Facing the Climate Change Challenge in a Global Economy

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NOTE: Preliminary and Incomplete. Please Do Not Distribute, Quote, or Cite

Abstract: Over the past two decades, the international community has struggled to deal constructively with the problem of mitigating climate change. This is considered by many to be the preeminent public policy challenge of our time, but real progress has been disappointingly slow. This essay provides an abbreviated narrative history of international policy in this domain, with a special emphasis on aspects of the problem, proposed solutions, and unresolved issues that are of interest to international economists and informed observers of the global economic system. We also discuss the potential conflict that could emerge between free trade principles on the one hand and environmental policy imperatives on the other.

*/** The authors thank Peter Adams, Joseph Aldy, Sean McCoy, and Allen Robinson for helpful comments and suggestions. All opinions and policy judgments in this paper are the private views of the authors and do not necessarily represent the official views of any branch of the Government of the United States.

1. Introduction

As concern about greenhouse gas (GHG) emissions and possible human-induced climate change has intensified, the volume of economic research on prospective climate change, its negative economic impacts, and cost-effective methods of limiting those impacts has grown substantially. We will make no effort in this paper to offer a comprehensive review of the recent literature on the economics of climate change.[1] Instead, we focus in this paper on the particular challenge of international policy coordination to reduce emissions, the processes through which this coordination is or is not emerging, and the implications for international trade. Even in this narrower domain, there is a substantial and growing literature comprising important contributions from scholars working in multiple disciplines. Our aim is to summarize and place in context some of the lessons of this literature for economists interested in the general question of multilateral policy coordination in the 21st century. Because our intended audience is the general community of international economists and policymakers interested in international economic policy issues, rather than the community of climate specialists, our exposition will necessarily cover a broad range of topics, sometimes with limited depth.

In the view of the authors, the impressive collection of evidence documented by the successive reports of the Intergovernmental Panel on Climate Change (IPCC) leaves little doubt that anthropogenic GHG emissions are already changing the earth's climate system.[2] Unconstrained growth in GHG

[1] Readers interested in a recent, comprehensive survey of key issues and controversies are directed to Aldy et al (2010). The Stern Review (N. H. Stern & Great Britain, 2007), one of the more recent and most thorough efforts to quantify the economic case for strong action, staked out positions on many of these difficult questions and stirred up considerable debate in the process (see, for example, Mendelsohn, 2006; W. D. Nordhaus, 2007; Martin L. Weitzman, 2007).

[2] The IPCC is an international panel of scientific experts charged under the United Nations Framework Convention on Climate Change (UNFCC) to produce periodic reports on the scientific evidence for the existence and extent of anthropogenic global warming. The most recent IPCC assessment report (Pachauri & Reisinger, 2007) was published in 2007 and can be accessed on-line at http://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html. The drafting of the fifth assessment report

emissions is likely to intensify these changes in coming decades, raising the prospect of serious damage to ecological and economic systems worldwide.[3] Many scholars and political leaders view an effort to limit climate change as the preeminent policy challenge of our time.

But this effort carries with it special challenges that stem from the intrinsic characteristics of the climate change problem. The majority of GHGs, including carbon dioxide (CO_2), persist for a very long time in the atmosphere -- time spans measured in centuries -- which implies that the consequences of global warming, while potentially significant, will only fully emerge over an intergenerational time span. This makes it difficult for democratic political systems with relatively short decision making time horizons to come to terms with the problem. And, despite the remarkably strong consensus among physical scientists regarding the reality of anthropogenic climate change, significant uncertainties still exist around exactly how and when the earth's climate system might respond to increases in GHG concentrations. This uncertainty about the earth's future physical circumstances is only compounded by our general uncertainty about the impact of climate change on human systems, driven by the uncertain evolution of future economic growth, population expansion, and technological change. If our political systems find it difficult enough to reckon with long-run problems when the consequences are well known, it is even more difficult when they are highly uncertain. Meanwhile, the almost direct relationship between carbon dioxide emissions and energy use, and, ultimately, economic activity, often makes the cost of taking action all too palpable.

Domestic political difficulties have arisen in many countries, but most notably – and importantly – in the United States. While no longer the largest emitter in the world (Buckley, 2010), policy decisions in the United States are immensely important. U.S. emissions are still the highest among developed

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is currently underway. In 2007, the IPCC shared the Nobel Peace Prize with former U.S. Vice President Albert Gore for its efforts to promote public understanding of climate change.

[3] A useful nontechnical summary of the basic physical science of climate change can be found in Collins et al (2007). Concerns over the possibility of small probability, high consequence has also spurred a line of work questioning the basic notion of (presented discounted) expected utility analysis (M. L. Weitzman, 2009)

countries, and others look to the United States for leadership. Yet, following promising developments towards a legislated emissions trading program in 2009, the political shift up to and including the November 2010 elections led even the President to declare that he was "going to be looking for other ways to solve that problem" (Soraghan, 2010).

We are of the view that, while the political stars are no longer aligned for such a comprehensive solution in the United States, the long-term trend is encouraging and there are even occasionally positive near-term signs (Levi, 2011). More importantly, the developments in 2009 offer important insights into what will ultimately matter in a U.S. policy – particularly the competitiveness concerns we discuss later. Indeed, it is this view that the United States will eventually enact climate legislation that motivates our interest in how various national, regional, and global initiatives can be best made operational in a global economy.

This possibility of a jumble of various national, regional, and global policies reflects the final, perhaps most vexing aspect of the climate change problem: its global nature. Most pollutants are essentially local problems. Emissions inflict damage, but the intensity of that damage diminishes sharply with increasing geographic distance from the point of emissions. GHG emissions, by contrast, are a textbook case of a transnational environmental externality. GHG emissions have the same impact on the global climate system, regardless of where they are emitted. A molecule of CO_2 emerging from a cooking fire in rural India has the same impact as a molecule of CO_2 emerging from the tailpipe of an SUV in the Houston suburbs.

Coupled with the high correlation among emissions, energy use, and economic activity, this global nature has created an unusually polarizing international dilemma. The preponderance of projected growth in GHG emissions over the next several decades will come in developing countries whose ongoing industrialization will bring in its train a rapid increase in per capita energy use and GHG

emissions. These countries have made it clear in international negotiations that they view the continuation of rapid economic growth as a greater priority than the curbing of emissions, and they expect significant support from developed countries to finance emission mitigation. Meanwhile, many developed countries face severe fiscal constraints that constrain their ability to finance mitigation in their own, let alone developing, countries. The international system has thus struggled to deal with the reality, on the one hand, that the greatest source of current and especially future emissions sees itself as having relatively little to gain from a strong, self-financed commitment to climate change mitigation and, on the other hand, that other countries will have a hard time paying them to do so.

In this essay, we start by laying out some basic facts about the current and prospective future distribution of emissions across countries. We will also summarize what that the basic economic theory of environmental regulation would prescribe as the first-best solution to the problem of emissions reductions. Unfortunately, we shall see that the ability of current global institutions to practically implement anything like this first-best solution in the near term is practically zero. We will then summarize the recent, major shift in the direction of global negotiation away from the top down, legally binding developed-country-only targets and timetables of the Kyoto Protocol, and towards a bottom up set of mitigation commitments by all major economies, provisions for transparent review, and financial support – both public and private – for poorer countries.

Toward the end of the paper we also address an idea that many international economists may find controversial and unwelcome. As policies to mitigate emissions are strengthened in some countries – particularly through mechanisms that price emissions and effectively raise energy costs – pressure will build to shield domestic energy-intensive manufacturing industries from competition with producers based in other countries with weak or nonexistent carbon control policies. The existence of "carbon tariffs" or other border measures may be required, both to allow progress in those countries seeking to

strengthen their carbon control regimes and to convince other, laggard countries that some degree of global cooperation on carbon control is warranted. These ideas raise important legal and economic questions, which we will review.

2. The Global Distribution of GHG Emissions: Past, Present, and Future

Today, global negotiations on climate change policy are conducted primarily under the aegis of the United Nations Framework Convention on Climate Change (UNFCCC). This is the legal framework under which the Kyoto Protocol was created. The recent Copenhagen and Cancun meetings, which we will discuss below, were international negotiating conferences among the parties to this convention focused on further elaborations and extensions. The UNFCCC itself is a treaty that came into force in 1994 after first being presented for signing at the Earth Summit in Rio de Janeiro, Brazil 1992. With 195 parties, the treaty enjoys near universal participation among UN member states. Among the provisions of the UNFCCC, the participating developed-country nations – enumerated in "Annex I" to the UNFCCC – made (nonbinding) pledges to reduce GHG emissions below 1990 levels by 2000 while no such quantified target was established for developing countries (see Article 4, specifically 4.1(a) and 4.2(b), United Nations, 1994).

Given the persistence of this differentiation among countries, particularly the anchoring to developmental status in the early 1990s through inclusion or exclusion to Annex I, it is worth reflecting on the context in which this arrangement took shape. In the early 1990s, the developing world as a whole was slowly and fitfully emerging from the multiple recessions and financial collapses initially triggered by a severe recession in the developed world and sustained by the Third World debt crisis of the 1980s. Throughout that decade, progress in terms of sustained growth in per capita income had been minimal, and many regions had witnessed substantial declines in the real purchasing power of the median worker. Developing nations in East and Southeast Asia were doing much better, but the growth

miracles of China and, especially, India were still at an early stage, and were not yet recognized as such by the global community. The developed world had fared much better in the 1980s, with reasonably robust GDP expansion in Japan, Western Europe, and the U.S., and most forecasters looked forward to a short- and medium-term future that would resemble the recent past. This would be a world where wealth, prosperity, and energy consumption were disproportionately concentrated in the advanced industrial countries. Despite their relatively small collective share of the world's population, these countries accounted for the overwhelming majority of greenhouse gas emissions. As UNFCCC emerged in 1992, it made sense to concentrate on the advanced industrial countries as a first step, since they were both the primary source of the problem and the set of nations best suited to shoulder the economic costs of reducing emissions.

