PROBLEMS OF EQUITY AND EFFICIENCY IN THE DESIGN OF INTERNATIONAL GREENHOUSE GAS CAP-AND-TRADE SCHEMES

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The flexibility and efficiency of domestic cap-and-trade schemes for conventional pollutants is often taken to imply quite directly that an international cap-and-trade regime for greenhouse gas ("GHG") emissions can be designed that will also realize comparable efficiency benefits.[1] Moreover, advocates of international GHG cap-and-trade regimes tend to believe that such regimes can also be used to simultaneously pursue the global warming equity objective[2] of putting the cost of GHG reduction primarily on those wealthy industrialized countries that have accounted for most of the anthropogenic GHG emissions to date.[3] Using the tools of economic analysis, this Article argues to the contrary that international GHG cap-and-trade schemes suffer from inherent problems of enforceability and verifiability that both cause significant inefficiencies and create inevitable tradeoffs between equity and efficiency.

These tradeoffs arise because countries differ greatly both in their marginal cost of reducing GHG emissions and in the marginal benefit that they can expect from such reductions. In addition, while the cost of reducing GHG emissions is quite certain, the benefits from such reduction are subject to fundamental, non-quantifiable uncertainty. The uncertainty of the benefits from costly GHG reduction strengthens the argument in favor of having relatively wealthy, developed countries bear most of the cost of GHG emission reduction. Within an international GHG cap-and-trade regime, such a distributive result can be achieved through an initial allocation of permits to emit GHGs that favors relatively poor, developing countries. Moreover, because such poor countries may be unable or politically unwilling to buy GHG emission permits, an allocation of initial permits that favors such countries may be necessary not only to further the redistributive goals but also the efficiency of an international GHG cap-and-trade scheme.

This coincidence of equity and efficiency is, however, unlikely to be realized under more realistic assumptions about enforcement and monitoring in an international GHG cap-and-trade scheme. Both economic theory and evidence from the European Union's emission trading scheme strongly suggest that under an international cap-and-trade scheme, high-marginal-cost

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[1] *See, e.g.*, RICHARD B. STEWART & JONATHAN B. WIENER, RECONSTRUCTING CLIMATE POLICY (2003).

[2] For a representative statement of this conception of climate change equity or fairness, see STEVE VANDERHEIDEN, ATMOSPHERIC JUSTICE: A POLITICAL THEORY OF CLIMATE CHANGE 45-47 (2008).

[3] *See* STEWART & WIENER, *supra* note 1.

GHG emission abaters will not face binding caps that are enforced against them by their national governments. The failure of such high-cost abaters to participate in cap-and-trade schemes causes significant inefficiencies. The prospect of enlisting the participation of such high-abatement-cost, developed-world GHG emitters and restoring efficiencies by opening up trading to include low-cost GHG abatement projects in the developing world is appealing, but ultimately doomed by the inability to verify that such developing world projects generate real GHG emission reductions. Due to inherently imperfect and limited verifiability, there is an inevitable tradeoff between efficiency and equity: the broader the coverage of an international GHG cap-and-trade scheme, the greater its potential to redistribute income to people in poor countries, but the less likely it is to efficiently generate reductions in GHG emissions.

This Article proceeds as follows. Since both efficiency and equity in international climate change policy depend upon the pattern of costs and benefits from GHG emission reduction across countries, I begin in Part I by setting out what climate change science and economics have discovered so far about the regional costs and benefits of GHG emission reduction. Part II then traces some of the implications for climate change policy of the uncertainty surrounding benefits from GHG emission reduction. Part III then turns to a more detailed analysis of the economics of an international GHG cap-and-trade regime. This Part focuses on problems that arise when realistic account is taken of the incentives of countries to actually enforce GHG emission caps against domestic GHG emitters and of the ability of international institutions to credibly verify that developing world projects are generating real GHG emission reductions.

I. Positive Analysis: The Simple but Uncertain Cost-Benefit Analysis of Climate Change Leaders and Laggards

Both the fairness and efficiency of any proposed international climate change regime depends upon the geographic pattern of costs and benefits that such a regime is expected to produce. In this Part, I look to the recent Assessment Reports of the Intergovernmental Panel on Climate Change ("IPCC") and recent work in climate change economics for recent and authoritative projections of such costs and benefits. What one learns from the IPCC's Reports is that the impact of climate change is currently believed to depend not only on where a country or region is located on the globe, but also — in a complex and relatively poorly understood way — on a country or region's wealth, income, and level of development. Moreover, from the climate change economics literature, one learns that the benefits of GHG abatement, like the costs, are quite uncertain.

A. Regional Climate Change Projections and Impacts

In its most recent Assessment Reports, the IPCC has, with increased confidence, set out its projections not only for global mean temperature and precipitation, but for regional impacts of climate change.[4] The Reports generally suggest that the impact of global warming will vary greatly across regions. For example, during the present century, some parts of North America (particularly Canada and the northeastern United States), as well as a good deal of Russia, are expected to see both an increase in average temperature, with warmer winters, and an increase in precipitation.[5] Economists who have looked at these sorts of projections have estimated that global warming could bring countries such as Canada, Russia, and the United States substantial benefits from increased agricultural productivity,[6] while the IPCC has concluded with "high confidence" that warming will generally mean fewer deaths from cold.[7]

Other regions are not expected to enjoy such benefits from global warming. The IPCC's latest Assessment Report on climate change science sets out, with quite remarkable precision, a large number of projected regional consequences from global warming. The Fourth Assessment Report states, for example, that it is "very likely" that Africa will experience greater warming than will the Earth on average, and that rainfall is "likely"

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[4] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS (Susan Solomon et al. eds., 2007) [hereinafter IPCC, THE PHYSICAL SCIENCE BASIS], *available at* http://www.ipcc.ch/ipccreports/ar4-wg1.htm; INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: IMPACTS, ADAPTATION AND VULNERABILITY (Martin Parry, et al. eds., 2007) [hereinafter IPCC, IMPACTS, ADAPTATION AND VULNERABILITY], *available at* http://www.ipcc.ch/ipccreports/ar4-wg2.htm.

[5] On North America, see IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 4, at 859, 890 fig.11.12; on Russia, see V.P. Meleshko et al., *Anthropogenic Climate Change in Russia in the 21st Century: An Ensemble of Climate Model Projections*, 29 RUSS. METEOROLOGY & HYDROLOGY 38, 40 (2004), *available at* http://www.ifaran.ru/~mokhov/MeleshkoEtAl2004_MiG4.eng.pdf ("Annual mean increase of precipitation over the entire territory of Russia dramatically exceeds the [projected] global changes."); IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 4, at 875 fig.11.5, 883 fig.11.9.

[6] On the United States, see sources cited and discussed in Jason Scott Johnston, *Climate Change Confusion and the Supreme Court: The Misguided Regulation of Greenhouse Gas Emissions Under the Clean Air Act*, 84 NOTRE DAME L. REV. 1, 26-29, 33-36 (2008); on agriculture in Canada and Russia, see William R. Cline, *Global Warming and Agriculture*, FIN. & DEV., March 2008, at 23, 25 (finding that in a Ricardian equilibrium model of agriculture and climate, warming generates no change in agricultural productivity in either Russia or Canada, but that when carbon fertilization effects are taken into account, averaged across the Ricardian economic model and a crop-based model that does not incorporate equilibrium adjustment by farmers, Russia can expect a six percent increase in agricultural productivity, while Canada can expect a twelve percent increase in agricultural productivity). *Cf.* Robert Mendelsohn et al., *The Distributional Impact of Climate Change on Rich and Poor Countries*, 11 ENV'T & DEV. ECON. 159 (2006) (finding that poor countries will suffer the bulk of damages from climate change in large part because of their location in the low latitudes where temperatures are already high).

