners could induce free riders and even cooperative losers to participate because of the fear that non-cooperation would be more costly than cooperation.[lxx] While 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 are often ineffective because they strengthen the target government's domestic political case for resistance to foreign meddling.[lxxi] 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.[lxxii] Finally, trade sanctions imposed by wealthy countries against poorer countries cut against principles of fairness.[lxxiii]

Third, GHG taxes might be employed. But because taxes impose the highest costs on sources, they will likely induce the greatest rate of nonparticipation. GHG taxes would likely 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 assure positive national net benefits -- compensating for abatement costs, foregone environmental benefits to cooperative losers, *and* the burden of the tax on residual unabated emissions. But such a side payment would undercut the ability of the tax to reduce emissions in recipient countries. The side payment could not be "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 deploy 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 emissions 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 emissions reductions to be accomplished wherever abatement costs are lowest. An even better design for quantity-based instruments would be to employ tradeable allowances, reducing costs dramatically. The side payments could then be embedded in the allowance trading system itself. In this "cap-and-trade" system, cooperative losers (most likely 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 could be used by the country to increase emissions or sold to earn profits in the allowance trading market. Wealthier countries would 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.[lxxiv] This was the strategy used in the Kyoto Protocol to engage Russia's participation: Russia was assigned headroom allowances in exchange for her agreement to join the treaty. 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 emissions allowances would be so difficult that the system would never get off the ground.[lxxv] 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 require a burden-sharing negotiation. The real question is the *relative* difficulty of negotiating the initial assignment using the alternative instruments, *given* the Consent framework.[lxxvi] In that context, tradeable 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.[lxxvii] Technology standards, fixed quantity limits and taxes provide no flexibility for subsequent reallocations of entitlements. But allowance trading makes post-agreement reallocations possible, hence 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 payments create. The best instrument for achieving this result is a system of international tradeable emissions 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.

4. 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 emissions 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 really 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."[lxxviii] And thus there are good reasons to expect allowance trading to be superior to alternative regulatory instruments at inducing compliance. First, the improved cost-effectiveness (30 to 70% 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 non-cooperators, and the prospect of continuing to sell allowances over time provides a strong discipline against temptations 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 tradeable allowance system is also likely to nurture domestic political constituencies – allowance sellers, allowance buyers, abatement investors, brokers, and environmentalists – who would pressure their governments to comply with emissions limits so as not to have their allowances devalued or their market access hindered.[lxxix]

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 international policy on domestic industries. This "fiscal cushioning" would in turn undermine the effect of the tax or technology standard on actual emissions.[lxxx] 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 quite 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 to 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.

D. Assessing the Kyoto Protocol and Bonn accord

In terms of spatial complexity and participation efficiency, the Kyoto Protocol gets things about half right. On the bright side, it does adopt a quantity constraint on emissions, eschewing technology standards and emissions taxes; and it does authorize emissions trading (in Article 17) to enhance cost-effectiveness, rather than adopting fixed performance standards. Moreover, it does make some use of allowance allocations to secure participation. It allocates the burden of emissions 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 which 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 emissions 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 emissions leakage from capped industrialized countries to uncapped developing countries are rampant. Under the Consent voting rule (and also for reasons of distributional equity), these developing countries will certainly require side payments to attract their participation.

The Kyoto Protocol tries to address developing country abatement by introducing a new and well-intentioned device -- the Clean Development Mechanism (CDM) created in Article 12 -- through which industrialized country sources could purchase emissions 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-emissions growth paths. These are important advantages.

But the CDM could prove to 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 is the regulatory instrument 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 cooperative loser developing countries to participate in the cap-and-trade system. But if those countries can earn just as much by selling CDM credits outside of 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) in order to reflect their lesser effectiveness in achieving global abatement. This would lower their attractiveness and push more countries toward agreeing to caps in order to take advantage of more lucrative formal trading.[lxxxi]

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-Gore administration did not submit the treaty to the Senate for ratification. In 2001 the Bush administration announced it would not pursue the Kyoto Protocol, but did not propose an alternative.