Legal scholars tell us that founding documents have enduring consequences. By the time serious negotiations surrounding the Kyoto Protocol were taking shape in the mid-to-late 1990s, observers of the world economy had begun to take industrial Asia much more seriously. But negotiations remained focused on legally binding targets for Annex I countries and no others. The diplomatic die had already been cast, and newly emerging economies were able to evade the efforts made to create legally binding emissions reduction targets that applied to them.[4]

As the rest of our essay will attest, this has been a significant omission. Even in the mid 1990s, observers understood that manufacturers in energy-intensive industries could face a strong incentive to relocate production from countries that imposed a cost of emissions to countries with weak or nonexistent carbon regulation regimes. The development of a high level of manufacturing capacity in East and Southeast Asian nations with no obligations to curb emissions raised the specter of "leakage"

[4] Interestingly, the goal of reducing emissions below 1990 levels, also originally embodied in the UNFCCC's founding documents, remained the salient benchmark for the Kyoto Protocol negotiations.

of carbon intensive industrial activity from the Western countries to this region. This leakage has an environmental angle – that emission reductions efforts in developed countries could be partially, wholly, or even more than wholly offset by increases in unregulated emerging economies. But equally important, it has an economic angle as jobs are pushed overseas, a concern faced by environmental regulations more generally (Jaffe, Peterson, Portney, & Stavins, 1995).

As early as 1997, there were responses to this concern. Prior to the Kyoto meetings (where the final negotiation and signing of the Kyoto Protocol occurred), the United States Senate passed the Byrd-Hagel Resolution (by a vote of 95 to 0) expressing the "sense of the Senate" to oppose any climate change treaty that failed to impose meaningful constraints on developing countries. This meant, of course, that the Kyoto Protocol was effectively dead in the United States even before a final version had been agreed upon by international negotiators. The Clinton administration signed the agreement, but never submitted it to the Senate for ratification, and it therefore never became binding as U.S. law. After the election of President George W. Bush, the United States formally withdrew from the Kyoto Protocol altogether.

Even as resistance to a focus on "Annex I only" obligations was building in the U.S. and elsewhere, economic developments worldwide were rendering the Annex I designations increasingly obsolete. The 1990s were a time of dramatically slower economic growth in Japan and in much of Western Europe, lowering the rate of growth of Annex I country emissions.[5] At the same time, the growth boom that had begun in China in the 1980s significantly accelerated in the 1990s and India's economy responded to the liberalization program of the 1990s with a significant growth acceleration of

[5] At the same time, economic sclerosis in Western Europe and Japan limited the growth in emissions in that decade, and made a reduction of emissions below 1990 levels, as eventually called for in the Kyoto Protocol, more feasible for these countries. Relatively robust economic growth in the U.S. in the 1990s pushed emissions well above 1990 levels by the end of the decade, which meant that the "Kyoto pledge" would be many times more economically costly for the U.S. to implement than for its European or Japanese trading partners. See Victor (2004), who lays out this contrast.

its own. Industrial Asia expanded throughout much of the decade. The global pattern of emissions was shifting away from Annex I countries and toward the set of countries for which no binding emissions limitations existed.

These trends accelerated in the 2000s. China's rapid and sustained growth during this decade led the Asian giant to displace the United States as the world's single largest emitter around 2006, and the gap between the two widened sharply in the wake of the global financial crisis (World Climate Report, 2011). Figure 1 illustrates this dramatic shift over the past 30 years, whereby developed countries emissions went from being nearly double those in developing countries to being barely two-thirds.

Looking ahead, at the time of this writing the near universal expectation among market forecasters is that growth in the developed world will continue to proceed at a relatively slow pace -- much slower than in the developing world. According to growth projections widely touted by Citigroup, China will exceed the United States in terms of total economic size by 2020, developing Asia will account for 44% of world GDP by 2030, and today's developing regions will collectively account for nearly 75% of world GDP by 2050.[6] The future consequence for emissions is profound.

Figure 2 presents one "baseline" estimate of carbon emissions generated by groupings of developed ("Annex I"), emerging, and developing countries in the global economy from the year 2000 through 2100. These estimates arise out of a study undertaken through the Energy Modeling Forum (the study is referred to as EMF-22) (Clarke et al., 2009). This initiative utilized ten of the world's leading integrated assessment models to forecast future levels of GHG emissions and atmospheric concentrations over time in the absence of serious efforts to mitigate global warming as well as the

[6] See the forecasts contained in Global Economics View: Global Growth Generators, Moving beyond 'Emerging Markets' and 'BRICs', by Willem Buiter, available at http://www.nber.org/~wbuiter/3G.pdf. The forecasts of economic size are measured using (prospective) PPP exchange rates.

climatic and economic implications of various policy efforts to slow down or even reverse this trend.[7] Obviously, any exercise of this kind is speculative -- the models must incorporate assumptions about population growth, economic growth, technological progress, public policy, and other variables that are hard to predict with any degree of accuracy. However, the general picture that emerges has broad agreement among most experts: While per capita income will continue to rise in the rich countries, slow population growth and a general transition to a post-industrial economy will limit emissions growth. In striking contrast, developing countries and especially the so-called BRICs will see rapid and substantial growth in emissions. This particular forecast suggests developing country emissions will be nearly three times those of the current developed countries by the middle of the century, and four times by the end.

Against this backdrop, it is clear that even large emissions reductions by the Annex I countries will be insufficient to offset increases in expected emissions by the developing countries over coming decades, let alone be the basis for global reductions. Real reductions, at a global level, in emissions will require that developing countries deviate from their baseline. Depending on how aggressive we want to be, those deviations may need to occur within years rather than decades. This was the central theme of EMF-22: What does developing country participation imply about the feasibility (as well as costs) of various targets?

Figure 3 summarizes the EMF-22 results. This figure shows the global emission reductions required in 2050 (*y*-axis) to achieve increasingly ambitious long-run concentration targets (*x*-axis). For each target, the results are further differentiated based on (1) whether concentrations can overshoot

[7] Integrated assessment models are computer simulation tools which integrate models of the earth's physical environment with models of economic growth. Perhaps the best known model of this family for economists is William Nordhaus's DICE (Dynamic Integrated Model of Climate and the Economy) model, which he has used in numerous papers and in his recent book, Nordhaus (2008) . They have become a central analytic tool within the climate change community.

("O.S.")[8] the target or are not-to-exceed the target ("N.T.E."), and – importantly – (2) whether all countries fully participate from the beginning ("Full") or developing countries delay participation. This "Delay" scenario specifies the BRICs starting in 2030 and other developing countries starting in 2050. Each of the ten participating models (and four variants) are indicated by different colored dots in the figure.

Several results are striking. A concentration target of 450 ppm CO2e is virtually impossible without immediate full participation by all countries and the ability to overshoot 450 before falling back to it – an unsurprising result given atmospheric GHG concentrations are roughly 450ppm already.[9] Yet, 450 is the target required for an expected average global warming of 2 degrees C, the most frequently identified goal for maximal temperature change.[10] And, even with full global participation and the ability to overshoot, many of the models were unable to achieve the target, as indicated by the collection of models in the "could not be modeled under criteria of study" box, suggesting it may be practically infeasible. Those that do solve suggest global emissions will need to decline by 50% relative to 2000 levels by 2050, a target consistent with the 2008 G-8 declaration in Hokkaido, but one that has yet to be endorsed by any emerging economy. Meanwhile, a concentration of 550 ppm CO2e still requires emissions in 2050 to be roughly the same as 2000 (if overshooting is allowed), which is no small task given expectations about developing country growth. A more likely outcome, if major emerging

[88] Overshooting has arisen as a practical – but controversial – way of achieving aggressive long-term targets as the possibility of near-term progress recedes. The controversy arises because of concerns that critical geophysical and biological systems could collapse if atmospheric concentrations rise to certain key threshold levels, even for a short period of time.Once these "collapse" scenarios start to unfold, a later reduction in concentrations may be insufficient to undo the damage..

[9] Concentrations of carbon dioxide (CO2) in the atmosphere are measured in terms of "parts per million" (ppm) – that is, among a million molecules of gas in the atmosphere, how many are carbon dioxide. CO2e or "carbon dioxide equivalent" converts concentrations of all greenhouse gases into the amount of carbon dioxide that causes the equivalent amount of warming.

[10] The L'Aquila Declaration of Leaders (2009) "recognized the scientific view that the increase in global average temperature above pre-industrial levels ought not to exceed 2 degrees C." Both the Copenhagen Accord and Cancun Agreements contained similar language recognizing the need for deep emission cuts "with a view to reduce global emissions so as to hold the increase in global temperature below 2 degrees Celsius."

economies fail to significantly limit emissions growth, is a 650ppm world where expected global warming is 3 degrees C and perhaps more than 5 degrees.

While the EMF-22 study suggested that many targets are simply *infeasible* without the participation of major emerging economies, an obvious corollary is that all targets are *more expensive* without their participation. Common sense suggests that if emerging economies generate a large share of global emissions, they will also contain a large share of cost-effective mitigation opportunities. On top of this first-pass reasoning, compared to developed countries, developing countries also tend to be less energy efficient and face many more first-time (versus retrofit) energy investments, two features that make low-carbon alternatives even cheaper. It should therefore not come as a surprise that the EMF-22 study found the delayed participation of emerging economies raised the global cost of the 550 ppm target by 50 to 100 percent (Clarke, et al., 2009). The common sense conclusion that economic efficiency requires global participation enjoys universal support from the climate change modeling community (e.g., W. Nordhaus, 2007).