[7] IPCC, IMPACTS, ADAPTATION AND VULNERABILITY, *supra* note 4, at 393 (cautioning, however, "that these will be outweighed by the negative effects of rising temperatures worldwide").

to decrease in northern Africa, with a "greater likelihood" of decreasing rainfall the closer one gets to the Mediterranean coast; that warming is "likely" to be "well above" the mean in central Asia, with precipitation "very likely" to increase in northern Asia and the Tibetan plateau and "likely" to decrease in central Asia, while it is "very likely that heat waves/ hot spells in summer will be of longer duration, more intense and frequent in East Asia"; and that it is "likely" precipitation will decrease in "most of Central America."[8] As for small island states, the IPCC says that sea levels are "likely" to rise on average during the twenty-first century "around the small islands of the Caribbean Sea, Indian Ocean and northern and southern Pacific Oceans," with the rise "likely not [to] be geographically uniform [though] large deviations among models make regional estimates across the Caribbean, Indian Ocean and [North and South] Pacific Oceans uncertain."[9] Nevertheless, the models are good enough for the IPCC to conclude that:

> Summer rainfall in the Caribbean is likely to decrease in the vicinity of the Greater Antilles but changes elsewhere and in winter are uncertain. Annual rainfall is likely to increase in the northern Indian Ocean with increases likely in the vicinity of the Seychelles in December, January and February, and in the vicinity of the Maldives in June, July and August, while decreases are likely in the vicinity of Mauritius in June, July and August.[10]

Though the popular media has reported that these projected regional climate changes are likely to have a dire impact on people who live in poorer, developing countries,[11] the IPCC's Fourth Assessment Report on the impacts of climate change actually paints a much more nuanced and valuable picture. Consider, for example, Africa. Regarding the impacts of projected climate change on Africa, the IPCC concludes that "[a]lthough future climate change seems to be marginally important when compared to other development issues, it is clear that climate change and variability, and associated increased disaster risks, will seriously hamper future development."[12] At the same time, it is quite frank in admitting that:

> The contribution of climate to food insecurity in Africa is still not fully understood, particularly the role of other multiple stresses that enhance impacts of droughts and floods and possible future climate change. While drought may affect production in some years, climate variability alone does not explain the limits of food production in Africa.[13]

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[8] IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 4, at 850 (emphasis omitted).

[9] *Id.* at 851 (emphasis omitted).

[10] *Id.* (emphasis omitted).

[11] *See, e.g.*, Andrew C. Revkin, *Poorest Nations Will Bear Brunt as World Warms*, N.Y. TIMES, Apr. 1, 2007, at A1.

[12] IPCC, IMPACTS, ADAPTATION AND VULNERABILITY, *supra* note 4, at 457 (internal citation omitted).

[13] *Id.*

Similarly, the IPCC Report's chapter on climate change impacts for Asia is even more cautious, concluding that:

> Sustaining economic growth in the context of changing climate in many Asian countries will require the pursuit of enhancing preparedness and capabilities in terms of human, infrastructural, financial and institutional dimensions with the aim in view of reducing the impacts of climate change on the economy. For instance, in many developing countries, instituting financial reforms could likely result in a more robust economy that is likely to be less vulnerable to changing climate. In countries with predominantly agrarian economies, climate change, particularly an increase in temperature and reduction in precipitation, could, in the absence of adequate irrigation and related infrastructural interventions, dampen the economic growth by reducing agricultural productivity.[14]

For small island states such as Tuvalu — which have become poster children for the likely catastrophic consequences of global warming[15] — the IPCC Report notes that the diverse and resource rich coastlines of small islands are "threatened by a combination of human pressures and climate change and variability arising especially from sea-level rise, increases in sea surface temperature, and possible increases in extreme weather events."[16] Still, the report cautions that "in the present assessment we can cite few robust investigations of climate change impacts on small islands using more recent scenarios and more precise projections."[17]

Overall, in discussing the impact of projected global warming on developing countries, the IPCC is consistently careful to point out the difficulty of isolating the impact of warming versus institutional and economic factors. For example, although there seems to be a general belief that the world's poor people are most vulnerable to suffering harm from global warming,[18] the evidence appears to be accumulating that traditional, low-technology economic systems have much greater capabilities of adapting to changing climate than many Western observers suppose,[19] and that even poor countries

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[14] *Id.* at 495 (internal citation omitted).

[15] *See, e.g.*, Alexandra Berzon, *Tuvalu Is Drowning*, SALON, Mar. 31, 2006, http://www.salon.com/news/feature/2006/03/31/tuvalu/ (last visited Apr. 30, 2009) (on file with the Harvard Environmental Law Review).

[16] IPCC, IMPACTS, ADAPTATION AND VULNERABILITY, *supra* note 4, at 697.

[17] *Id.* at 711.

[18] *See, e.g.*, Ramus Heltberg et al., *Addressing Human Vulnerability to Climate Change: Toward a "No-Regrets" Approach*, 19 GLOBAL ENVTL. CHANGE 89, 90 (2009); Mendelsohn et al., *supra* note 6.

[19] Perhaps the most dramatic and apparently unexpected example of the resilience of traditional economic systems comes from the Sahelian region in Africa, where satellite images confirm that over the last thirty years, through changes in farming and husbandry practices, at least 7.4 million acres have been reforested in Niger. *See* Lydia Polgreen, *In Niger, Trees and Crops Turn Back the Desert*, N.Y. TIMES, Feb. 11, 2007, at A1; *see also* Fabiano Toni & Evandro Holanda Jr., *The Effects of Land Tenure on Vulnerability to Droughts in Northeastern*

with extremely hazardous geographic locations, such as Bangladesh, have greatly increased their ability to cope with natural disasters such as hurricanes.[20]

It seems fanciful to think that any kind of meaningful dollar figure could be attached to the potential losses that might be suffered by poor and developing countries due to global warming. Moreover, while the IPCC Reports express a great deal of confidence in their projection that global mean temperature will increase during the century, the vector of temperature/precipitation/sea level changes projected by the IPCC varies widely from one region to another, even over a given continent, and these projections vary tremendously across different general circulation climate models.[21]

Hence from the point of view of individual countries, the current state of knowledge about likely twenty-first century global warming seems to carry two somewhat conflicting messages. On the one hand, different regions and countries vary greatly in what they stand to lose from global warming — with some actually potentially being better off, rather than worse off, with the projected warmer and (globally) wetter climate. At the same time, there is substantial uncertainty about how much, if at all, different countries would benefit from present-day reductions in GHG emissions that would moderate future warming.

B. Costs, Benefits, and Climate Change Bargaining

In thinking about international cooperation to reduce GHG emissions, the first and most important thing to realize is that the benefits from such costly action are both regionally disparate and highly uncertain. The costs to different nations of reducing GHG emissions is much more certain and predictable, being largely a function of factors that are well known — such as the extent to which a country currently relies on fossil fuels for its energy supply, the size of the country and its population density, the mix between mass transit and personal automobile transportation, and its current climate (which determines the demand for wintertime heating and summertime air conditioning).[22]

What we know now about the likely national costs and benefits of GHG emission reduction provides a direct explanation for why some countries

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Brazil, 18 GLOBAL ENVTL. CHANGE 575 (2008) (presenting evidence that traditional farming systems are not necessarily more vulnerable to drought).

[20] Mohammed Fazlul Karim & Nobuo Mimura, *Impacts of Climate Change and Sea-level Rise on Cyclonic Storm Surge Floods in Bangladesh*, 18 GLOBAL ENVTL. CHANGE 490 (2008).

[21] *See, e.g.*, IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 4, at 869 (discussing projections for the Sahelian region of Africa and noting that "[i]ndividual models generate large, but disparate, responses in the Sahel").

[22] *See, e.g.*, Andrew J. Leach, *The Welfare Implications of Climate Change Policy*, 57 J. ENVTL. ECON. & MGMT. 151, 152 (2009) (discussing how the benefits of climate change policies are much more uncertain than the costs); Juan-Carlos Altamirano-Cabrera & Michael Finus, *Permit Trading and Stability of International Climate Agreements*, 9 J. APPLIED ECON. 19, 26 fig.1 (2006) (showing how benefits of climate change cap-and-trade regimes vary widely across countries).

have been leaders and other laggards in international efforts to reduce GHG emissions. Consider, for example, the European countries that have been the leaders in pushing for GHG emission reductions virtually from the instant that climate change became an international issue. By the 1980s, Japan and many European countries had made large investments in alternative energy technologies in response to the oil crises of the 1970s, were fossil fuel importers rather than exporters, and wanted to protect their investments in alternative energy.[23] By the time of the Kyoto Protocol in 1997, changes that had nothing to do with environmental policy had made it relatively cheap for Germany and Britain to commit to large reductions relative to the 1990 base year: Germany was shutting down highly inefficient East German factories, and Britain was well on the way to substituting North Sea natural gas for coal in its power plants.[24] By 1997, when the Kyoto Protocol was signed, it was widely anticipated that decreases in GHG emissions from Britain and Germany would lead to a ten percent reduction in European emissions by 2005 regardless of what the other member states did.[25] As for France, due to the fact that almost eighty percent of the country's electricity is generated by nuclear power, with twelve percent from hydroelectric power, its GHG emissions are less than half of those of Germany.[26]

Though not all of Europe will suffer from global warming,[27] and there is a great deal of uncertainty surrounding all benefit estimations, Europe is expected on balance to realize very large benefits from curbing global warming.[28] With relatively low marginal costs of reducing GHG emissions, Europe would seem potentially likely to realize a net gain from any international agreement requiring further GHG emission reduction.[29] The United States and China are in far different positions, both from each other

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[23] Sonja Boehmer-Christiansen, *Global Climate Protection Policy: The Limits of Scientific Advice*, *Part 2*, 4 GLOBAL ENVTL. CHANGE 185, 194 (1994).