The accord reached at Bonn in July 2001 omitted both the developing countries and the U.S., portending quite limited effectiveness in reducing global emissions. It also retained some restrictions on emissions trading, including a "reserve" requirement to limit allowance selling. The cost savings expected from emissions trading in theory need to be re-estimated with the actual Bonn/Kyoto restrictions in place. To be environmentally effective (as well as less costly), the Kyoto/Bonn accord ought to 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 July 2001 Bonn accord seemed to sacrifice broad participation, it might set the stage for an even better result: joint accession by both the U.S. and China. Politically, the U.S. 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 politically, China will not join without the U.S. (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 Bonn/Kyoto will want the US and China to join simultaneously. If one joins without the other, it will distort allowance prices in the emissions trading market: prices will go way up if the U.S. (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 at Bonn may pave the way for joint accession by the US and China. If not, the Kyoto/Bonn 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 U.S. and China may be the only plausible future for the climate treaties. And this reality in turn gives the U.S. and China significant leverage to negotiate for a sound global regime that improves on Bonn/Kyoto. The real difficulty in this scenario will not be the U.S., it will be China. The U.S. 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 above, suggest that China would on balance benefit from a warmer world. Thus 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 -- just as was done in Kyoto to engage Russia.

IV. 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, so we may discover new energy and land use systems that ease or exacerbate abatement costs. Temporal complexity implies two challenges that are each difficult to address: optimally allocating abatement efforts over time, and adapting climate policy as conditions and knowledge evolve. Compared to causal and spatial complexity, temporal complexity has received the least attention in the actual climate change treaty negotiations.

A. 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 emissions 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 for the development of new technologies, and spend scarce resources later rather than sooner.

One strategy to optimize abatement over time is to set emissions targets not for single years, but for multi-year aggregates such as ten-year emissions budgets for each country. Such multi-year targets (or extended "commitment periods") enable each country to exercise "when" 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. "When" flexibility through multi-year budgets is conceptually similar to the cost-saving "where" flexibility afforded by tradeable allowances: because abatement costs vary across the relevant dimension (temporal or spatial), flexibility improves cost-effectiveness. A more embracing version of "when" flexibility would authorize "banking" of extra early emissions reductions for application to subsequent emissions 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 emissions 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 ten or more years in advance of their effective dates. Major investments in capital and innovation often take longer than five to ten 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 themselves 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 to set a continuous schedule of emissions limits, beginning with small or no reductions from business-as-usual 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 in the Montreal Protocol on CFCs.

Third, the time path of emissions 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.) Studies have found that 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.[lxxxii] 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. Hammitt[lxxxiii] compares (1) the emissions reductions implied by the least-cost path to stabilize atmospheric GHG concentrations at designated levels, with (2) the emissions 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 emissions reductions below the business as usual (BAU) emissions forecast than does the least-cost path to stabilize atmospheric GHG concentrations at 750, 650, or even 550 ppm by the period 2100 to 2150.[lxxxiv] 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 emissions reductions – roughly 3% below BAU by 2010, 5% below BAU by 2025, and 20% below BAU by 2100 -- while 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 cases of the 550 ppm target, for example). The optimal path exhibits a more smoothly but slowly rising emissions profile which is about 2 to 5 % below the least-cost stabilization profile in the near term (through about 2025), but eventually exceeds the least-cost stabilization emissions profile after 2107, 2069, and 2024, respectively for stabilization at 750, 650, and 550 ppm.[lxxxv] 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.[lxxxvi]

As Hammitt notes, one would need to start building the institutional structure for climate policy some time before the dates at which emissions 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% below BAU in 2010, 5% below BAU in 2025, and 20% below BAU in 2100, one would need to begin constructing and implementing the institutional design well before 2010 – that is, roughly, now.

B. Adaptation of Policy over Time

Temporal complexity also means that the level of protection initially set may later seem erroneous or need to be updated as conditions and knowledge have changed. The direction of our likely errors is highly debatable: are we acting 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[lxxxvii]; others say that temporal complexity counsels in favor of adopting more stringent limits now to prevent even greater harms than we now foresee.[lxxxviii]

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 the 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 re-assess regulations regularly in light of the latest expert advice. The role of the Intergovernmental Panel on Climate Change (IPCC) and of national research programs will therefore 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, new emissions targets are debated every few years, rather than trying to adopt a permanent set of emissions limits once and for all. This repeat-playing implies keeps options open. On the other hand, this process of sequential decisions creates uncertainty about future targets and may be at odds with the objective suggested above of setting a schedule of continuous emissions limitations over many years so that investments respond accordingly and cost-effectively. Sequential target-setting should in any case be undertaken transparently, so that investors have advance signals of likely next steps.[lxxxix]

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.[xc] Our current forecasts may not only be off a bit, they 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.