3. Economic Logic Versus Political Reality: The Conception and Failure of Kyoto

This economic logic of reducing costs was, in fact, an important backdrop for the design and implementation of the Kyoto Protocol before it began to fall victim to very deep political rifts. By the mid 1990s, it was clear that the UNFCCC's aforementioned goal of returning developed country emissions to their 1990 levels was not being met and even moderate concentration targets required yet larger reductions. Our noted economic logic demanded that any global effort address emission reductions in developing countries, but the world continued to be (legally) anchored in a model with obligations focused entirely on developed countries. The solution envisioned in Kyoto was a system of legally binding reduction targets for developed countries, coupled with the flexibility both (1) to buy and sell emission commitments among those developed countries and (2) to generate offsets in developing

countries. While these flexibility measures represented a hard fought victory for economists, the targets themselves were a disaster for the United States and the architecture ultimately has proven unable to adapt to the dramatic shift in emissions growth to emerging economies.

Indeed, it was partly the recognition of particularly high costs in the U.S. of implementing the envisioned targets through domestic measures that led the U.S. delegation in Kyoto to push hard for economic flexibility within the Kyoto framework. The Kyoto targets involved multiple greenhouse gases and emissions from land-use changes, and allowed for trade-offs within this basket of targets. International emissions trading was made a central feature of the protocol, over the initial reservations of the Europeans.[11] While only Annex 1 countries were required to reduce emissions, they were allowed to obtain credit against their targets through the funding of emissions reductions in developing countries (as well as through trading with each other). Given the importance of U.S. participation (as the world's then largest emitter), the other delegations eventually endorsed these flexibility mechanisms.

The United States (under both the Clinton and Bush administrations) never sought to ratify the Kyoto Protocol. The sharp distinction between the United States' "legally binding emission limit" and none for China failed to meet the Byrd-Hagel resolution standard for meaningful participation by all countries. Equally important, the targets themselves were viewed as a bad deal for the United States.[12] The focus on fixed historic emission levels as the benchmark for progress was a serious disadvantage for the United States (as well as Canada and Australia) who faced, and continue to face, population growth

[11] The U.S. team was a strong advocate of a global cap-and-trade style approach to regulating GHG emissions for another reason. The federal government has employed this tool with great success to combat acid rain in the Northeastern U.S. Sulfur dioxide emissions had declined more rapidly and at lower economic cost than either industry or environmentalists had anticipated. Interestingly, cap-and-trade was viewed in environmental circles at the time as a "conservative" idea, implemented under George H. W. Bush's Administration and championed by Pennsylvania's Republican Senator, Jack Heinz.

[12] Prominent climate change economists, including Yale's William Nordhaus, publicly criticized the Kyoto Protocol on the grounds that it imposed unreasonably (and therefore politically unacceptable) costs of compliance on the United States (Nordhaus & Boyer, 1998).

of around 1 percent, versus the European Union and Japan who do not. Population growth generally involves a proportional increase in emissions, other things equal.[13] In addition, 1990 was a particularly advantageous year for Europe because of the subsequent shift from coal to natural gas use in the United Kingdom and, following the reunification of East and West Germany, the collapse and more efficient reconstruction of a highly inefficient East German economy.[14]

Underlying this issue of the U.S. target is a much deeper schism over the appropriate basis for dividing up any global emission limit. As noted, historic baselines favor already-developed countries with low (or negative) population growth. Developing countries often put forward models instead based on per capita emissions or historic cumulative emissions, which are even more difficult for countries like the United States.[15] Meanwhile, the U.S. has emphasized comparability based on cost or effort (T. Stern, 2009b). These conceptual differences give an analytical rationale for the basic point that key countries have wildly different views about what they should be doing relative to other countries. This makes mutual agreement on targets virtually impossible (in fact, one might instead ask, what unusual alignment of the stars led to the Kyoto agreement on targets in the first place?).[16] Finally, the notion of "countries having views" is itself an extremely tricky issue for a country like the United States, with polarized national politics and fickle popular views.

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[13] This notion that national emissions are the product of population, income per capita, and emissions per unit of GDP, was developed early in the analysis of climate change economics and is referred to as the "Kaya" or "IPAT" identity (Kaya & Yokobori, 1997; Waggoner & Ausubel, 2002).

[14] The UK's 1990s emissions levels reflected heavy use of coal that was phased out during the 1990s as the UK took increasing advantage of North Sea natural gas to replace coal. This transition largely accounts for the UK's success in meeting its target. Likewise, Germany benefitted from the fact that its 1990 emissions level includes the emissions of the Eastern Lander. Reunification coincided with a deep and persistent industrial collapse that left emissions in the states of the former East Germany well below 1990 levels even in the late 2000s. This largely accounts for German success at meeting its Kyoto targets.

[15] See, for example, den Elzen et al (2009), Houser (2010), and Dellink and Corfee-Morlot (2010) who compare the Copenhagen commitments across various metrics.

[16] Internal documents show that U.S. administration views concerning the Kyoto Protocol varied significantly in the months leading up to Kyoto, with economic interests arguing for a much looser target (Sperling, McGinty, & Tarullo, 1997). Interestingly, the U.S. delegation ultimately agreed to a target more stringent than anything in the internal documents.

Even if the particulars of the U.S.' Kyoto target could have been fixed – and there was a window of opportunity for the Bush administration to do so ("EU ready to renegotiate Kyoto," 2001) – the sharp distinction between developed and developing country commitments could not be. At first, this was not as problematic for other, non-U.S. members of Annex I. President George W. Bush formally withdrew the United States from the protocol in 2001 and ceased participating in relevant meetings, but all other Kyoto member states remained in and ratified the protocol. Outside of the European Union, those countries did little to enact national policies that would effectively ensure compliance (New Zealand adopted a cap-and-trade program in 2010; Australia appears perpetually on the verge of such a step). Nonetheless, thanks largely to the U.S. withdrawal, the Annex I countries are as a group likely to meet their Kyoto targets. Without the U.S., the generous targets afforded the formerly socialist "economies-in-transition" (EITs) offset the roughly 10 percent shortfall among non-EIT members of Annex I.

As negotiations on a second commitment period for Kyoto have intensified, however, other Annex I countries have called it quits. Japan and Russia announced in December 2010 that they would not participate in a second commitment period, while Canada made the same statement in June. All cite the need for a new agreement to include the world's largest emitters – China and the United States. Meanwhile, the Kyoto model will not change: China and other major developing countries refuse to step up to the kinds of legally-binding commitments contained in Kyoto.

Why won't emerging economies agree to Kyoto-style commitments? The developing countries -- especially the big ones that really matter, including China and India -- harbor grave reservations about signing up for significant limits on absolute emissions.[17] These countries understand that industrialization and economic growth will raise their emissions per capita. In fact, they see the current

[17] A recent article noted recent statements about regional emissions trading in China, but also voiced skepticism (Reklev & Garside, 2011).

gap between their own emissions per capita and those of the industrialized West as a strong reason for them to refuse to make any concessions whatsoever.

These developing country reservations crop up both quantitatively and qualitatively in the written mitigation pledges submitted by all major economies in January 2010 following the Copenhagen meetings. Numerical analyses of these pledges suggest that the emission pledges by China and India are relatively modest when viewed against a U.S. metric of cost or effort (Dellink & Corfee-Morlot, 2010; Houser, 2010).[18] Modeling suggests they could meet their target for less than $1 per ton compared to costs closer to $10-30 per ton for developed country targets in the EU and US. Under their submissions, Chinese and Indian emissions are also increasing around 70 percent over 2005 levels. Unlike China and India, who expressed their emissions target in relation to GDP (so emissions would be higher with higher GDP), all other developing countries made reductions pledges – some quite large – but against an unspecified baseline (an interesting exception is Brazil, who codified its baseline and reduction commitment into a domestic law; Hochstetler & Viola, 2010). Adding up all of the pledges, the analyses suggest a path towards at least 3 degrees of warming (Pew, 2010).

While the *quantitative* issues are important, equally if not more important are the *qualitative* differences reflecting the persistent view among developing countries that developed countries should agree to an internationally binding, economywide emission limits on total emissions, while developing countries should make non-binding pledges.[19] Regardless of what developing countries may pledge to do, it is hard to sell the idea that binding commitments are somehow valuable in developed countries when the largest and fast growing emitter is not part of the system. While this political reality started in the United States, it has clearly spread.

[18] For actual submissions, see http://unfccc.int/meetings/cop_15/copenhagen_accord/items/5265.php.
[19] See, for example, the February 2011 statement by the "BASIC" countries – Brazil, South Africa (or "Afrique du Sud" in the BASIC acronym), India, and China – who have been particularly vocal about the developed / developing country distinction. http://www.fmprc.gov.cn/eng/wjb/zwjg/zwbd/t802845.htm.

It is possible to look at this political reality as the consequence of a greater economic reality. There is no shortage of economic models to drive home the difficulty of negotiating a mutually agreeable means of moving forward when large emitters have a limited interest in mitigation and the global system lacks legal mechanisms to compel participation in emissions reductions by reluctant nations. An extensive game theoretic literature illustrates these problems. Carraro and Siniscalco (1993) and Barrett (1993) show that the presence of asymmetries across countries and the incentive to free ride make the existence of global self-enforcing agreements quite unlikely. When self-enforcing international agreements exist, they are signed by a limited number of countries (Barrett, 1994; Hoel, 1992, 1994). A grand coalition, in which all countries sign the same agreement, is unlikely to be an equilibrium (Finus & Rundshagen, 2003). The difficulties the international community has encountered in practice bear out these theoretical predictions, as can be seen in the history of the Kyoto Protocol.