[24] *See* S. Fred Singer, *The Kyoto Protocol: A Post-Mortem*, 4 NEW ATLANTIS 66, 70 (2004); *see also* Charles D. Kolstad, *The Simple Analytics of Greenhouse Gas Emission Intensity Reduction Targets*, 33 ENERGY POL'Y 2231, 2232 (2005) ("Germany and the UK did very well . . . in reducing the GHG intensity of [their economies during the 1990s], though the absorption of East Germany made this somewhat easier for Germany and the introduction of North Sea gas (and phase out of coal) made this easier for the UK.").

[25] Miranda A. Schreurs & Yves Tiberghien, *Multi-Level Reinforcement: Explaining European Union Leadership in Climate Change Mitigation*, GLOBAL ENVTL. POL., Nov. 2007, at 19, 33.

[26] *Id.* at 39; *see also* Cass R. Sunstein, *The World vs. the United States and China? The Complex Climate Change Incentives of the Leading Greenhouse Gas Emitters*, 55 UCLA L. REV. 1675, 1689 tbl.3 (2008).

[27] For example, the productivity and quality of northern European vineyards is expected to increase. *See* Orley Ashenfelter & Karl Storchmann, *Using a Hedonic Model of Solar Radiation to Assess the Economic Effect of Climate Change: The Case of Mosel Valley Vineyards* 17–18 (Nat'l Bureau of Econ. Research, Working Paper No. 12,380, 2006), *available at* http://www.ssrn.com/abstract=921546. Other agricultural impacts in Europe may be positive as well. *See* Gianpiero Maracchi et al., *Impacts of Present and Future Climate Variability on Agriculture and Forestry in Temperate Regions: Europe*, 70 CLIMATIC CHANGE 117, 131–32 (2005).

[28] *See* Altamirano-Cabrera & Finus, *supra* note 22, at 26 fig.1.

[29] *See id.* at 26.

and from Europe. Both the United States and China have very low marginal costs of reducing GHG emissions, while their benefits vary from relatively high benefits for the United States to somewhat lower benefits for China.[30] Hence, although Europe, the United States, and China have for some years been the leading GHG emitting nations (or groups of nations) in the world,[31] they face very different costs and benefits from GHG emission reduction.[32]

The less developed countries in the world fall into two categories with respect to the costs and benefits of GHG emission reduction. There are those — such as India and Brazil — that have been rapidly industrializing and, by virtue of such industrialization, have become relatively large GHG emitters. Just because these countries have been rapidly industrializing, however, does not mean that they are similar when it comes to GHG abatement: Brazil is expected to benefit modestly from GHG emission reduction but is estimated to have extremely high marginal costs of GHG abatement (rising very steeply into the thousands of dollars per ton), whereas India is expected to reap larger benefits and also to have an extremely low marginal cost of abatement.[33] Secondly, there is the category of relatively undeveloped countries that are also relatively insignificant GHG emitters.[34]

The wide variation among countries with respect to both the national costs of reducing GHG emissions and the — much more uncertain — benefits from costly GHG reduction has a direct and immediate consequence for the problem of designing institutions for international GHG emission reduction. Viewed as a strategic game played out among nations,[35] the GHG reduction dilemma is most decidedly *not* a relatively simple game in which the obstacle is to figure out a means of getting countries to cooperate in providing a good that all benefit from — GHG emission reductions. Instead, it is a game with conflicting interests, in which only some countries are likely to find that costly GHG emission reduction is in their narrow self-interest. Moreover, and perhaps most significantly, due to the enormous uncertainty surrounding the benefits of GHG emission reduction, whether or not a particular country would find such emission reductions to be in its self-interest

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[30] *See id.* at 26 fig.1.

[31] *See* Jay S. Gregg et al., *China: Emissions Pattern of the World Leader in CO_2 Emissions from Fossil Fuel Consumption and Cement Production*, 35 GEOPHYSICAL RES. LETTERS 1, 1 (2008); Maximillian Auffhammer & Richard T. Carson, *Forecasting the Path of China's CO_2 Emissions Using Province-Level Information*, 55 J. ENVTL. ECON. & MGMT. 229, 229-30 (2008).

[32] The relatively large marginal benefits to the United States presented by Altamirano-Cabrera and Finus, *supra* note 22, at 26 fig.1 are, it must be stressed, somewhat dated. Recent work discussed in Johnston, *supra* note 6, at 21-36, for example, suggest that the United States might get very real agricultural, recreational, and health benefits from a moderately warmer climate, thus suggesting that the benefits to the United States from cutting GHG emissions may well be much smaller than Altamirano-Cabrera and Finus estimate.

[33] On benefits and costs to Brazil and India, see Altamirano-Cabrera & Finus, *supra* note 22, at 26 fig.1, 27 fig.2.

[34] *See* Sunstein, *supra* note 26, at 1685 tbl.4 (presenting data indicating that all of Africa contributed only 3.4% of global CO_2 emissions in 2004).

[35] For a discussion of environmental treaty-making, including, but not limited to, GHG treaties, see, for example, SCOTT BARRETT, ENVIRONMENT AND STATECRAFT (2003).

depends upon a complex weighing of potential future effects from global warming that cannot be captured in a simple cost-benefit calculus. For example, the United States is generally not expected to suffer much from moderate global warming during this century.[36] However, were GHG emissions to lead to very large increases in temperatures after 2100, then the United States would be at risk of suffering great harm.[37] In the meantime, developing countries might be so adversely affected by global warming that even in a narrow sense, the self-interest of the United States would be harmed (for example, by large increases in the number of people attempting to illegally immigrate to the United States). Depending upon the perceived likelihood and cost of such a short- to medium-term impact, and the likelihood and rate used to discount the even longer-term direct effects on the United States from very large temperature increases, the perceived benefits to current and future generations of U.S. citizens from costly present-day GHG emission reductions could vary by many orders of magnitude.

In a very real sense, however, the expected benefits cannot be meaningfully quantified, because the probabilities of very high temperature increases, and truly catastrophic global warming, are simply not known. This has been elegantly demonstrated in a recent paper by Gerard Roe and Marcia Baker.[38] As climate scientists well know — but the media and popularizers such as Al Gore rarely mention — the bulk of the warming predicted by climate models to result from a doubling of atmospheric CO_2 is caused not by the direct effect of increasing CO_2, but instead from positive feedback mechanisms.[39] The most quantitatively important of these is the water vapor feedback mechanism: when lower tropospheric temperature increases, so too does the equilibrium amount of water vapor held by the troposphere, and water vapor is a much more powerful GHG than CO_2.[40] Roe and Baker show that because numerical climate models assume that positive feedbacks predominate, even if uncertainty regarding particular positive feedbacks is reduced, climate models will still attach positive probability to very high (larger than five degrees centigrade) global temperature increases.[41] Hence, given the structure of numerical climate models, no amount of knowledge about particular positive feedback effects can ever reduce uncertainty suffi-

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[36] *See* sources cited and discussed in Johnston, *supra* note 6, 21-41.

[37] Consider just the impact on water resources in the western United States: one study estimates that a five degree centigrade increase in temperature would increase withdrawals of Colorado River basin water by so much that welfare would fall by $175 million (in 1994 dollars). *See* Brian Hurd et al., *Economic Effects of Climate Change on U.S. Water Resources*, *in* THE IMPACT OF CLIMATE CHANGE ON THE UNITED STATES ECONOMY 133, 160 tbl.6.5 (Robert Mendelsohn & James E. Neumann eds., 1999).

[38] Gerard H. Roe & Marcia B. Baker, *Why Is Climate Sensitivity So Unpredictable?*, 318 SCIENCE 629 (2007).

[39] *Id.* at 630.

[40] For a succinct explanation of the role of water vapor as a GHG and the water vapor feedback effect, see JOSE P. PEIXOTO & ABRAHAM H. OORT, PHYSICS OF CLIMATE 30 (1992). *See also* IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 4, at 632-35.

[41] Roe & Baker, *supra* note 38, at 631.

ciently, in the sense of allowing us to rule out potentially catastrophic global warming.