C. Assessing the Kyoto Protocol

The FCCC and Kyoto Protocol have done only a little to address temporal complexity. Kyoto allowed some "when" flexibility by setting targets as average emissions over a five-year "commitment period," 2008-2012. But even greater temporal efficiencies could have been achieved through a longer commitment period (such as ten years), and through expressly authorizing both banking of early reductions and perhaps the borrowing of early exceedances against later limitations (with an interest rate reflecting the time value of abatement). Kyoto did not give any credit for emissions reductions before 2008 (except, oddly, for CDM projects), and did not allow borrowing. Banking and borrowing make most sense as early departures below and above a continuous emissions 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 ratifications it was already 2001, making the 2008 effective date seem far too near to achieve substantial emissions cuts without major costs.

Kyoto also set targets that depart significantly from the both the least-cost stabilization path and Hammitt's illustrative optimal path. The Kyoto Protocol called for emissions reductions by industrialized countries of about 5% below 1990 levels by 2012, which corresponds to a U.S. reduction of about 30% below BAU in 2012, and a reduction in all industrialized countries' emissions of roughly 15% below BAU by 2012. Thus the Kyoto Protocol appears to require (at least for industrialized countries) much sharper near-term emissions reductions than those required by either Hammitt's optimal path (which requires global emissions to be 3% below BAU by 2010, 5% below BAU by 2025, and 20% 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).[xci] 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 over time need to do a better job of accounting for damages over time and non-linear climatic effects.[xcii]

As to adaptive management, the Kyoto process does involve 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 much to advise the treaty negotiators on the optimal time path of abatement. Thus the Kyoto process may well result in repeated updating of its emissions targets, but those updates may not reflect a considered evaluation of the optimal temporal path for abatement.

V. 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% lower cost than a piecemeal approach. Second, international allowance trading would reduce costs by perhaps 70% compared to 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 agreements, but global allowance trading holds the promise of engaging both the U.S. 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 tradeable 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 "safety valve" 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 accord have made good progress on comprehensive coverage and on emissions 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.

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[ii] This chapter examines the design of the regulatory mechanism, not its goals -- that is, it discusses the means or instruments of protection, and not the ends or level of protection that should be sought. Although the two questions are ultimately interrelated, deciding "how to" reduce emissions can usefully be analyzed as a distinct matter from deciding "how much" to reduce emissions. See Peter Bohm & Clifford Russell, "Comparative Analysis of Alternative Policy Instruments," in Handbook of Natural Resource and Energy Economics 395, 397 (Allan V. Kneese & James L. Sweeney, eds., 1995) ("Choice of policy goal and choice of instrument or implementation system are essentially separable problems.").

[iii] See Stephen G. Breyer, Regulation and Its Reform (Harvard Univ. Press, 1982).

[iv]This section draws on Jonathan Baert Wiener, "Protecting the Global Environment," in John D. Graham & Jonathan Baert Wiener, eds., Risk vs. Risk: Tradeoffs in Protecting Health and the Environment (Harvard University Press, 1995); Richard B. Stewart & Jonathan B. Wiener,"The Comprehensive Approach to Global Climate Policy: Issues of Design and Practicality," 9 Ariz. J. Int'l & Compar. L. 83 (1992); and Richard B. Stewart & Jonathan B. Wiener, "A Comprehensive Approach to Climate Change," 1 American Enterprise no. 6 at 75 (November-December 1990).

[v]The classic case for narrow incrementalism is Charles E. Lindblom, "The Science of 'Muddling Through'," 19 Public Admin. Rev. 79 (1959).

[vi]See Jonathan Baert Wiener, "Managing the Iatrogenic Risks of Risk Management," 9 Risk: Health Safety & Environment 39 (1998).

[vii] See John T. Houghton, G.J. Jenkins and J.J. Ephraums (eds.), IPCC First Assessment Report, The Science of Climate Change (Cambridge Univ. Press 1992).