Of course, these same models would never predict why countries like the European Union would pursue a unilateral mitigation at exactly the moment the United States announces it is walking away from any commitment. Or why Brazil would unilaterally pass a law to reduce greenhouse gas emissions. This leaves open the question of what economic interest drives national commitments and action. Moreover, it points to a way forward internationally: If negotiating mutually and internationally agreed commitments is not possible, both because key developing countries cannot ratchet up their form of commitment to match the Kyoto Protocol and because the range of views on appropriate quantitative targets cannot be bridged, then move to a system of national pledges for *all* countries. This is the essence of the Copenhagen Accord and Cancun Agreement.

Importantly, the history of the Protocol has highlighted the limited mechanisms states have under international law to punish states that fail to live up to the full letter and spirit of the agreement. The penalty for a noncompliant state under Kyoto would be a 30% reduction in some (unspecified)

reduction target that would be negotiated in an (unspecified) successor agreement. But, of course, any state that found itself in a position in which that 30% reduction was onerous could simply withdraw in the next round.[20] Legally binding targets and timetables often make sense in the context of domestic laws and policies internal to the states that are part of the Western "zone of law".[21] Every day in these countries, reluctant firms, agencies, and consumers are forced to meet the provisions of laws passed over their objections but with which they must comply. However, the international legal environment is a completely different story -- in that context, the apparent strengths of the legally binding targets are compromised by the legal weakness of the international system. This again suggests a focus on a system of national pledges.

4. The Cancun Agreement

At Cancun, all major emitters (including China) made (nonbinding) mitigation pledges in what was effectively a legitimized version of the outcome in Copenhagen.[22] In the language of the Cancun decisions, all parties agreed to "take note" of both the "quantified economy-wide emission reduction targets" submitted by developed countries and the "nationally appropriate mitigation actions" submitted by developing countries. All of the developing country submissions contain aggregate quantifications (though relative to GDP or a future baseline, as noted above). And the section heading for developed countries reads "mitigation commitments or actions" while the (separate) developing country heading reads "mitigation actions" only. Thus, all parties were able to interpret the decisions as they saw fit: developing countries could emphasize the differences between developed and developing

[20] In the absence of a successor agreement to the Kyoto Protocol that also features binding targets and timetables, member states like Canada, that ratified the protocol but did absolutely nothing to address their noncompliance, have been able to evade any sanction whatsoever.

[21] Victor (2004) refers to the Western industrial democracies as residing within a "zone of law" that provides a basis for the trust that must be present before any high level of asset exchange can take place.

[22] In Copenhagen, it proved impossible to achieve more than a general acknowledgement of the existence of the Copenhagen Accord due to severe acrimony over the process leading to the Accord. However, most of the Copenhagen Accord language exists almost verbatim in the Cancun Agreement.

country commitments, developed countries could emphasize the similarities. In addition, the negotiations over a second commitment period for the Kyoto Protocol continue despite the absence of the U.S., Japan, Russia, and (as of June) Canada.

Concrete mitigation pledges by China in an international venue, alongside pledges by other major emitters, represent a huge success by the U.S. In his first public address as the U.S. Special Envoy on Climate Change, Todd Stern emphasized that an international agreement on climate change needed to reflect ambitious national actions by all major economies (T. Stern, 2009a). An equally significant and important advance is that all the major emitters have accepted (in principle) provisions for measuring progress toward those mitigation commitments in a transparent and objective way. This was a domain in which the large developing country emitters had been dragging their feet, and this concession is another victory for the West.[23]

In return for these concessions from the major developing country emitters, the developed countries agreed to provisions providing for financial support for developing country mitigation and, especially, adaptation. The developed economies first committed to providing resources approaching $30 billion over the 2010-2012 period, a substantial short-run commitment offered up in return for the concessions on mitigation commitments and transparent monitoring. In the longer run, the developed countries committed to mobilizing $100 billion per year by 2020 to address the needs of developing countries. However, this latter sum explicitly includes both *private* and public funding, and the latter explicitly including both bilateral aid and multilateral development assistance. The Cancun Accord also establishes a committee to improve coherence and coordination of climate finance delivery.

[23] For several years after international observers concluded that China had surpassed the United States as the world's largest emitter, China rebutted these claims in ways that looked increasingly awkward to external observers. See statements by Stern (2009c).

Can the developed countries really mobilize $100 billion per year? In March 2010, the UN Secretary General appointed a high-level advisory group to look at possible sources of finance to achieve this goal. One of us was heavily involved in the work of this group and helped produce the November 2010 report that concluded the goal was "challenging but feasible" (UN SyG 2010). The report argues that the key to effective realization of this goal is the establishment of active carbon markets in the developed world that effectively impose a price on emissions in the neighborhood of $20-$25 per ton. These markets would generate private sector demand for developing country trading or offsets that could supply a large portion of this total on an annual flow basis. More specifically, to the extent that the carbon markets in the industrial West could allow the purchase of permits or offsets in developing countries, this could generate annual flows on the order of $30-$50 billion. And the carbon markets would likely stimulate hundreds of billions of dollars in related capital investments in developing countries over time. Successfully mobilizing the private sector leaves a much smaller role for public sector aid and allows it to focus on those areas where the private sector may fail – including adaptation for the poorest.

The report also suggested that carbon markets, with a price of $20-$25 per ton, would generate substantial permit auction revenues. Earmarking just 10% of these revenues to international climate action could, in principle, generate annual flows on the order of $30 billion. In a related way, pricing emissions from the international transportation industry (maritime and aviation) could create revenue with fewer domestic claims and possibly a larger share dedicated to international climate finance purposes. This industry generally requires some form of international harmonization to avoid the rerouting of shipments through unregulated ports in any case. Regulating this industry under a globally harmonized system of national market-based regulations could generate additional revenue flows on the order of $10 billion per year. It would also avoid the kind of conflict currently erupting over the

E.U.'s effort to regulate emissions on both inbound and outbound international flights (e.g., Shannon, 2011). All of this, the report notes, however, hinges on national-level decision-making.

In a very crude sense, the deal in Cancun can be viewed as a trade where developing countries received pledges of financial support from the developed countries and the developed countries received mitigation pledges from the developing countries. But it is considerably more complex than that because the important countries making mitigation pledges – the emerging economies – are not the ones lining up for financial support – the poorest countries and Africa in particular. And it was only through some creative ambiguity, allowing developed and developing countries to interpret the outcome differently, that an agreement was reached. This makes elaboration of some elements of the Cancun agreement elusive. For example, the climate finance report noted above specifically highlighted divergent views about the relative roles of public and private finance within the $100 billion pledge. Efforts to formalize the review of pledges has also become bogged down.[24] And meanwhile, questions surrounding the future of the Kyoto Protocol, minus the U.S., Japan, Russia, and Canada, lurk in the background and continue to confound the negotiations.

While the serious engagement of emerging economies was a historic development in Cancun, it is hard to see how the UNFCCC moves much beyond a struggle to implement the Cancun agreement in the foreseeable future. This is observation is based on the multitude of noted challenges, and the fact that two years of negotiations and attendance by more than 100 heads of state in Copenhagen failed to deliver more.

5. Beyond Cancun

[24] Widely divergent views can be seen in the negotiation summary released in June 2011 http://unfccc.int/files/meetings/ad_hoc_working_groups/lca/application/pdf/summary_on_ica_17_june_version_0900.pdf.

In the much longer run, even Kyoto critics like Victor concede that a strong, broad-based agreement with legally binding targets of some kind will eventually be needed to mitigate climate change.[25] In the short run, though, the UNFCCC has demonstrated its inadequacy as a framework within which such an agreement could be built. This has given rise to an alternative view about how to proceed. Rather than pursue a "broad and shallow" strategy (the current UNFCCC approach) that seeks to engage the maximal number of states by only requiring commitments that they are all willing to accept, Victor and others instead advocates a "narrow and deep, then broad" strategy that first brings together the subset of states that are willing to engage in meaningful policy experimentation.

For advocates of this strategy, there are interesting historical parallels, some of which are the focus of other chapters at this conference. One is the WTO itself. When it first began, as the GATT, it was narrow in focus and in membership. The original agreement's purview was restricted to trade in physical goods and focused almost solely on a gradual multilateral reduction in tariff rates. The initial membership excluded the Soviet bloc, and as decolonization proceeded in the 1950s and 1960s, many of the newly created states did not rush to join. Over the span of several decades, however, the GATT morphed into the WTO -- an international organization with a much broader purview (that extended to trade in services, intellectual property, and multinational investment), a near-universal membership, and much more powerful means of adjudicating disputes and punishing offending member states than had ever existed under the GATT. In fact, for Victor, the only current international body that possibly has the clout to enact and enforce a meaningful international agreement to limit climate change is the WTO.

[25] As Cooper (2010) and Nordhaus (2007) have argued, these international targets can take the form of commitments to specific carbon prices (enforced through taxes) rather than levels of emission reduction. Cooper (2009) points out several theoretical and practical reasons why a price target may be more easily implementable by the international system.

In some ways, an even more intriguing parallel is the growth of the EU. What is now the EU originally started as the European Coal and Steel Community, an effort by six European states to coordinate policy and reconstruction in these two sectors. Over time, the depth of cooperation and the extent of policy coordination broadened. Eventually, of course, the European Union became something so important that the states of the post-Communist East and even Turkey were willing to make quite substantial changes and amendments to their own national laws, and engage in costly concessions in order to quality for membership.

In similar fashion, a near-term future could emerge in which a handful of states are willing to undertake serious policy experiments to combat global warming. Rather than constrain the progress of this group by forcing it to meet the objections of the least committed states, or trying to negotiate an agreement before each nation resolves its internal political debates, it is far better to permit this group (and other groups) to move forward, engage in policy experimentation that other states could learn from, and turn the zone of law, or at least part of it, into a "zone of experimentation" in climate mitigation policy. As the successes (and failures) of policies within the zones of experimentation become manifest, and the case for action becomes more compelling, others may opt for accession into the zone. At some point, the countries inside the zone become an important enough collective that other countries perceive a penalty for remaining outside.