II. Uncertainty and the Error Cost of a GHG Emission Standard

The presence of such fundamental uncertainty on the benefits side of GHG emission reduction analysis not only profoundly complicates the calculation of national self-interest, but also fundamentally impacts the determination of what would constitute a fair and efficient international GHG emission reduction goal. Consider first the efficiency problem. Efficiency generally requires that we equate the marginal cost of emissions reduction to its marginal benefit. As argued above, from what climate change scientists and economists tell us, it seems that the problem of GHG emission reduction is one in which the marginal cost of GHG reduction is relatively certain and well known, but the marginal benefit could be anywhere from relatively small to almost incomprehensibly large. The standard way that environmental economics deals with such a situation — certain marginal costs and uncertain marginal benefits — presumes that society is risk-neutral, and equates the expected marginal benefit of GHG emission reduction to the marginal costs. The various possible marginal benefit curves are averaged, by multiplying each by the probability that it will be realized, and then this average marginal benefit curve is compared to the marginal cost curve. The emissions reduction level that equates marginal cost with expected marginal benefit is that which maximizes the expected net social benefit from emissions reduction.[42] From the standpoint of ex ante efficiency, this is the efficient level of emissions reduction.

This efficient level of emissions reduction is depicted, in standard fashion, in Figure 1. In Figure 1, there are two possible realizations of the marginal benefit curve, MB_L and MB_H, with the expected or average marginal benefit curve given by MB. The emissions level e^* where this curve meets the marginal cost curve, given by MC, is that which maximizes the net expected social benefit from emissions reduction.

As applied to the GHG emission reduction problem, a large marginal benefit from emissions reduction means averting potentially catastrophic but fundamentally uncertain consequences. It may be argued that with respect to such catastrophic consequences, global society, far from being risk-neutral, is strongly risk-averse. If this is so, the global social-welfare function would attach much more weight to such catastrophic consequences. This would be true even if such consequences were remote, provided that society did not discount such future benefits by too much.[43] In Figure 1, such a shift

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[42] For a lucid explanation of the standard analysis, see Charles D. Kolstad, Environmental Economics 183-88 (2000).

[43] Nicholas Stern, The Economics of Climate Change: The Stern Review (2007) is perhaps the best known economic analysis that discounts by very little remote but significant

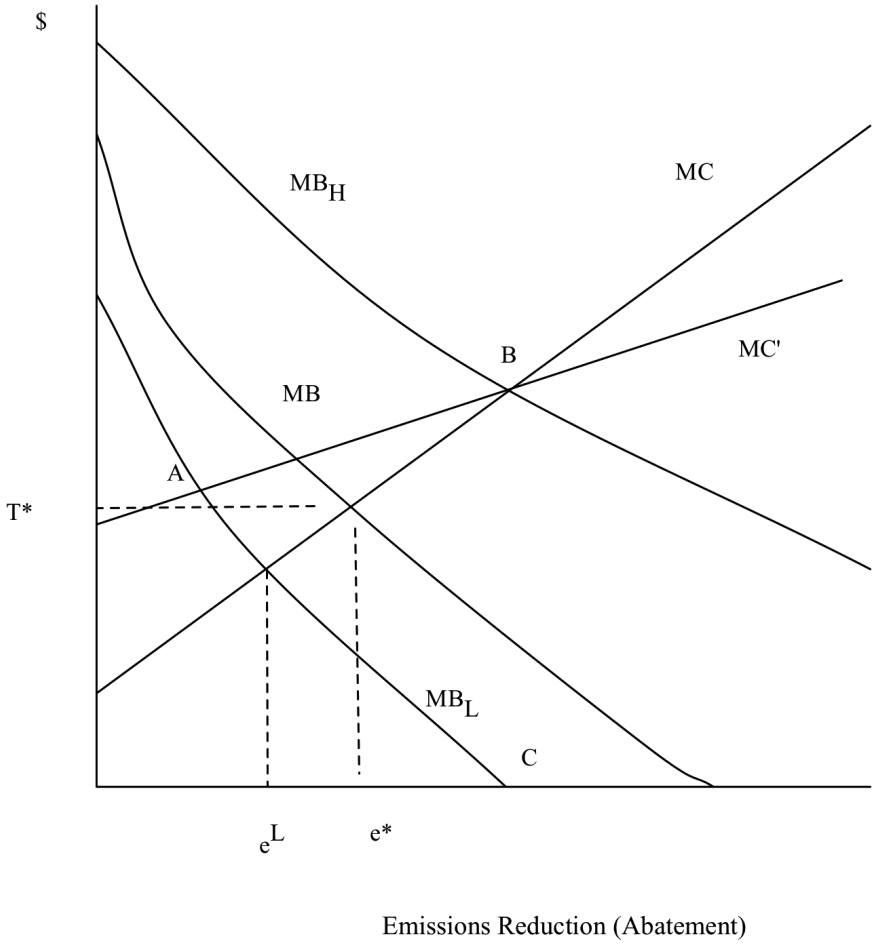

FIGURE 1

away from simple expected-value calculation would cause the curve MB to shift to the right, increasing the optimal level of emissions reduction *e**.

However, as noted earlier, the potentially catastrophic, long-term consequences of global warming follow from projections of very large temperature increases, but these projections themselves reflect fundamental uncertainties about climate feedback mechanisms. Larger potential marginal benefits from GHG emission reductions — the curve MB_H shifting further to the right in Figure 1 — are also more uncertain, in that such very large

benefits of reducing the risk of catastrophic harm from global warming. *See id.* at 35 (arguing that "if we treat the *welfare* of future generations on par with our own," it is hard to see any ethical justification for discounting future benefits).

marginal benefits are due to very high temperature increases, and such temperature increases are due to poorly understood, and fundamentally uncertain, feedback effects.[44]

This uncertainty about marginal benefits is very important when considering the efficient level of GHG emission reduction and the potential costs in choosing a GHG emissions standard or overall cap on emissions. The downside of giving more weight to potentially catastrophic long-term consequences in choosing an optimal level of emissions reduction *e** is that it increases e*, which increases the odds of error[45] and spending too much money on reducing GHG emissions.

Furthermore, as one can see by rotating the MC curve to the position of the flatter curve MC' in Figure 1, the flatter the marginal cost curve for GHG emissions reductions — the more constant the cost — the larger the impact of uncertainty regarding the marginal-benefit curve in determining the optimal level of emissions reduction e*. If we consider, for example, shifting the curve MB_H further to the right, the optimal level e* moves more and the curve MC is flatter. If these catastrophic consequences are not realized, so that the actual marginal-benefit curve is given by MB_L rather than by the curve MB_H (to which we have given so much weight in determining the desired emissions reduction e*), then there can be a potentially enormous social loss from over-weighing catastrophic consequences. This loss is equal to the area of the triangle ABC in Figure 1.

One implication of this result, stressed in the environmental economics literature, is that when there is uncertainty about the marginal benefits of emissions reduction and the marginal cost curve is flat (very elastic), an emissions standard such as *e** is likely to risk potentially large social loss and to be dominated on efficiency grounds by an emissions tax or charge.[46] If, for example, we set the tax equal to *T** in Figure 1, then this would determine the marginal private benefit of emissions reductions, causing polluters to reduce emissions up until the point where the MC curve intersected the horizontal line through *T**, a point that obviously moves farther and farther to the right the more we rotate the MC curve down. In the context of GHG emission reduction policy, this result suggests the likely superiority (under the presumed conditions regarding the elasticity of the marginal cost curve) of an emissions charge over a cap. For present purposes, however,

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[44] Consider for example, cloud feedback. Summarizing the enormous uncertainty surrounding this particular feedback, Graeme L. Stephens, *Cloud Feedbacks in the Climate System: A Critical Review*, 18 J. CLIMATE 237, 246 (2005) says: "the diagnostic tools currently in use by the climate community to study [cloud] feedback, at least as implemented, are problematic and immature and generally cannot be verified using observations."

[45] As shown by Roe & Baker, *supra* note 38, while positive, the probability of extremely high temperature increases from CO_2 doubling becomes very small the higher the temperature increase; hence when policy attaches weight to such very large, catastrophic temperature increases, the probability that such increases are not realized, and that policy is ex post wrong, increases.

[46] For a graphical representation, see Kolstad, *supra* note 42, at 183-85 fig.10.4.

what I want to stress is that relatively low, flat marginal costs cut in two ways for a GHG emissions cap: they lead to very aggressive targeted reductions when emphasis is given to the potentially catastrophic consequences of global warming, but if those consequences do not eventuate, there will be an enormous social loss, borne by whatever industries or countries have undertaken the cost of emissions reduction.