[viii] See Winston Harrington, Acid Rain: A Primer (Resources for the Future, 1989).

[ix] See Lakshman Guruswamy, The Case for Integrated Pollution Control, 54 Law & Contemporary Problems 41 (1991).

[x] See Henning Rodhe, "A Comparison of the Contribution of Various Gases to the Greenhouse Effect," 248 Science 1217-1219 (June 8, 1990).

[xi] See Wiener, "Protecting the Global Environment," in Risk vs. Risk, *supra*, at 209-212.

[xii] See William H. Schlesinger, Carbon Sequestration in Soils," 284 Science 2095 (June 25, 1999).

[xiii] "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, "Protecting the Global Environment," in Risk vs. Risk, *supra*, at 218-219. Meanwhile, some emissions of GHGs could aid forests: CO_2 emissions help fertilize plant photosynthesis, a beneficial effect that the other GHGs do not offer. See id. at 214-218; Evan H. DeLucia et al., "Net Primary Production of a Forest Ecosystem with Experimental CO_2 Enrichment," 284 Science 1177-1179 (May 14, 1999). Thus, in order to be fully environmentally comprehensive, a comprehensive 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 & Wiener (1990, 1992), *supra*.

[xiv] See Richard Bradley, E. Watts & E. Williams, Limiting Net Greenhouse Emissions in the United States, Volume II: Energy Responses 8.10-8.12 (U.S. Department of Energy, Office of Environmental Analysis, 1991).

[xv] See World Bank, World Development Report 1992: Development and the Environment, box 8.6 (1992).

[xvi] See John Reilly, Ronald Prinn, et al., "Multi-Gas Assessment of the Kyoto Protocol," 401 Nature 549-555 (October 7, 1999).
[xvii] See James Hansen et al., "Global Warming in the Twenty-First Century: An Alternative Scenario," 97 Proceedings of the National Academy of Sciences 9875 (2000).
[xviii] See Stewart & Wiener (1992) and (1990), *supra*. The comprehensive approach was staunchly advocated by the United States through both the Bush and Clinton Administrations. See., e.g., Andrew C. Revken, "Study Proposes New Strategy to Stem Global Warming," NY Times, Aug. 19, 2000, 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.").
[xix] For further discussion see Stewart & Wiener (1992), *supra*.
[xx] This section draws on Jonathan Baert Wiener, "Global Environmental Regulation: Instrument Choice in Legal Context," 108 Yale Law Journal 677-800 (1999).
[xxi] 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.
[xxii] See Garrett Hardin, "The Tragedy of the Commons," 162 Science 1243 (1968).
[xxiii] See Robert Axelrod, The Evolution of Cooperation 7-9 (1984).
[xxiv] See Robert O. Keohane, After Hegemony (1984).
[xxv] Council of Economic Advisors, Economic Report of the President 170-172 (1998) (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, International Energy Outlook (2001) (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).
[xxvi] Richard Schmalensee, Greenhouse Policy Architectures and Institutions, in William D. Nordhaus (ed.), Economics and Policy Issues in Climate Change 137, 146 (1998).
[xxvii] S. Res. 98, 143 Congressional Record S8113-05 (July 25, 1997). The Clinton-Gore administration decided not even to submit the Kyoto Protocol to the Senate for ratification until "meaningful participation" by developing countries had been secured.
[xxviii] Scott Barrett, Reaching a CO_2 Emission Limitation Agreement for the Community: Implications for Equity and Cost-Effectiveness, 1 European Economics 3, 16 (1992).
[xxix] See William J. Baumol, Environmental Protection and Income Distribution, in H.H. Hochman and G.E. Peterson (eds.), Redistribution Through Public Choice 93 (1974) (observing that the demand for environmental protection typically rises with income).
[xxx] Richard Tol, Estimates of the Damage Costs of Climate Change, Part I: Benchmark Estimates. Environment & Resource Economics, forthcoming 2001; Richard Tol, Estimates of the Damage Costs of Climate Change, Part II: Dynamic Estimates. Environment & Resource Economics, forthcoming 2001. Tol's synthesis does not account for other adverse impacts, such as fisheries losses, extreme weather events, and the possibility of catastrophic changes in ocean currents or other critical natural systems.