As a pre-requisite to even this narrow-and-deep approach, countries will essentially take initial steps unilaterally, as the EU ETS has done. While exercises like the GATT and the EU itself offered significant and immediate economic benefits (overall gains to trade) for each country to be weighed against the costs (those domestic industries hurt by freer trade), climate cooperation offers only near-term costs and long-term potential benefits. For this reason, it may be hard to negotiate something narrowly that leaders return home to implement within any kind of agreed window. Instead, it may be

necessary to key countries to pursue mitigation on their own terms and *then* seek to weave together cooperation afterwards or as a second step.

Regardless of how such a narrow-and-deep model arises, all of the economic inefficiencies and leakage concerns that we discussed in earlier paragraphs arise in the context of a less-than-global agreements. If a small group of countries begins to raise the price of carbon emissions, that begins to create incentives for emitting activities to relocate outside the group. And so long as the scope of search for emissions reductions opportunities is less than fully global, the marginal cost of those reductions will surely increase.

While simple economic logic might argue for a global unified approach, political reality points toward a less appealing, but more realistic future, over the short-to-medium run, of "fragmented carbon regimes" perhaps with little trading between them, and regional initiatives rather than global, multilateral ones.[26] Victor coins an evocative phrase, "variable geometries of participation," to indicate the need for flexibility, multiple approaches, and the need to let the theoretically optimal not get in the way of the practically beneficial.

6. *The Unsetting World of Border Measures*

Moving forward, those states and groups of states taking increasingly ambitious steps to mitigate climate change – whoever they are – will have to deal with slower moving states and the the economic and environmental leakage issues generated by their slower movement. The asymmetries of economic size among countries are such that the actions (or inactions) of a large number of developing countries are effectively ignorable. In the grand scheme of things, emissions from Mali or Honduras are and will be simply too small to matter. The real question for the industrial West is what to do about

[26] As Stavins (2007) points out, there need not be direct trading among various cap-and-trade programs to achieve the associated efficiency gains if they all feed off the same pool of offsets, which effectively equalizes marginal costs.

states like China that are large emitters and extremely important participants in the international trading and financial system? Or, what Europe will do about a lagging United States?

The unsettling answer we will suggest to this question is that those in the zone of climate policy experimentation may be driven to use tariffs or other measures that tax the carbon content of tradable goods produced in reluctant countries. The literature has referred to these instruments as carbon tariffs or, more generally (and euphemistically), as "border measures," and we will use both terms in what follows. The good news is that near-term differentials across trading states in terms of the stringency of their carbon control regimes is unlikely to warrant the use of these instruments. The bad news is that, the farther some countries get ahead of others, the more pressure will build to utilize these instruments. We will deal in this section with three questions: 1) are carbon tariffs WTO-legal?, 2) can those in the zone of climate policy experimentation implement carbon control measures without employing carbon tariffs, and 3) could carbon tariffs be implemented in practice.

8.1 Are Carbon Tariffs WTO-Legal?

The WTO-legality of carbon tariffs is an open question among legal scholars. Advocates see in the so-called "shrimp turtle" case a WTO affirmation of principles that could support carbon tariffs, and we offer here a brief review of that case. In the mid-1990s, environmental groups sued the U.S. federal government over inadequate enforcement of a U.S. law, Public Law (P.L. 101-162, Section 609; now 16 U.S.C. 1537), that was designed to protect sea turtles from shrimp trawlers. The nets of U.S. fleets were equipped with so-called turtle exclusion devices (TEDs) that allowed sea turtles caught in nets to escape through a trap door mechanism. By the mid-1990s, however, the U.S. was importing large quantities of shrimp from South and Southeast Asian nations that did not require the use of these devices. The U.S. imposed an import ban on these nations pending adoption of TEDs.

India, Malaysia, Thailand and several other countries launched a formal dispute against the United States, basing part of their legal argument on a longstanding principle in international trade law that prevents importing nations from discriminating against otherwise identical products on the basis of differences in the processes of production. In its final ruling, the WTO ruled against the United States for technical reasons, but the ruling explicitly upheld the right of the U.S., in principle, to apply discriminating trade measures against the shrimp exporters without TED requirements because sea turtles were an exhaustible natural resource as covered by Article 20 of the GATT. This was true even if the sea turtles in Asia never migrated to U.S. waters.

Environmental advocates have seized on this ruling as creating a precedent for carbon tariffs. The atmosphere, they argue, is surely even more of an exhaustible natural resource than are migratory sea turtles. In fact, the extent of the precedent created by the shrimp turtle case is unclear. Chinese trade representatives have flatly declared carbon tariffs illegal under WTO rules and have vowed to launch an immediate case against any nation that enacts legislation requiring the imposition of carbon tariffs. The final legal status of this idea will likely be determined when the first attempt is made to implement it by a WTO member state.

Other environmental advocates point to the way the international system has dealt with value-added taxes. China, for instance, obtains the largest portion of government revenue through a value-added tax (VAT) of 17%. When foreign goods are imported into China, the customs authority imposes this tax on the imports, in addition to import duties. If the VAT taxes were not imposed, the foreign goods would hold a commanding advantage in the marketplace over the domestically produced goods subject to the VAT. Since the tax is imposed on all goods, regardless of national origin, the tax meets the "national treatment" test. Exporters are entitled to value added tax rebates to avoid penalizing them in global competition with producers based in other countries without such taxes. In the eyes of some

environmental advocates, carbon tariffs would function like a VAT and need pose no more of a threat to free trade than does China's practice with respect to levying its VAT on imported tradable goods.

8.2 Are Carbon Tariffs Necessary? Part 1: The Problem in Theory

The theoretical construct of costless international trade in a homogeneous commodity between two economies helps us make the case for carbon tariffs. Imagine the home country constructs a carbon regulation regime -- for simplicity, consider a carbon tax -- to contend with environmental externalities, but the foreign country does not. Imagine the home economy is large enough relative to the global economy that its policies can affect global prices. Consider a carbon-intensive good. The carbon tax would tilt the home country supply curve up, but would not affect foreigners' export supply curve. Under these conditions, the primary impact of the carbon tax would be to shift home demand from (more expensive) domestic producers to (cheaper) foreign producers. The global price of the carbon-intensive good would rise, but only a little. Foreign supply would expand to meet home demand, and the ability of the domestic carbon tax to reduce emissions associated with the carbon intensive good would be largely undermined by international trade.

In this context, a carbon tariff that applies to imports of the carbon intensive good the same implicit price on emissions created by the home country's carbon tax would equalize the playing field for domestic producers, lead to a more substantial rise in the home market price of the carbon-intensive good, and a more substantial decline in emissions. The environmental externality would be better addressed. Home producers shrink less under this policy than under a policy of a unilateral carbon tax, and the home economy exploits its international market power to extract surplus from foreign producers. On the other hand, the carbon tariff would cause the foreign price of the carbon-intensive good to decline, as imports are pushed out of the home market. This would lead to a decline in foreign production but an increase in foreign consumption.

In simple cases, it is possible that the combination of a carbon tax and a carbon tariff on imports could bring domestic production and consumption of the carbon-intensive good in the home country to the same level that would obtain in a world of uniform global carbon taxes. It is obviously not possible for the combination of domestic carbon taxes and carbon tariffs to bring about the same outcome in the foreign country.

Moving away from our stylized example, in the real world quality and technology differences between domestic and foreign products could blunt the impact of (initially) small differences in production cost. On the other hand, to the extent that the foreign economy is open to foreign direct investment, over time the advent of carbon regulation in only the home economy would confer upon home producers of carbon-intensive goods a powerful incentive to transfer their technologies, brand names, and quality-control methods to subsidiaries based in the foreign economy. Also over time, a general equilibrium setting blunts some of the negative impact of a shrinkage of domestic production in the home economy -- these resources would find employment elsewhere in the home economy, leading to an expansion of the non-carbon-intensive sectors. While this might mitigate long-term concerns about economic leakage, even a general equilibrium setting does not mitigate the problem of emission leakage, with carbon intensive activity moving from the regulated jurisdiction to the unregulated jurisdiction.

8.3 Are Carbon Tariffs Necessary? Part 2: The Problem in Practice in the Short Run

To what extent are these concerns likely to arise in the context of advanced Western (post)industrial economies? Precisely because the U.S. government has long harbored concerns about the impact of adopting carbon regulation on U.S. competitiveness when developing countries were not also similarly constrained, there is a body of research -- some of it undertaken by the U.S. government at the behest of nervous legislators -- to which we can turn. The following paragraphs draw heavily from

work by one of the authors (Joseph E. Aldy & Pizer, 2010) and from a U.S. government interagency report on the competitiveness effects of the Waxman-Markey bill (H.R. 2454, formally known as the American Clean Energy and Security Act of 2009) in which one of the authors was directly involved (Interagency Competitiveness Analysis Team, 2009; hereafter Interagency Report).

For those trade economists eager to avoid conflict between their free trade ideals and their environmental conscience, this work offers some good news. The primary impact of carbon regulation is to raise the price of fossil energy in the economy. The impact of such regulations on U.S. industrial competitiveness is bounded by the fact that on average, energy expenditures account for less than two percent of the value of U.S. manufacturing output. This means the vast majority of U.S. industry would be largely unaffected by carbon regulation in the short-run: Even advocates of such policies suggest that carbon prices would remain relatively modest ($10 - $25 per ton CO2-e) in the near-term future, and would imply modest increases in fossil energy prices that would have very limited impact on the overall cost structures of U.S. manufacturers.