As explained in Part III, from the standpoint of efficiency, we want countries and/or industries with relatively low marginal costs of abating GHG emissions to carry the bulk of the load in reducing world emissions. If aggressive emissions reductions targets are set because of concern over potentially catastrophic, but highly uncertain, consequences, then it is these low-marginal-cost countries and/or industrial sectors that will bear the error cost. In concrete terms error cost is opportunity cost: countries that have a low marginal cost of abating GHG emissions, and therefore do most of the abating in the economically optimal outcome, will be devoting resources to reducing GHG emissions rather than to investments that more directly stimulate economic growth or provide for other social goals. If such countries are already relatively wealthy, such as the United States, and can be said to be in some sense responsible for the bulk of the emissions that have accumulated in the atmosphere — as the United States undoubtedly can[47] — then on fairness grounds such an outcome may be judged acceptable. Having the cost of erroneously large and costly emissions reductions be borne by relatively wealthy countries that, in some sense, caused the global warming problem may seem relatively unobjectionable.

What would be objectionable on many conceptions of fairness is to have these error costs be borne by the citizens of countries that happen to have low marginal cost of reducing GHG emissions, but are not especially wealthy, at least in terms of per capita income. For example, if the bulk of emissions reduction is to be accomplished by China — because it has a very low marginal cost of abatement that remains low even for very large GHG emission reductions — then China is being asked to sacrifice present income and wealth, and to slow its economic growth rate, in order to benefit other countries that are more at risk from global warming. But for a developing country such as China, erroneously spending too much on GHG emission abatement today because of fears of a fundamentally uncertain future climate catastrophe might generate a much more certain present and future economic catastrophe. Cutting present-day Chinese wealth, income and growth not only harms the present generation of Chinese, but means lower wealth and well-being for future generations as well. Without growth today and the promise of increased future wealth and well-being that it offers, Chinese society and polity may be dangerously destabilized. The point is a general one: if at least one of the fundamental equity concerns of climate

[47] On relative carbon dioxide emissions, see Gregg et al., *supra* note 31, at 2 fig.1. *See also* Sunstein, *supra* note 26, at 1688 tbl.8.

change policy is with the well-being of future generations, then policies that may cause developing country resources to be diverted away from education and economic growth and toward GHG emission abatement may well harm future generations by impairing their opportunities.

It may be objected that one of the virtues of an international GHG cap-and-trade scheme is that by generously awarding emission allowances to low-marginal-cost developing countries such as China, such a regime offers the potential for such countries to actually gain on net from present-day expenditures on GHG emission reduction. As I show in more detail in the next Part, however, while this is indeed true, there remain other serious obstacles to achievement of cost-effective GHG reductions through such a scheme.

III. Conflicts Between Efficiency and Equity in International GHG Cap-and-Trade Regimes

This Part begins by demonstrating a positive result that is central to many proposed international GHG cap-and-trade regimes[48]: the ability to use the allocation of international GHG emission permits as a way to achieve both equity and efficiency in meeting the global emission reduction target. I then present some severe limitations on this happy result that do not seem to be much discussed in the climate change policy literature. First, the assumptions underlying the predicted efficiency gains from international cap-and-trade regimes are quite unlikely to be met. Furthermore, the use of allocations and allowances in such a regime to explicitly promote various conceptions of global equity are likely to cause even greater losses of efficiency.

A. *Efficient International GHG Abatement Under a Cap-and-Trade Scheme*

As drawn, Figure 1 assumes that there is a single, known marginal GHG emission reduction abatement cost curve. In reality, marginal GHG abatement costs are believed to differ greatly across countries.[49] As noted earlier, while Brazil's marginal cost of abatement rises quickly to thousands of dollars per ton, China's remains below $100 per ton until its level of abatement rises to hundreds of gigatons.[50] From an economic point of view, given any GHG emission reduction goal, such as e^* in Figure 1, the objective is to meet that goal at the lowest possible cost. With marginal costs varying across countries, cost minimization requires equalizing the marginal cost of abatement across countries. The primary virtue of a cap-and-trade system is that it simply sets a cap, and allows countries to determine how to meet that cap, with one option being buying unused GHG emission al-

[48] *See, e.g.*, Stewart & Wiener, *supra* note 1, at 66.
[49] *See* Altamirano-Cabrera & Finus, *supra* note 22, at 29.
[50] *See id.* at 27 fig.2.

lowances from countries whose emissions are below their allowance level. Thus, under certain assumptions, the cap-and-trade system accomplishes the goal of international marginal cost equalization.

Figure 2 depicts such a system in operation for a simple two-country world. At the global optimum, marginal costs are equalized and Countries 1 and 2 abate respectively at levels e^1 and e^2. Because Country *1*'s marginal cost curve is so low relative to Country *2*'s, the economic criterion of cost minimization dictates that Country *1* carries the bulk of the load in GHG emission reduction (that is, $e^1 >> e^2$). Under a system of tradable allowances in which countries can trade costlessly and face sufficient incentives such that they always comply either by reducing their emissions or buying allowances from other countries, we will reach the global optimum (e^1,e^2) regardless of how the countries' emissions are initially capped (that is, how many allowances to emit are given to each country). To see this, suppose (without any loss of generality) that we started with the burden of emission reduction shared equally between the two countries. In Figure 2, this is depicted by the point *E/2*, where *E* is the total emission reduction that we are seeking to achieve globally. As can be seen from Figure 2, at point *E/2*, Country 1 has much lower marginal costs of emission reduction than Country 2. Were Country 1 to reduce its emissions beyond *E/2*, all the way to e^1, then it would free up an amount of emission allowances equal to (e^1 - *E/2*) that it could sell to Country 2. Of course, for such a move to make economic sense for Country 1, it would have to receive a price that is equal to its marginal cost (which of course increases the more emissions are reduced). But as can be seen from the Figure, Country 2 would be willing to pay up to its saved marginal cost to buy allowances from Country 1 rather than incur the marginal cost of abatement. That is, by reducing only by the amount e^2 rather than *E/2*, Country 2 saves the entire cost given by the area under its marginal cost curve between these two points. Hence under a tradable permits regime, even if we start with each country given the goal of reducing by *E/2*, through the incentives created by trading, we end up with Country 1 doing the bulk of the abatement.

There are three fundamental assumptions underlying this scenario: 1) that monitoring and enforcement institutions are such that both countries find it in their self-interest to meet their emissions reduction obligation *E/2*, either by reducing emissions or by buying allowances from the other country; 2) that emissions reductions are "real" relative to some relevant baseline; and, 3) that Country 2 will be able to find the funds to pay Country 1 an amount at least equal to Country 1's marginal cost of "extra" abatement (that is, the amount e^1 - *E/2*). As I now explain, in the context of international GHG emissions trading, all three of these assumptions are problematic.

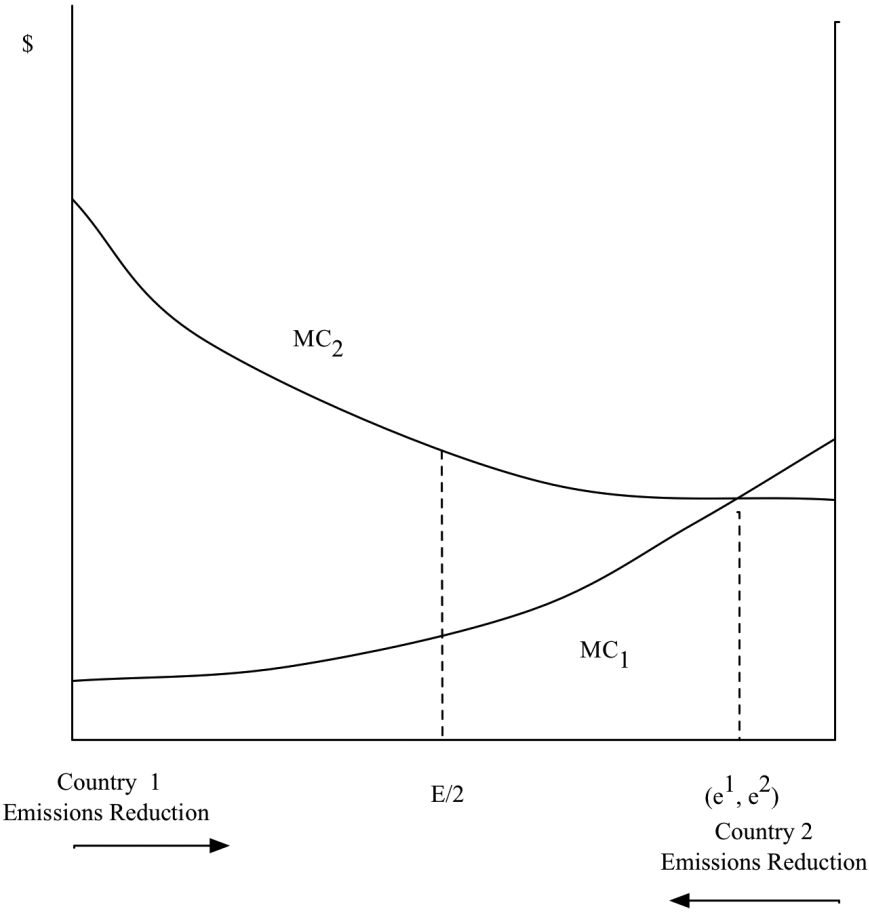

FIGURE 2

B. Harmonizing Efficiency and Equity in GHG Cap-and-Trade Schemes

Assume that our global emissions reduction goal *E* has come from a global social welfare calculus, like that presented in Part II above, which gives enormous weight to fundamentally uncertain but potentially catastrophic consequences of warming, and which therefore uses a very high marginal benefit of GHG emission reduction curve like MB_H. What has just been demonstrated is that under an international cap-and-trade regime, the bulk of the very aggressive emissions reduction goal *E* will be borne by Country 1. Of course, in the emissions trading story, Country 1 only agrees to such a high level of emissions reduction because it receives some payment from Country 2 equal to or greater than its marginal cost of additional reduction. Conversely, Country 2 decides to comply with its obligations by buying unused allowances from Country 1.