[xxxi] See Adam L. Aronson, From "Cooperator's Loss" to Cooperative Gain: Negotiating Greenhouse Gas Abatement, 102 Yale Law Journal 2143, 2150-2151 (1993).
[xxxii] See Wiener, *supra*, 108 Yale L.J. at 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." James N. Buchanan, "The Constitution of Economic Policy," 77 American Economic Rev. 243, 243 (1987).
[xxxiii] This is an approximation. Real national law in the U.S. 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.

[xxxiv] A classic statement is Lord McNair, The Law of Treaties 162 (1961): "No State can be bound by any treaty provisions unless it has given its assent…"

[xxxv] See Michael Hoel & Kerstin Schneider, Incentives to Participate in an International Environmental Agreement, 9 Environmental & Resource Economics 153, 165-167 (1997).

[xxxvi] See James Cameron, The GATT and the Environment, in Philippe Sands (ed.), Greening International Law 106-116 (1994).

[xxxvii] See Abram Chayes & Antonia Handler Chayes, The New Sovereignty 27 (1995).

[xxxviii] See Robert O. Keohane & Joseph Nye, Transnational Relations and International Governance (1972); Henry Lee, Shaping National Responses to Climate Change 14 (1995) ("de facto transnational coalitions" often have "enormous influence" on international diplomacy).

[xxxix] See e.g. David Humphreys, Forest Politics 162 (1996).

[xl] In this discussion I take the voting rules as given, and make no normative comment on their relative desirability. Cf. Jonathan Baert Wiener, "On the Political Economy of Global Environmental Regulation," 87 Georgetown L.J. 749 (1999) (discussing normative implications of alternative voting rules for international environmental law).

[xli] See Robert O. Keohane, After Hegemony 104 (1984); Wiener, *supra*, 108 Yale LJ at 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 -- i.e., it need not view joining as a net gain compared to 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 compared to the world with no treaty at all. See Lloyd Gruber, Ruling the World (2000). 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).

[xlii] See Wiener, *supra*, 108 Yale LJ at 743-755.

[xliii] James Buchanan & Gordon Tullock, The Calculus of Consent 113 (1962) (analogizing consent voting rules to contracts; Robert O. Keohane, The Demand for International Regimes, in International Regimes 141, 146-49, 152 (Stephen D. Krasner ed., 1983) (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.").

[xliv] See Richard B. Stewart, "Reconstitutive Law," 46 Maryland Law Review 86, 92 (1986).

[xlv] See Robert W. Hahn & Robert N. Stavins, "Incentive-Based Environmental Regulation: A New Ear from an Old Idea?" 18 *Ecology Law Quarterly* 1 (1991). A third type of incentive instrument is information disclosure.

[xlvi] See Robert N. Stavins, "Introduction," in Public Policies for Environmental Protection (Paul R. Portney & Robert N. Stavins, eds., 2d ed. 2000). 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 William J. Baumol & Wallace E. Oates, The Theory of Environmental Policy 21-22, 29 (Cambridge University Press, 2nd edition 1988).

[xlvii] See Robert W. Hahn & Gordon L. Hester, "Marketable Permits: Lessons for Theory and Practice," 16 Ecology Law Quarterly 387 (1989).

[xlviii] See Paul L. Joskow et al., "The Market for Sulfur Dioxide Emissions," 88 American Economic Review 669 (1998).

[xlix] See, e.g., Alan S. Manne and Richard G. Richels, "The Kyoto Protocol: A Cost Effective Strategy for Meeting Environmental Objectives?", in Efficiency and Equity in Climate Change 59 (Carlo Carraro, ed., Kluwer Academic Publishers 2000); John P. Weyant & J. Hill, "Introduction and Overview," The Energy Journal, Special Issue vii (1999); Peter Bohm, "Joint Implementation as Emission Quota Trade: An Experiment Among Four Nordic Countries," Nord 1997:4, Nordic Council of Ministers, Copenhagen (1997); Alan Manne & Richard Richels, "The Berlin Mandate: The Costs of Meeting Post-2000 Targets and Timetables," 24 Energy Policy 205 (1996); Jean-Marc

Burniaux et al., "The Costs of Reducing CO_2 Emissions: Evidence from GREEN," OECD Economic Department Working Paper No. 115 (1992).