The second factor limiting impact is that some energy-intensive activities are not subject to much international competition. H.R. 2454 contained provisions for measures to mitigate the impact of the bill on U.S. industrial competitiveness. "Presumptive eligibility" for these provisions was based on an industry's energy intensity, greenhouse gas intensity, and trade intensity. The Interagency Report concluded that only 44 of about 500 manufacturing industries would be presumptively eligible for relief, as shown in Figure 4. Together, these energy-intensive and trade-exposed industries collectively account for only 12 percent of total manufacturing output and 6 percent of manufacturing employment -- and only half a percent of total U.S. non-farm employment. On the other hand, these industries account for almost half of manufacturing greenhouse gas emissions.[27] It is exactly this concentration of

[27] See the Interagency Report, pp. 1-2.

GHG emissions in a relatively small number of industries that allows a cap-and-trade approach to carbon regulation, such as that put forward in H.R. 2454, to compensate vulnerable industries without necessarily invoking carbon tariffs or blunting the overall impact of the regulatory regime on the gradual decarbonization of the U.S. economy.

Having recognized that only a small number of industries are potentially impacted, the question of the impact on those industries remains. There is an extensive economic literature on the "pollution haven" hypothesis that evaluates the impact of environmental regulation on the shift of polluting activity to less regulated environments. Important recent papers included Jaffe et al. (1995), Levinson and Taylor (2008), Antweiler et al. (2001), Ederington et al. (2005), and Jeppesen et al. (2002). The general findings in this literature suggest that the ability of industry to profitably relocate to less regulated jurisdictions is significantly constrained by factors which limit the "footlooseness" of polluting industry, and most studies find the negative impact of domestic environmental regulation on domestic production to be quite limited.

The aforementioned studies focus on generic environmental regulation, taking advantage of historic variation in regulatory stringency to understand its effect. It is not possible to take the same approach for carbon regulation because such regulation has only recently been implemented (and only in Europe). The popular alternative has been use detailed, applied general equilibrium models to simulate effects (IPCC, 2001). Early analyses found emission leakage ranging from zero to 70 percent, but later analyses found a narrower range of 5 to 20 percent. That is, the ratio of emission increases *outside* those countries pursuing emission reductions (in these studies, typically Kyoto's Annex I) to the reductions achieved *inside* those countries, is some 5 to 20 percent.

As an alternative to these studies using assumed parameter values and large simulation models to estimate leakage effects, Aldy and Pizer (2010) take an econometric approach using historic energy

price variation to proxy for the effects of GHG pricing. They first define the competitiveness effect as the adverse effect (in terms of the percent decline in production) on domestic industry arising from the absence of foreign regulation when the U.S. regulates GHGs – a more economic and less environmental measure than the leakage rate described above.

They then run regressions of the form

$$Y_{it} = \alpha_i + \alpha_t + f(r_{US,it};\beta) + \delta' X_{it} + \varepsilon_{it}$$

where Y_{it} represents an industry and year-specific outcome measure – the natural logarithm of domestic supply and demand measures; the α's are fixed effects for industries (i), and years (t); $r_{US,it}$ represents the level of U.S. regulation – the natural logarithm of energy (electricity) prices; X_{it} is a vector of additional determinants of the industry outcome measures, including average industry tariffs and factor intensity variables (to estimate the returns to human capital and physical capital). They show that the difference in the effect of energy prices on demand and supply – that is, the effect of energy prices on net imports – equals the competitiveness effect under certain assumptions. When they estimate the effect and ask what the impact would be of regulation along the lines of H.R. 2454, they find that even the most energy intensive industries would face a competitiveness effect of less than 1 percent.

Regardless of whether we are concerned with economic or emissions leakage, these impacts can be substantially reduced when permits are freely allocated *and* done so in proportion to output (Fischer & Fox, 2010). While most climate change economists would support a policy that allocates emissions permits by open auction in the long run, most climate change bills seriously entertained in the U.S. Congress (including H.R. 2454) provide some transition path along which a significant fraction of permits are provided at no charge to emitting industries. If this free allocation is tied to current production

increases in the price of energy-intensive goods can be muted while the incentive to reduce direct emissions within the industry remains. Based on the Interagency Report, the allocation provisions in H.R. 2454 nullify price impacts in the most energy-intensive industries, as seen in Figure 5.

For international economists who understand the importance of protecting the world's open trading system, this is good news. It suggests that the first steps toward carbon regulation could be taken by groups of advanced industrial countries without imposing on those countries serious competitiveness concerns, and a regulatory framework like a cap-and-trade system can be designed to further minimize these impacts without generating a significant need for trade intervention. Even if there is a political need to include the specter of border measures in a national mitigation policy, their actual scope and use can be constrained to be minimal if not non-existent in practice.

8.4 Are Carbon Tariffs Necessary? Part 3: The Problem in Practice in the Long Run

The analyses above are limited to the case in which Western carbon prices are held to relatively low levels. Standard economic analysis suggests that this is where carbon prices have to start in any case. An immediate shift to punishingly high carbon prices would instigate costly output contractions, slow growth, and high unemployment. A gradual shift over time to high carbon prices permits the economy time to gradually transition from our current carbon-intensive industrial structure to something far more sustainable in the long run. This point – that emission reductions and increasing carbon prices should occur gradually over time – was first made in an influential paper by Wigley, Richels, and Edmonds (1996). However, even these analyses recognize that, in the longer run, those carbon prices have to rise to quite high levels to achieve stabilization.

Nordhaus (2008), drawing upon decades of work in the economic modeling of climate change policy, argues that by 2100, the global carbon price needs to be at least $202 in 2005 U.S. dollars. Limiting global mean surface temperature increase to 3 degrees (Celsius) or limiting global GHG

atmospheric concentrations to twice pre-industrial levels, as some environmentalists suggest, would require substantially higher carbon prices by 2100 and a steeper trajectory of carbon price increases over the 20th century. A more recent interagency study (IWG 2009) suggests optimal prices could be as high as $136 by 2050, though the central estimate is $45.

At these price levels, the aforementioned results emphasizing the limited import of competitiveness concerns vanish and countries enacting carbon regulation will have an increasing need for carbon tariffs if major economies remain outside the system. Such tariffs will be necessary either (or both) as a stick to compel developing country compliance with Western environmental goals or as a wall to defend against an onslaught of carbon intensive imports. If we reach that point without a comprehensive political solution – or without a breakthrough technology solution – the global system will face a number of uncomfortable choices. Those pursuing carbon regulation will have to decide whether continued, ambitious actions can be effective and worthwhile absent some of the largest emitters. And, if the decision is affirmative, they will have to choose between an adherence to free trade principles that has brought a greater measure of prosperity to billions, and preservation of the natural environment on which all of humanity ultimately depends.

8.5 Could carbon tariffs be implemented in practice?

As we wrap up our discussion of carbon tariffs, an important final question raised in some of the literature is whether a carbon tariff could even be implemented in a meaningful way. Two particular issues arise: supply chain and production technology. Carbon tariffs would presumably focus on the country of importation. However, many supply chains involve components manufactured and assembled in a multiple countries. Ascertaining where production and emissions occur, and which emissions occur in countries without appropriate emission regulations could be quite hard. In addition, if one country in a coalition of carbon-regulating countries fails to enact carbon tariffs, it would be

possible for non-regulating countries to ship goods to that country for final assembly. The final product could then be imported to other carbon-regulating countries without being subject to carbon tariffs.

Distinct from supply chain issues is how one could practically address the differences in production technology and energy supply. Carbon taxes and cap-and-trade systems are relatively simple policies in that they focus on the point of emissions or fossil fuel use, where emissions are easy to measure, and allow product prices to adjust based on the market. In contrast, carbon tariffs on products would have to estimate the carbon content of that product when it appears at the border, including indirect emissions from all sub-components. A standard tariff could be applied to similar product imports from all unregulated countries, or the rates could be differentiated by country of origin or even by individual producer. Differentiation would create an incentive for foreign producers to improve their technology, but could prove to be prohibitively expensive to implement (Persson, 2010). More generally, the government costs to track and apply even standard tariffs would be quite high; an entire government agency might be necessary to implement carbon tariffs, depending on how broad they were.

A different concern, and one that will be all too familiar to trade economists, is that it will be impossible for any well-intentioned border measure to remain well-intentioned. Any discretion given to officials responsible for implementing border measures would be ripe for abuse.

9 Conclusion

This essay has reviewed the history of international efforts to curb global warming and the rising specter of carbon tariffs. Despite more than two decades of international engagement on this issue, the international community has made surprisingly little progress toward the goal of substantially reducing GHG emissions. We have argued that the evolution of the Kyoto Protocol, its problems, and the difficulty key nations have had negotiating a successor agreement that broadens and extends its binding targets

and timetables points to several lessons for policymakers and social scientists. Of particular concern for economists is the degree to which the kinds of policies prescribed by straightforward application of economic theory often conflict with political reality.

Economic theory suggests that the most efficient approach to reducing emissions is a global, integrated approach that equalizes carbon prices across countries. It is particularly important to bring developing countries into this system, since that is where most emissions growth will occur over the next century and where the most inexpensive mitigation options are located. Recent modeling efforts suggest that even if the developed Annex I nations reduce their emissions to zero by 2050, growth in developing country emissions will make it all but impossible to hit even modest targets for atmospheric stabilization of GHG emissions.

Unfortunately, the reluctance of key developing countries (and, at the moment, the United States) to accept binding emissions reduction targets of any kind and the inability of the international system to compel a reluctant state to accede to a global climate change agreement makes the theoretically optimal approach impractical in the short-to-medium run. Moreover, developed countries are no longer willing to go it alone. Given that, this essay has suggested that progress in the short-to-medium run is likely to take place at the national or regional level through policies that are not globally enforced. Evidence suggests that the policies envisioned over this horizon on the one hand produce modest carbon prices and limited emissions reductions (relative to a no control baseline) but on the other hand nations or groups of nations can engage in this meaningful and useful policy experimentation without substantially harming their competitiveness.