There is a problem, however, if Country 2 is a relatively poor country, and it is unable or unwilling to pay the amount that is necessary to induce Country 1 to carry the burden of GHG emission reduction. Even if Country 2 could in some way find the funds (perhaps by borrowing from the World Bank or some such international agency), and even if Country 2 would benefit from GHG emission reduction, it might well have little self-interested reason to use those funds for GHG emission reduction rather than some other program — such as the provision of cleaner drinking water or improved education — that is much more pressing and valuable given its current state of economic development.[51]

With such a constraint on the ability of high-marginal-cost/low-marginal-benefit countries to pay low-marginal-cost countries for GHG emission reduction, the only way to induce low-marginal-cost countries to efficiently abate their GHG emissions is to begin with radically unequal emissions reduction targets. Consider, for example, a scheme in which Country 1 is given no allowances to emit GHGs, so that Country 2 is allocated the full targeted reduction E. In this case, Country 2 would sell GHG emission allocations in the amount of $E - e^2$ to Country 1 at some price between the two countries' marginal costs in this region, and Country 2 would actually reduce its emissions by the same amount (in order to be in compliance with a rule requiring that actual emissions not exceed the number of net allowances held after trade). That is, to overcome the low willingness-to-pay on the part of Country 2, we make use of the fact that GHG emission allowances are a currency with only one use, and we give sufficient allowances to Country 2 so that it is no longer a buyer of permits from the low-abatement-cost country, but is instead a seller of permits to that country.

Given the cross-national configuration of marginal benefits and costs from GHG emission reduction, the need to use GHG emission allowances in this way — giving a relatively large number of allowances to poor countries with high marginal costs of emission reduction — is far from fanciful. Brazil, for example, is precisely such a country.[52] In such a scheme, the ability to buy and sell permits does indeed lessen the relative burden borne by richer, low-abatement-cost countries, in that they lessen their cost of compliance by essentially purchasing low-cost GHG abatement in poor, high-marginal-abatement cost countries.

The existing economic work on national costs and benefits from GHG emission reduction suggests that there is another important configuration of national costs and benefits to consider before moving on.[53] This is the case of China and India, both of which have very low marginal costs of GHG emission abatement but are also, at least in per capita terms, quite poor countries with other more pressing development priorities. Both China and India

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[51] *See* STEWART & WIENER, *supra* note 1, at 42 (arguing that "many and probably most" developing countries have limited resources and have more immediate and pressing priorities than long-term climate protection).

[52] *See supra* note 33 and accompanying text.

[53] *See, e.g.*, Altamirano-Cabrera & Finus, *supra* note 22.

have been big proponents of international schemes that would allocate rights to emit GHGs on an equal per capita basis (that is, schemes that take global emissions and divide by world population and then give each country a total number of permits to emit GHGs that is equal to the global per capita amount multiplied by the country's population).[54] In terms of Figure 2, such schemes can be conceptualized by assuming that Country 1, the low-marginal-cost abater, is also a poor and very populous country that is given the vast majority of emission rights. Under such a scheme, we begin at a point far to the left, where Country 1 has little obligation to reduce emissions and Country 2 would be doing the bulk of the emissions reduction. As can be seen from Figure 2, at such a point, Country 1's marginal cost of GHG emission reduction is much less than Country 2's, and hence there would be gains from trade from having Country 1 reduce its emissions and sell unused permits to Country 2. Such gains would exist until we once again reach the point (e^1,e^2) where marginal costs are equal for the two countries.

Country 1 will presumably not agree to sell rights to Country 2 unless it receives a price at least equal to its marginal cost of GHG abatement. If Country 2 is a wealthy, high-marginal-cost-of-abatement country such as Japan or Germany, then it is reasonable to suppose that Country 2 would indeed be willing to make such a payment. The end result is that by giving most of the rights to emit GHGs initially to Country 1, we can achieve both efficiency and what can be deemed a fair sharing of the cost of GHG emission reduction: Country 1 has done the bulk of GHG emissions reduction, as efficiency dictates, but Country 2 has paid for that reduction.

C. The Efficiency and Equity of Cap-and-Trade Regimes Depends upon Enforcement and Monitoring That Are Unlikely in the International GHG Context

Unfortunately, while quite standard in the climate change policy literature,[55] the immediately preceding analysis almost surely vastly overstates both the likely efficiency gains from an international cap-and-trade regime and the ability to harmonize equity and efficiency through such a regime. The analysis presumes that all countries, rich and poor, in fact have an incentive to comply with their international obligations by holding sufficient allowances to cover their actual allowed emissions. It also assumes that emissions reductions are real — that there is some mechanism by which a status quo emissions level can be determined and set and by which emissions reductions relative to that baseline can be verified. In the international context, however, existing evidence suggests that neither assumption is

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[54] For further details on such per capita schemes, see Eric A. Posner & Cass R. Sunstein, *Should Greenhouse Gas Permits Be Allocated on a Per Capita Basis?*, 97 CAL. L. REV. 51 (2009). *See also* Jeffrey Frankel, *Formulas for Quantitative Emissions Targets*, *in* ARCHITECTURES FOR AGREEMENT 31, 40 (Joseph E. Aldy & Robert N. Stavins eds., 2007) (noting that advocacy of equal per capita emissions rights has "long been India's position").

[55] *See, e.g.*, STEWART & WIENER, *supra* note 1, at 59-75.

likely to hold,[56] and economic theory shows that when these assumptions are violated, the performance of a cap-and-trade regime is severely diminished on both efficiency and equity grounds.

1. *Imperfect and Nationally Variable Enforcement Shrinks the Market and Leads to Trading Primarily Among Countries or Entities with Low Marginal Costs of Abatement, Dissipating Cost Savings from Cap-and-Trade*

The incentive of any entity to spend money to abate GHG emissions or to buy allowances hinges on the existence of a credible and sufficiently stringent sanction for failure to meet agreed-upon emission caps. Thus, the key question for any international GHG emission reduction regime is whether there are credible enforcement mechanisms. If countries do not enforce GHG emission caps domestically, then such caps can only be made effective if there is some mechanism for other countries to either force domestic enforcement or to enforce directly against entities controlling GHG emission sources. Mechanisms to force domestic enforcement are interstate sanctions such as trade sanctions and the like. Trade sanctions are not likely to be credible against the most important laggard countries such as China, and are of unclear effectiveness for poor countries with high emission costs. Direct enforcement mechanisms require an international institution that has the power to directly sanction polluting entities for failing to comply with domestically or internationally imposed caps. Such an entity does not exist. It seems likely that many countries might view their optimal strategy as one in which such caps are imposed by law — thus placating international demands for GHG emission limits — but then simply not enforced — thereby ensuring that their citizens do not bear any costs from apparent compliance with international demands (or, more formally, treaty obligations).

A realistic view of varying national incentives to actually enforce a GHG emissions cap-and-trade regime suggests that the efficiency gains from an international GHG cap-and-trade regime are likely much lower than economic models commonly suppose. The best way to develop the intuition for this result is to consider the opposite case, of tough uniform enforcement. This case is exemplified by the acid rain (sulfur dioxide) trading program set up under Title IV of the Clean Air Act Amendments of 1990.[57] Title IV allowed covered electric utilities to meet sulfur dioxide emissions caps by buying allowances from other firms covered under the program,[58] and economists now are quite certain that Title IV was effective in lowering sulfur dioxide emissions in a cost-effective way, and that allowance trading was an important part of this success.[59] Moreover, Title IV has had a 100% compli-

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[56] *See* sources cited *infra* Part III.C.2.