[l] See Adam Jaffe & Robert N. Stavins, "Dynamic Incentives of Environmental Regulation: The Effects of Alternative Policy Instruments on Technology Diffusion," 29 Journal of Environmental Economics and Management S-43 (1995).

[li] See, e.g., Arthur M. Okun, Equality and Efficiency: The Big Tradeoff (1975); Steven Kelman, What Price Incentives? Economists and the Environment 84-86 (1981). 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.

[lii] See Joaquim Oliveira-Martins, et al., The Costs of Reducing CO_2 Emissions: A Comparison of Carbon Tax Curves with GREEN, OECD Economics Department Working Paper No. 118 (1992) (estimating developing country revenues at $10 billion per year initially and increasing over several decades to $100 billion per year under global emissions trading).

[liii] Michael J. Sandel, "It's Immoral to Buy the Right to Pollute," New York Times, December 15, 1997, p.A23 (op-ed).

[liv] See Baumol & Oates (1988), *supra*, at 211-222; Wallace E. Oates, "Economics, Economists, and Environmental Policy," 16 Eastern Econ. J. 289, 290 (1990); Robert E. Kohn, "When Subsidies for Pollution Abatement Increase Total Emissions," 59 Southern Econ. J. 77 (1992).

[lv] Richard A. Posner, Economic Analysis of Law 64 (4th Edition 1992).

[lvi] See Hoel & Schneider, *supra*.

[lvii] See Martin L. Weitzman, "Prices vs. Quantities," 41 Review of Economic Studies 477 (1974).

[lviii] William A. Pizer, Prices vs. Quantities Revisited: The Case of Climate Change, Resources for the Future, Discussion Paper No. 98-02 (1997).

[lix] See, e.g., Lawrence H. Goulder, Environmental Taxation and the "Double Dividend": A Reader's Guide, 2 International Tax and Public Finance 157 (1995).

[lx] See Robert W. Hahn, Market Power and Transferable Property Rights, 99 Quarterly Journal of Economics 753 (1984). Alternatively, a few large buyers could try to exercise monopsony power, depressing allowance prices.

[lxi] See Daniel J. Dudek & Jonathan Baert Wiener, Joint Implementation, Transaction Costs, and Climate Change, OECD/GD (96)173 (1996), at 20-21.

[lxii] In addition, recent research suggests that under more realistic models with imperfect enforcement policies, quantity instruments are preferable to price instruments. See Juan-Pablo Montero, "Prices versus Quantities under Imperfect Enforcement," MIT CEEPR Working Paper (1999).

[lxiii] See Thomas W. Merrill, Golden Rules for Transboundary Protection, 46 Duke Law Journal 981 (1997).

[lxiv] This concept is advanced and discussed in Wiener, *supra*, 108 Yale L.J. at 742-770.

[lxv] See Wiener, *supra*, 108 Yale LJ at 748 & n.266, 761 & n.311.

[lxvi] Baumol & Oates (1988), *supra* at 279-281.

[lxvii] Baumol & Oates (1988), *supra*, at 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.

[lxviii] Hoel & Schneider, *supra* at 165.

[lxix] Howard F. Chang, An Economic Analysis of Trade Measures to Protect the Global Environment, 83 Georgetown Law Journal 2131 (1995).

[lxx] See Scott Barrett, Building Property Rights for Transboundary Resources, in Rights to Nature 265, 280-82 (Susan S. Hanna et al. eds., 1996).

[lxxi] Richard N. Haass, Sanctioning Madness, Foreign Affairs, Nov-Dec 1997, at 74, 77-80.

[lxxii] See Harold K. Jacobson & Edith Brown Weiss, "Compliance with International Environmental Accords: Achievements and Strategies," in Mats Rolen et al., eds., International Governance on Environmental Issues 78, 109 (1997).

[lxxiii] Andrew Hurrell & Benedict Kingsbury, The International Politics of the Environment: An Introduction, in A. Hurrell & B. Kingsbury, eds., The International Politics of the Environment 7-8 (1992).