The international agreements reached at Copenhagen and in Cancun have moved away from top-down, Kyoto-style global agreements with binding targets and instead have embraced a more bottom up, pluralistic approach along these lines. Current negotiations also establish the practical and

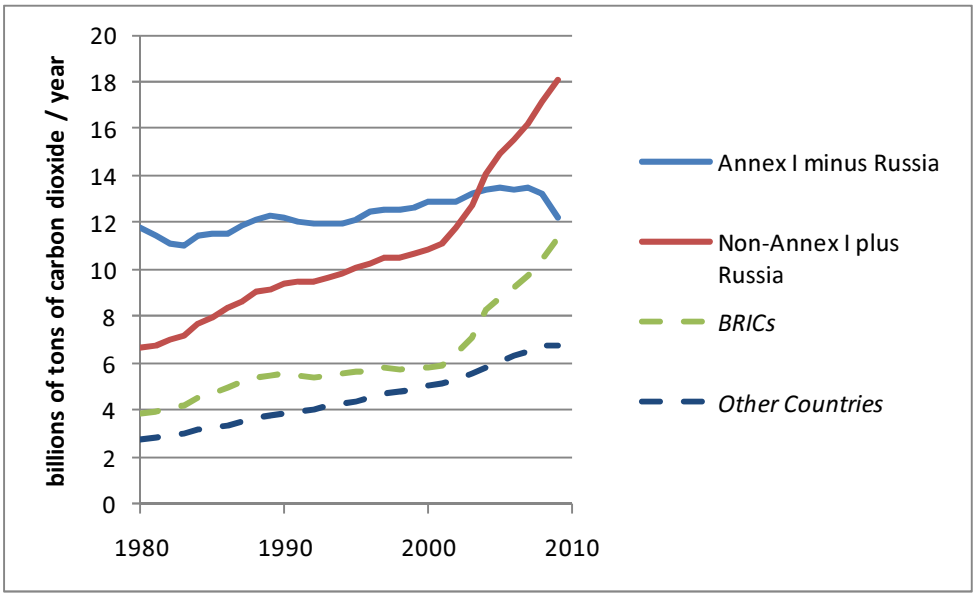
political goal to mobilize significant financial flows – public and private – to developing countries to promote climate change mitigation and adaptation. The implementation of modest market-based carbon regulation regimes in the Western countries, along with provisions allowing developing country offsets, could generate private capital flows that would go a long way toward meeting these goals. Market-based policies in developed countries could also generate substantial domestic revenues, of which a portion might be directed towards developing country efforts.

As those nations willing to engage in meaningful carbon regulation proceed down this path and other key countries lag behind, there is increasing pressure for them to use "border measures" to prevent the leakage of carbon-intensive emissions and economic activity out of these countries and into more lightly regulated jurisdictions. Most analyses suggest that such effects are not large enough over the near term to require such a border-measure response and that alternatives such as output-based free allocation are more effective and practical to implement. Nonetheless, political pressure could easily lead to a roadblock where domestic policies will not proceed without at least the threat of trade measures – as they did during the development of H.R. 2454 – bringing the goals of trade openness and effective mitigation of climate change into conflict. Over the longer run, with higher prices and without a comprehensive agreement or a technology breakthrough, ambitious action will almost certainly *require* substantial border measures, although such action may not make a lot of sense if large sources of unregulated emissions remain unchecked, let alone the conflicting goal of trade openness.

For many in the environmental community, the grumblings of economists over conflicts with free trade are virtually inconsequential compared to the broader consequences of having abandoned pursuit of global legally binding targets. Catastrophic climate change is such a looming threat that a lengthy period of incremental advance that precedes real global efforts to substantially reduce emissions is unacceptable. However, many of those grumbling economists will disagree. As noted

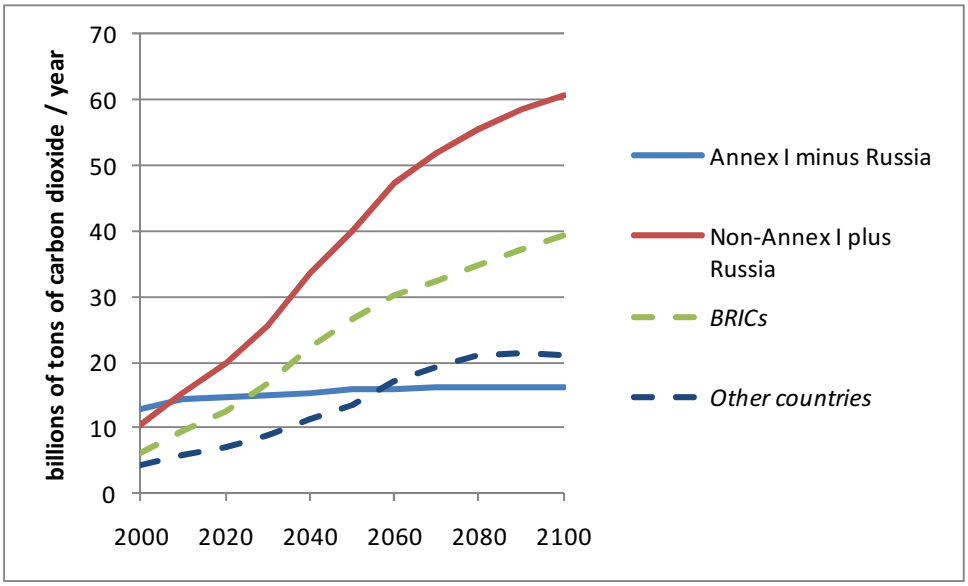
earlier, analyses of the targets agreed to in Cancun and Copenhagen point to 3 degrees or more of warming, which is still less than the counterfactual of no mitigation effort where expected temperature change would be in the 6 degree (or higher) range. Arguably, the incremental advances in Copenhagen and Cancun will reduce the negative economic impact of climate change, but still risk significant impacts including reduced agricultural productivity, water shortages, ecosystem loss and extinctions, increased coastal flooding, and increased health burdens (IPCC 2007). More importantly, they may simply be the necessary and unavoidable institutional steps that precede a more robust international response.

Figure 1 The Majority of Emissions Now Comes from Developing Countries



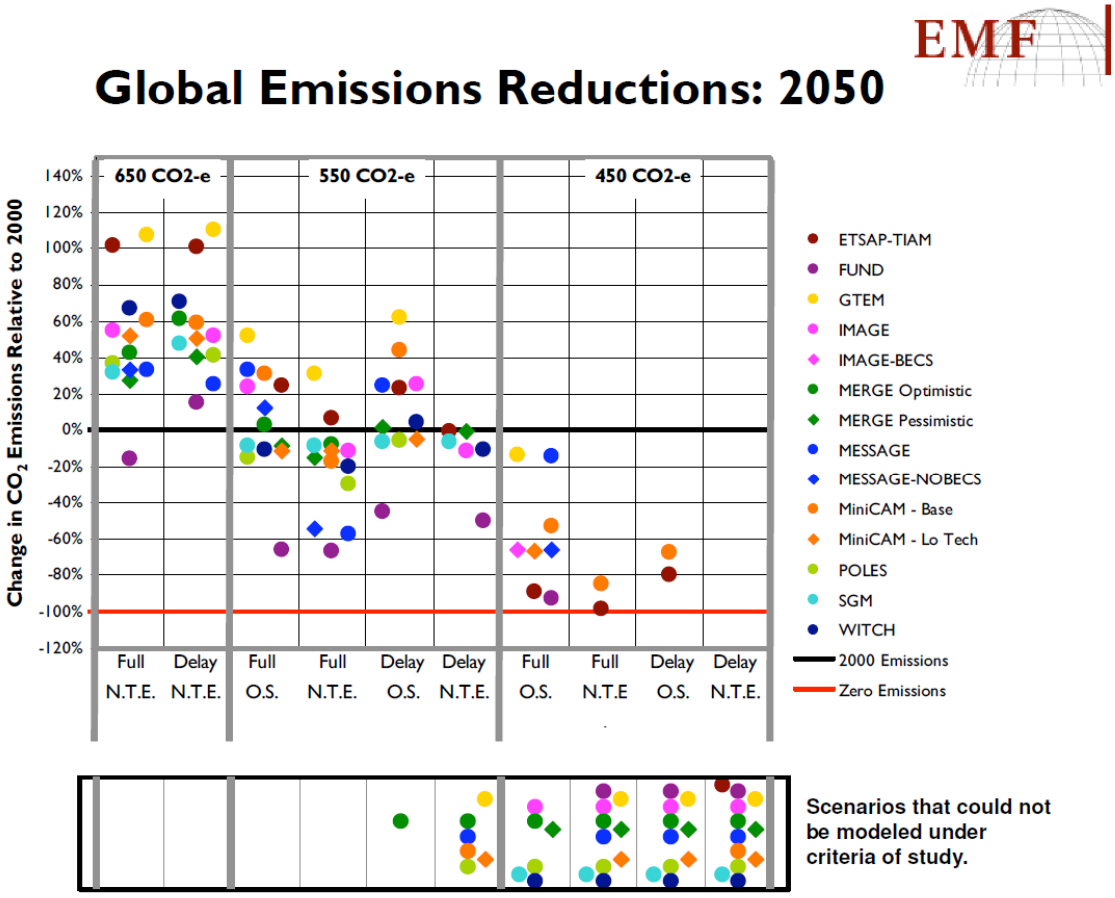
Source: Energy Information Administration (2011). Groupings were chosen to match those used by the Energy Modeling Forum below: Annex I (referring to a listing in the UNFCCC) includes the traditional "developed countries" and former Soviet republics. BRICs include Brazil, Russia, India, and China.