[57] 42 U.S.C.A. §§ 7651a-o (1990).

[58] *See* 42 U.S.C.A. § 7651b(b) (setting out the criteria for trades).

[59] *See* A. Denny Ellerman et al., Markets for Clean Air: The U.S. Acid Rain Program 109-196, 253-296 (2000).

ance rate: every firm covered has held the required number of allowances.[60] Underlying this success were two features: a uniform sanction for non-compliance that, at between $2000 and $3000 per ton, has always been far in excess of the market price of sulfur dioxide emission allowances,[61] and — due to the continuous emissions monitoring requirement — a 100% probability of being detected and assessed this steep fine if ever in non-compliance.[62] Because monitoring and enforcement with very high fines are guaranteed under Title IV, all firms comply, and when all firms comply, none pays fines. Because the equilibrium for firms subject to Title IV is to comply — and incur their marginal compliance cost — the equilibrium price of sulfur dioxide permits is determined by present (and expected future) compliance costs. That is, it is because of the enforcement institutions that underlie Title IV and which effectively rule out non-compliance that the equilibrium price of Title IV sulfur dioxide emission permits is based on marginal compliance costs, allowing the tradable permits market to realize the kinds of efficiency depicted in Figure 2 above.

However, under an international GHG cap-and-trade system, there is no uniform sanction. Rather, one would expect that the effective sanction for violations will vary across countries. Firms in countries with the weakest sanctions for non-compliance will not comply with the cap-and-trade requirement that their emissions not exceed the number of allowances they hold. Therefore, it can be presumed that at least some countries that are not themselves subject to effective international sanctions for failing to meet their *national* obligation to reduce emissions will end up in violation because they do not have the political wherewithal to enforce domestic GHG emission standards against their own GHG emitting industrial *sectors.* Their willingness-to-pay for emissions allowances will be determined in equilibrium not by their marginal cost of abatement, but rather by the very low expected sanction that they face. In a system with uniform sanctions, entities with high marginal costs of GHG emission reduction would be the highest-value potential offset buyers and make up a crucial part of the market. If such high-marginal-cost reducers are located in countries with very weak sanctions for non-compliance, they will have very low willingness-to-pay for offsets, will drop out of the market, and violate their caps unless the offset price is set at a trivially low level.

One might well expect to find a negative correlation between the average marginal GHG emission reduction cost of entities in a country and the stringency of the sanctions that the country imposes on entities that fail to comply with an internationally imposed cap. In general, a higher marginal

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[60] *Id.* at 109.

[61] *See* EPA, EPA-430-R-06-015, ACID RAIN PROGRAM: 2005 PROGRESS REPORT 7 (2006) (noting that the penalty for non-compliance set a $2000 penalty that went into effect in 1990 but has been adjusted annually for inflation).

[62] *See* Joseph A. Kruger et al., *A Tale of Two Revolutions: Administration of the SO_2 Trading Program*, *in* EMISSIONS TRADING: ENVIRONMENTAL POLICY'S NEW APPROACH 115, 117 (Richard F. Kosobud et al. eds., 2000).

cost of regulatory compliance correlates with a higher optimal expenditure by regulated entities to lobby for lowering the sanctions for violating the edict. For this reason, one would expect to find the lowest national sanctions for violation of an international GHG cap in precisely those nations whose regulated entities face the highest marginal cost of complying with the edict. If such a relationship in fact holds, then it is likely that demand for offsets under such a cap-and-trade regime will be determined not by regulated entities' relative marginal cost of compliance, but rather by the relative strength of domestic sanctions and enforcement. In such an equilibrium, offsets may well be purchased by entities with relatively low marginal costs but stringent domestic enforcement, while entities with relatively high costs but weak domestic enforcement stay out of the market.

The efficiency rationale for cap-and-trade regimes arises precisely because such regimes give an incentive for low-marginal-cost abaters to do most of the pollution abatement, freeing permits for sale to entities with higher abatement costs (recall the earlier analysis using Figure 2).[63] On the argument here, it is very likely that under an international GHG emission cap-and-trade regime that relies on national enforcement, the market may be made up only of those firms located in countries that actually are serious about compliance with their international obligations and actually enforce domestic GHG emission laws against domestic GHG-generating firms. Many high-marginal-cost emitters located in countries without credible enforcement will be missing from the international GHG emissions market. This greatly shrinks the size of the GHG emissions market and, most importantly, limits the efficiency gains provided by such a market. The international GHG emissions market is likely to involve trades among countries (or firms within countries) that have relatively low marginal costs, thus generating relatively modest cost savings.

The development to date of the European Union's emissions-trading scheme ("ETS") strikingly confirms this theoretical prediction. As explained by Niels Anger, the European ETS covers only energy-intensive sectors that have relatively low marginal costs of GHG emissions abatement, while excluding sectors such as transportation and households with higher marginal costs.[64] Similar structures — including energy-intensive industries in the national cap-and-trade scheme, while leaving other high-marginal-cost sectors out — have been proposed by Japan and Canada.[65] Especially when, as in Europe, such schemes are very generous in giving GHG emission permits to covered sectors, they involve very large inefficiencies: the covered sectors have so many permits that they have little need to reduce emissions, while the higher-marginal-cost sectors that would be permit buyers are not

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[63] *See* discussion *supra* Part III.A.

[64] Niels Anger, *Emissions Trading Beyond Europe: Linking Schemes in a Post-Kyoto World*, 30 ENERGY ECON. 2028, 2035-36 (2008).

[65] *Id.* at 2035.

covered by the cap-and-trade regime at all.[66] Both the exclusion of high-marginal-cost emitters from the European ETS and the decision by participating countries to give the covered energy-intensive sectors large amounts of emission permits are precisely what the previously discussed model of differentiated national enforcement predicts. Countries in the ETS have excluded precisely those high-marginal-cost sectors that would be permit buyers but have used their political power to lobby against costly emissions reduction requirements (and indeed, have lobbied with some success already for emissions reduction subsidies).[67] This leaves only low-marginal-cost firms covered by the cap-and-trade regime; even there, gains from trade are even less than I have presumed, because so many allowances have been granted that firms do not need to reduce their emissions in order to comply.

2. *The Inevitable Tradeoff Between Equity and Efficiency in Defining Allowable Offsets*

One possible solution to the loss of efficiency due to the exclusion of high-marginal-abatement-cost sectors from regional GHG cap-and-trade schemes has been to link such schemes across countries and regions.[68] If very low marginal-cost abaters from countries outside the region can be included as possible trading partners, then high-marginal-cost abaters within the region could comply with their obligations to reduce emissions by buying permits from the very low-marginal-cost abaters, thus making them willing to become part of the regional cap-and-trade regime. In the case of Europe, it has been shown that compliance costs of the high-marginal-cost sectors that are now excluded from the European ETS could fall by ninety percent if firms and households in those sectors could buy allowances generated in developing countries under the Kyoto Protocol's Clean Development Mechanism ("CDM") and in other industrialized countries under the Protocol's Joint Implementation ("JI") mechanism.[69]

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[66] *Id.* at 2035, app. A1 tbl.3, *available at* http://dx.doi.org/10.1016/j.eneco.2007.08.002; *see also* Christoph Böhringer et al., *Assessing Emission Regulation in Europe: An Interactive Simulation Approach*, 26 ENERGY J. 1 (2005).

[67] *See* EURACTIV, EU EMISSIONS TRADING SCHEME (2009), http://www.euractiv.com/en/climate-change/eu-emissions-trading-scheme/article-133629?_print (noting that the transport and building sectors are excluded from the ETS) (last visited May 12, 2009) (on file with the Harvard Environmental Law Review); DEUTSCHE BANK RESEARCH, NEW ERA UNFOLDING FOR THE AUTOMOBILE INDUSTRY (2009), *available at* http://www.dbresearch.com/PROD/DBR_INTERNET_DE-PROD/PROD0000000000239030.pdf (noting the very high abatement costs for the German auto industry and the complex political compromises necessary to bring the industry, eventually, into the ETS). Marginal abatement costs in the German auto industry have been estimated as ranging from 260-1530 Euro, almost ten times more than in the ETS trading segment. Ferdinand Dudenhöffer & Marcus Krüger, *Kohlendioxid: Zu viele unterschiedliche Preise für den Autofahrer*, 61 IFO SCHNELLDIENST 17 (2008).

[68] Anger, *supra* note 64, at 2039-40.