[lxxiv] 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 Dallas Burtraw & Michael A. Toman, "Equity and International Agreements for CO_2 Containment," 118 Journal of Energy Engineering 122, 131-132 (1992). Ironically, the reduced role of the bureaucracy in allowance trading (as compared to 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 exhibited by government officials whose national economies would benefit greatly from trading. See Wiener, *supra*, 87 Georgetown L.J. at 780-81.

[lxxv] See David Victor, The Collapse of the Kyoto Protocol (2001); Richard Cooper, "Toward a Real Global Warming Treaty," Foreign Affairs, March-April 1998, pp.66, 70-72, 74, 78.

[lxxvi] See Robert W. Hahn, The Economics & Politics of Climate Change 43 (1998).

[lxxvii] See Ronald Coase, The Problem of Social Cost, 3 J. Law & Economics 1 (1960). The Coase theorem holds that in a world of zero transactions costs, the initial assignment is be irrelevant to efficiency and to the ultimate allocation after bargaining. To be sure, distributional impacts would still matter. The point here is just that, all other things equal, the more a regime is designed to reduce the transaction costs of post-assignment contractual reallocations, the easier it will be to negotiate that regime initially.

[lxxviii] Scott Barrett, A Theory of International Cooperation, Fondazione Eni Enrico Mattei Working Paper No. 43-98 (1998), at 7.

[lxxix] See Richard B. Stewart, Jonathan Baert Wiener and Philippe Sands, Legal Issues Presented by a Pilot International Greenhouse Gas Trading System 45 (UNCTAD 1996).

[lxxx] See Wiener, *supra* , 108 Yale L.J. at 785-787.

[lxxxi] 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 & Wiener (1996), *supra*. And rules for "buyer liability" under Article 12 (but not under Article 17, where emissions limits will be enforced through national emissions 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 would also encourage developing countries to join the formal cap-and-trade system (with headroom allowances).

[lxxxii] See Tom Wigley, Richard Richels and Jae Edmonds, "Economic and Environmental Choices in the Stabilization of Atmospheric CO2 Concentrations," 379 Nature 240-243 (1996). Cf. Stephen H. Schneider and Lawrence H. Goulder, Achieving Low-Cost Emissions Targets, 389 Nature 13-14 (1997).

[lxxxiii] James K. Hammitt, Evaluation Endpoints and Climate Policy: Atmospheric Stabilization, Benefit-Cost Analysis, and Near-Term Greenhouse-Gas Emissions, 41 Climatic Change 447-468 (1999).

[lxxxiv] The atmospheric CO2 concentration in the year 2000 is about 375 parts per million (ppm).

[lxxxv] 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 over $300 per ton of carbon within about 50 years after those dates in order to accomplish stabilization.

[lxxxvi] Hammitt finds that several alternative assumptions – a higher climate sensitivity (4.5 degrees Celsius increase in temperature due to a doubling in GHG concentrations, rather than 2.5 degrees), a higher damage function (15% of world GDP rather than 2% lost due to a warming of 2.5 degrees), a damage function related to the rate of climate change rather than to the level of climate change, and earlier technological innovations that significantly reduce abatement costs – each call for even greater near-term emissions reductions to achieve the optimal (net benefits) path. With high climate sensitivity, Hammitt's optimal path requires an 8% reduction in emissions below BAU in 2010, yet

remains 40% 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.

[lxxxvii] See Hahn (1998), *supra*; Schmalensee (1998), *supra*.

[lxxxviii] See e.g. Michael Oppenheimer & Robert H. Boyle, Dead Heat (1990).

[lxxxix] See James K. Hammitt, Robert J. Lempert and Michael E. Schlesinger, "A Sequential Decision Strategy for Abating Climate Change," 357 Nature 315-318 (1992).

[xc] See Robert J. Lempert and Michael E. Schlesinger, "Adaptive Strategies for Climate Change," in Innovative Energy Strategies for CO2 Stabilization (Cambridge University Press, forthcoming 2001).

[xci] The Kyoto target of 5% below the 1990 level for industrialized countries (roughly 15% 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% 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.

[xcii] See Stephen H. Schneider, Integrated Assessment Modeling of Global Climate Change: Transparent Rational Tool for Policymaking or Opaque Screen Hiding Value-laden Assumptions? 2 Environmental Modeling and Assessment 229-248 (1997).