Figure 2 Expected Emissions Growth Is Overwhelmingly in Developing Countries



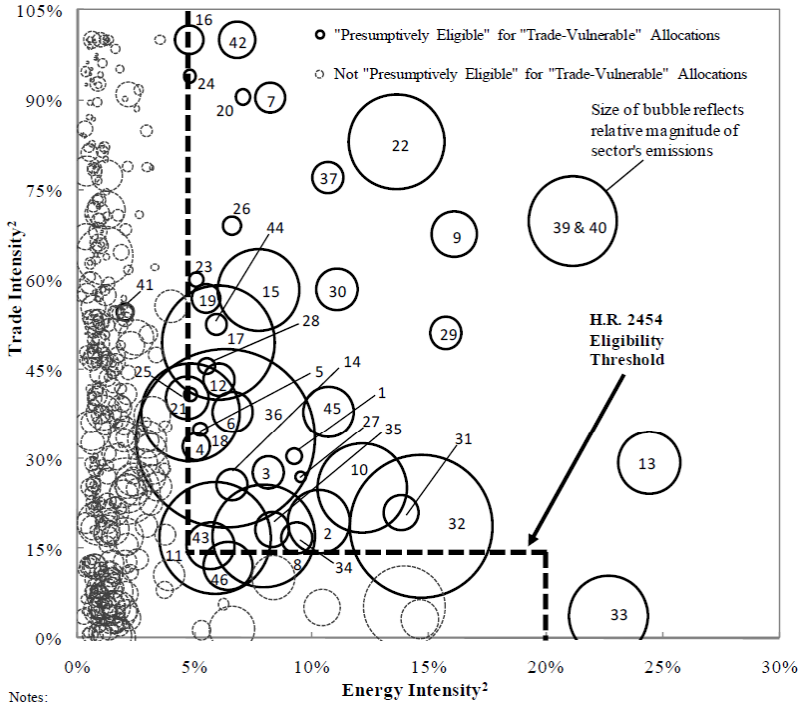
Source: SGM reference case, Energy Modeling Forum (2009). Annex I (referring to a listing in the UNFCCC) includes the traditional "developed countries" and former Soviet republics. BRICs include Brazil, Russia, India, and China.

Figure 3: Limiting Warming to 2 degrees C (450 CO2e) Requires Immediate Participation by All Countries and Negative Global Emissions.



Source: Clark et al (2009). The figure shows the relationship between concentration targets (*x*-axis) and emissions (*y*-axis) and highlights the consequences of a delay in developing country actions ("delay") and the requirement that atmospheric GHG concentrations are not to exceed ("NTE") the long-run target.

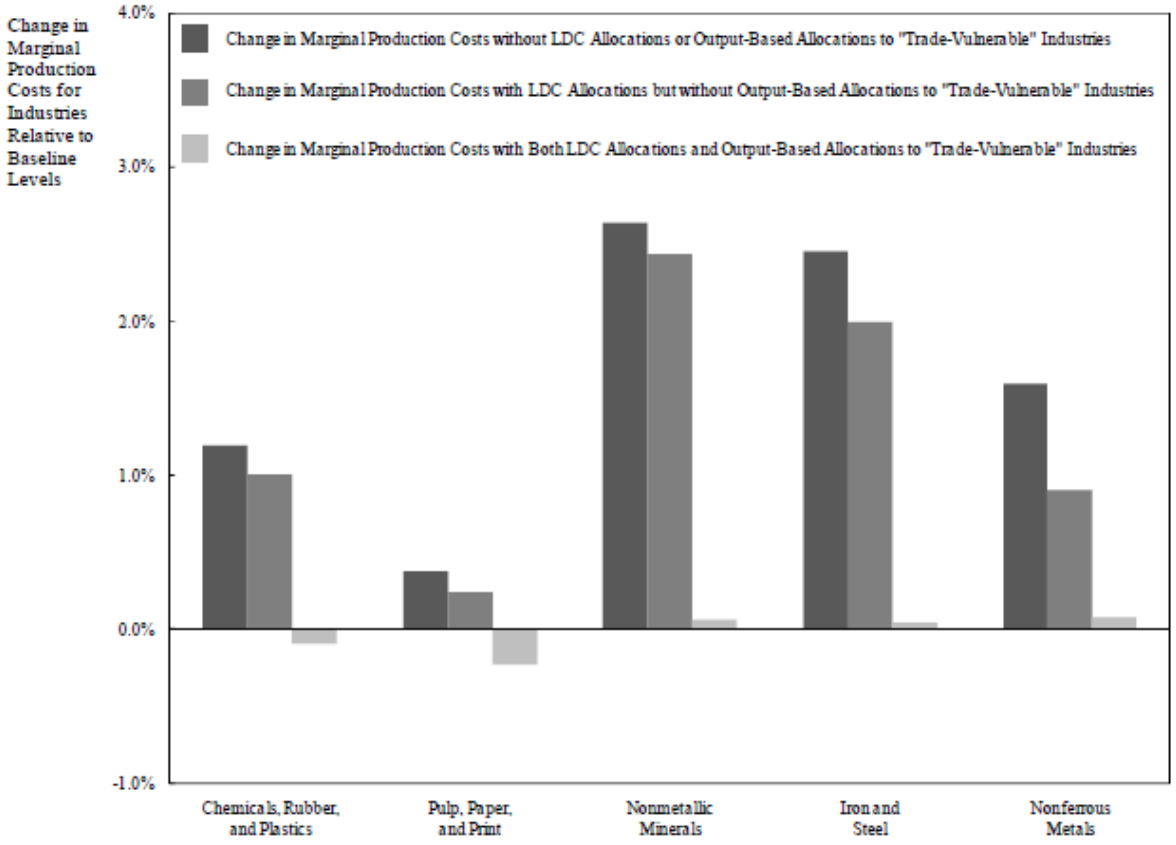
Figure 4 The bulk of carbon dioxide emissions come from a small number of industries that have high energy and/or trade intensity; these are "presumptively eligible" for free allowances under H.R. 2454



Notes:
1. Petroleum refining is not depicted because it is explicitly excluded from H.R. 2454's allocations to "trade-vulnerable" industries. Also, 91 other sectors, with 130 $MMTCO_2e$ of emissions, are not depicted due to lack of trade intensity data. One of these, iron and steel pipe and tube manufacturing from purchased steel (331210; 2.6 $MMTCO_2e$) is expected to be eligible based on language in the bill. Four others meet the energy-intensity threshold, each with 2 to 3 $MMTCO_2e$ of emissions: beet sugar manufacturing, broadwoven fabric finishing mills, steel foundries (except investment), and metal heat treating. Twelve sectors with a calculated trade intensity greater than 100% are depicted here with an intensity of 100% (the maximum possible intensity). The two copper sectors (212234 and 331411) do not meet the energy or trade intensity thresholds specified in H.R. 2454 but are expected to be eligible based on other language in the bill.
2. Energy intensity and trade intensity measures are as defined in H.R. 2454 and elsewhere in this report.
Source: EPA analysis.

1. Malt Manufacturing (311213)
2. Wet Corn Milling (311221)
3. Rendering and Meat Byproduct Processing (311613)
4. Yarn Spinning Mills (313111)
5. Tire Cord and Tire Fabric Mills (314992)
6. Reconstituted Wood Product Manufacturing (321219)
7. Pulp Mills (322110)
8. Paper (except Newsprint) Mills (322121)
9. Newsprint Mills (322122)
10. Paperboard Mills (322130)
11. Petrochemical Manufacturing (325110)
12. Inorganic Dye and Pigment Manufacturing (325131)
13. Alkalies and Chlorine Manufacturing (325181)
14. Carbon Black Manufacturing (325182)
15. All Other Basic Inorganic Chemical Mfg. (325188)
16. Cyclic Crude and Intermediate Manufacturing (325192)
17. All Other Basic Organic Chemical Mfg. (325199)
18. Plastics Material and Resin Manufacturing (325211)
19. Synthetic Rubber Manufacturing (325212)
20. Cellulosic Organic Fiber Manufacturing (325221)
21. Noncellulosic Organic Fiber Manufacturing (325222)
22. Nitrogenous Fertilizer Manufacturing (325311)
23. Vitr. China Plumbing Fixture and Other Mfg. (327111)
24. Vitreous China and Other Pottery Mfg. (327112)
25. Porcelain Electrical Supply Manufacturing (327113)
26. Ceramic Wall and Floor Tile Manufacturing (327122)
27. Other Structural Clay Product Manufacturing (327123)
28. Nonclay Refractory Manufacturing (327125)
29. Flat Glass Manufacturing (327211)
30. Other Pressed/Blown Glass and Glsswr. Mfg. (327212)
31. Glass Container Manufacturing (327213)
32. Cement Manufacturing (327310)
33. Lime Manufacturing (327410)
34. Ground or Treated Mineral and Earth Mfg. (327992)
35. Mineral Wool Manufacturing (327993)
36. Iron and Steel Mills (331111)
37. Electrometallurgical Ferroalloy Product Mfg. (331112)
38. Iron/Steel Pipe/Tube Mfg. from Purchsd. Steel (331210)
39. Alumina Refining (331311)
40. Primary Aluminum Production (331312)
41. Primary Smelting and Refining of Copper (331411)
42. Smltg./Rfg. of Nonfrs. Mtl. (ex. Cpr. and Almn.) (331419)
43. Iron Foundries (331511)
44. Carbon and Graphite Product Manufacturing (335991)
45. Iron Ore Mining (212210)
46. Copper Ore and Nickel Ore Mining (212234)

Figure 5 **Effect of Domestic Cap-and-Trade Program on Marginal Production Costs of Energy-Intensive Trade-Exposed Industries without and with Allocations to Local Distribution Companies and Output-Based Allocations to "Trade-Vulnerable" Industries**



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