[69] *Id.* at 2039, 2046. For a succinct summary of these and other key aspects of the Kyoto Protocol, see Joseph E. Aldy & Robert N. Stavins, *Introduction: International Policy Architecture for Global Climate Change*, *in* ARCHITECTURES FOR AGREEMENT, *supra* note 54, at 1, 8-9.

The problem with such proposals is that the ultimate objective of GHG emission cap-and-trade schemes is not to simply reduce compliance costs, but to minimize the cost of achieving a given targeted reduction in GHG emissions — yet neither the JI nor CDM mechanism can credibly provide real reductions in GHG emissions.

The defense of this assertion requires a brief discussion of the Kyoto Protocol's CDM and JI mechanisms. These are two of three types of "offsets" — credits for GHG emissions reduction — created by the Kyoto Protocol.[70] The most direct kind of offset under the Kyoto Protocol is the kind described in Figure 2 above: emissions trading among the Annex 1, high-GHG-emitting industrialized countries covered by Kyoto's cap-and-trade regime. The other two Kyoto mechanisms expand the possibilities of trading beyond the direct trades captured by Figure 2. JI allows Annex 1 countries to earn credit for cutting emissions in other Annex 1 countries; CDM gives Annex 1 countries the chance to earn GHG offsets by investing in projects in developing countries.[71] In terms of my earlier analysis, the CDM process in particular can be understood as a way to give project-specific allowances to poor, low-marginal-cost countries that can be sold only if the GHG-reducing projects are actually undertaken.

As envisioned by the designers of the European ETS, expanding the potential trading set of a GHG emission cap-and-trade regime to include both JI and CDM projects increases the number of low-marginal-cost abaters located in poor countries that can be paid for their GHG abatement, thus facilitating efficient, low-cost abatement and the redistribution of wealth and income to the owners of such projects. Unfortunately, recent work by Michael Wara and David Victor shows that CDM projects are neither effectively reducing GHG emissions nor redistributing income to the poorest countries.[72] As Wara and Victor report, the growth of the CDM market has been spectacular, totaling 12 billion euros in 2007, a more than 200% increase over 2006, with the EU's ETS being the largest source of demand for CDM projects.[73] However, their investigation revealed that over the period of rapid CDM market growth, 2004-2006, the vast majority of Certified Emissions Reductions ("CERs"), the emission reduction credits generated by CDM projects, came from flaring a gas (HFC-23) generated as a by-product from the production of a gas used in air conditioners and plastics as

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[70] For an introduction and further background, see UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, THE MECHANISMS UNDER THE KYOTO PROTOCOL: EMISSIONS TRADING, THE CLEAN DEVELOPMENT MECHANISM AND JOINT IMPLEMENTATION, http://unfccc.int/kyoto_protocol/mechanisms/items/1673.php (last visited April 25, 2009) (on file with the Harvard Environmental Law Review).

[71] Kathryn Harrison & Lisa McIntosh Sundstrom, *The Comparative Politics of Climate Change*, GLOBAL ENVTL. POL., Nov. 2007, at 1, 3.

[72] *See* Michael W. Wara & David G. Victor, *A Realistic Policy on International Carbon Offsets* (Stanford Program on Energy & Sustainable Dev., Working Paper No. 74, 2008), *available at* http://iis-db.stanford.edu/pubs/22157/WP74_final_final.pdf.

[73] *Id.* at 9.

a substitute for ozone-harming chlorofluorocarbons.[74] This gas is an extremely powerful GHG — about 12,000 times more potent than CO_2 — but the market price of CDM credits generated by flaring this gas was so high that it became more profitable to produce the refrigerant gas just to get the byproduct for sale on the CDM market.[75] In this way, the CDM market created a perverse incentive to produce a potent GHG.[76] According to Wara and Victor, in the last two years, governments and the CDM Executive Board — an essentially regulatory board that decides which projects qualify to generate CDM credits that can be sold — have attempted to "clamp down" on the HFC-23 credits, and they have succeeded, but only by shifting the CDM market to the purchase and sale of credits generated by new hydroelectric, wind, and natural-fired electricity generating facilities in China.[77] Indeed, Wara and Victor find that "essentially all new hydro, wind and natural gas fired capacity is applying to claim credit for emissions reductions under the CDM."[78] The problem with these projects is that many would be undertaken without regard to the CDM: they are not generating real reductions in GHG emissions.[79]

What Wara and Victor have found to be true of the Kyoto CDM offset market evidences a fundamental tradeoff in the design of an international GHG emissions cap-and-trade market, a tradeoff that seriously damages the ability to pursue both equity and efficiency through such a system. The tradeoff, simply put, is between enlarging the market and redistributing income by increasing the number of GHGs and projects covered, and credibly verifying that covered projects are really generating GHG emission reductions that would not otherwise have occurred. The more GHGs and projects are covered, the more difficult it is to ensure that GHG emission reductions are "real," and the greater the chance that the market for GHG emission reduction credits is creating a perverse incentive for new projects that actually *produce* GHGs.

At the most basic level, this tradeoff reflects the enormous difficulty and high transaction cost of monitoring and verification in the context of an international GHG emissions cap-and-trade regime. As argued previously, the Title IV sulfur dioxide trading regime under the Clean Air Act is successful because there is accurate monitoring of the actual sulfur dioxide emissions from a particular entity and highly credible and serious sanctions for non-compliance. Accurate monitoring of actual emissions is just as important as the credibility of the sanction, not only to ensure that entities are not incorrectly found to be in compliance, but also because accurate monitoring guarantees that when a company sells unused permits, it really is

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[74] *Id.* at 11.
[75] *Id.*
[76] *Id.*
[77] *Id.* at 12-14.
[78] *Id.* at 13.
[79] *Id.* at 14.

emitting less sulfur dioxide than permitted and therefore is being incentivized to cut emissions.

With GHG emissions the story is very different. There are a large number of GHGs, and many (like HFC-23) are much more potent than CO_2. There are also a huge number of widely varying types of sources of different GHGs. Unlike the Title IV experience — where one could be confident that permits for sale really did reflect the lower marginal cost of real sulfur dioxide reductions by sellers — an international GHG-reduction cap-and-trade scheme is likely to involve at least some sales with no real GHG emission reduction by the seller. Under Title IV, continuous emissions-monitoring systems required by law provide extremely accurate plant-specific information as to sulfur dioxide emission levels, and there is no room for regulated entities to argue about whether they have reduced emissions of that pollutant below the cap that applies to them. Under an international GHG cap-and-trade regime, however, countless projects arguably qualify as generating credits for sale under the CDM mechanism, and the CDM Executive Board must make an essentially regulatory determination of which projects count as real reductions of GHG emissions and which do not.

The CDM Executive Board faces an insoluble dilemma. On the one hand, by narrowly defining what counts as a developing-world project generating CDM credits, it ensures that certified projects really do generate reductions in GHG emissions, but it also cuts the number of credits generated by such projects that can be sold to high-marginal-cost abaters in the developed world, and thereby lessens significantly the incentive for such high-marginal-cost abaters to agree to participate in cap-and-trade schemes.[80] Moreover, a narrow definition of certifiable CDM projects also means that less income is transferred to developing countries, reducing their incentive to participate in the global GHG-reduction system. On the other hand, by more generously granting CDM project status, the Executive Board effectively uses the CDM mechanism to redistribute income to developing-world project owners, and increases the incentive for high-marginal-cost abaters to participate in a cap-and-trade system — but at the cost of approving many projects that do not generate any real reduction in GHG emissions.

IV. Conclusion

Long advocated by economists, cap-and-trade regimes for pollution reduction have indeed led to cost-effective reductions in conventional pollutants such as sulfur dioxide. Because their efficiency is generally independent of the initial allocation of permits across polluters, such regimes may seem to be the preferred instrument for achieving both equity and efficiency in reducing international GHG emissions. But just as is true of do-

[80] *Id.* at 18 (recommending that the definition of CDM credits be tightened, with the shortfall in developing country GHG emission reduction, and transfers, made up by direct bilateral aid for new technological and infrastructure investments in the developing world).

mestic cap-and-trade regimes for conventional pollutants, both the efficiency and fairness of international GHG cap-and-trade regimes hinges on uniform enforcement of caps and verifiable, real emission reductions. Both theory and the existing evidence suggest that in the case of international GHG emissions, neither uniform enforcement nor emission reduction verification is likely. Without these preconditions, an international GHG emission reduction regime is likely to achieve only limited efficiency gains and to redistribute wealth in a manner that may bear little relationship to the goal of lessening the burden to poor people of reducing GHG emissions. Other policies — targeted much more directly at encouraging both the development of new, energy efficient technologies and their adoption in the developing world — are necessary if the international goal of reducing GHG emissions is to be achieved in a fair and efficient way.