Theory and Evidence…

Carbon Emissions: Credit Trading versus Taxation

Policy Choices for Reality

by

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Introduction

The Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) states with ninety percent certainty that human created releases of greenhouse gases are the primary cause of global warming.[1] If global warming continues, it will have grave implications for the planet. Science predicts that a warmer planet will seriously alter weather patterns, causing severe weather that ranges from extremely intense hurricanes to floods and droughts. Heat waves will threaten the young and elderly as well as severely strain the electricity infrastructure in the developed world. Disease will spread more readily as colder seasons fail to ward off germs and populations of disease carrying insects. Melting polar ice caps will drastically alter ocean salinity and cause coastal flooding. Temperature, weather, and other environmental shifts will cause the extinction of species that cannot move or adapt quickly enough to survive the changes. On a human and economic level, these events will displace millions of people and cause severe hardship for those affected. We have already begun to see the effects.

Scientists and politicians immediately labeled 2005's devastating hurricanes Katrina and Rita as the product of a warming planet. Unsurprisingly, these events and their characterizations have personalized global warming and added a sense of urgency to the issue, particularly in the United States. In 2006, Al Gore's Academy Award winning documentary on climate change, *An Inconvenient Truth*, brought scientific evidence about global warming into the mainstream, adding to public concern. Americans and the rest of the world showed their concern for and curiosity about the subject by turning out

[1]House Speaker Nancy Pelosi, "We Will Work Together to Tackle Global Warming, One of Humanity's Greatest Challenges," February 8, 2007, United States House of Representatives, http://www.house.gov/pelosi/press/releases/Feb07/GlobalWarming.html (accessed April 1, 2007).

in record numbers to see the film; In its first weekend in theatres, *An Inconvenient Truth* grossed an average of $91,447 per theater, the highest ever average gross for a documentary.[2] The film went on to gross over $48 million worldwide, roughly equally split between the United States and abroad.[3] Prominent political figures quickly noticed the public's response to the film and the issue in general.

With two major storms ravaging much of the Gulf Coast region and a documentary proposing how much more destruction could result from global warming, politicians took advantage of an opportunity to make headlines on an issue that was of great public interest. By February of 2007, roughly ten months after the release of *An Inconvenient Truth*, Democratic Congresswoman and newly elected Speaker of the United States House of Representatives, Nancy Pelosi, began calling climate change "One of Humanity's Greatest Challenges."[4] In her remarks to a Science and Technology Committee hearing on global warming, she went further, promising prompt legislative action, when she said, "I have also asked the committees that have jurisdiction over energy, environment and technology policy to report legislation on these issues by June."[5] Adding a sense of national pride, importance, and patriotism to the issue, she remarked, "We hope to have legislation that will be a starting point on global warming and energy independence through the committees by July 4th, so that this year,

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[2][Internet Movie Database], "Studio Briefing," May 30, 2006, http://imdb.com/news/sb/2006-05-30/ (accessed April 1, 2007).

[3]"An Inconvenient Truth Summary," http://boxofficemojo.com/movies/?id=inconvenienttruth.htm (accessed April 1, 2007).

[4]House Speaker Nancy Pelosi, We Will Work Together to Tackle Global Warming, One of Humanity's Greatest Challenges," http://www.house.gov/pelosi/press/releases/Feb07/GlobalWarming.html.

[5]House Speaker Nancy Pelosi, We Will Work Together to Tackle Global Warming, One of Humanity's Greatest Challenges," http://www.house.gov/pelosi/press/releases/Feb07/GlobalWarming.html.

Independence Day is also Energy Independence Day."[6] Domestic issues, however, are not the only factors influencing political action.

Aside from the domestic issues driving the debate today, there is also large pressure from the international community, and particularly Europe, for the United States to adopt some type of proactive climate change policy. Currently, the European Union has implemented its own legislation aimed at meeting or exceeding its targets under the Kyoto Protocol, and these actions have placed their industries at somewhat of a competitive disadvantage by imposing abatement costs on businesses that competitors, particularly in the United States and China, do not bear. It is unlikely the United States can avoid adopting a policy for too much longer without angering its major trading partners in Europe or having its reputation suffer severely abroad. The time for action is nearing.

With so much evidence to show the reality of global warming, an increasingly concerned population, international pressure, and political control shifting toward a more environmentally conscious Democratic party, it is highly likely that the United States will adopt comprehensive climate change legislation in the next three to five years. Supposing this prediction comes to fruition, the enormous question of "what is the proper policy tool?" must be answered.

Literature Review

One might expect that issues of climate change, and specifically air pollution, would only have been discussed by scientists and environmentalists, but economists also

[6]House Speaker Nancy Pelosi, We Will Work Together to Tackle Global Warming, One of Humanity's Greatest Challenges," http://www.house.gov/pelosi/press/releases/Feb07/GlobalWarming.html.

have a rich history of work on the subject. In 1920, when Arthur Pigou published *The Economics of Welfare,* much of his work focused on the marginal costs and benefits to parties who were external to a given transaction. He deemed any effect felt by those who were external to the decision making process an "externality." In this seminal work, Pigou recognizes that self-interested economic actors often overlook the greater consequences of their activities, and he calls on the government to correct this market inefficiency, writing that "there is wide agreement that the State should protect the interests of the future *in some degree* against the effects of our irrational discounting and of our preference for ourselves over our descendants."[7] He calls this premise the basic conviction on which "the whole movement for 'conservation' in the United States is based," a notion that is still true today.[8] Pigou does not view this task of protection as a mere day-to-day responsibility of the government; he calls it a "clear duty of Government," a government which he views as the "trustee for unborn generations as well as for its present citizens, to watch over, and, if need be, by legislative enactment, to defend, the exhaustible natural resources of the country from rash and reckless spoliation."[9] An astute scholar of political economy, Pigou carefully notes that the extent to which the governments should legislate and how they should legislate "is a more difficult problem."[10] He did, however, suggest one policy choice.

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[7]Pigou, Arthur C., *The Economics of Welfare* [book on-line], Fourth ed. (London: Macmillan and Co., 1932, accessed 10 April 2007); available from http://www.econlib.org/LIBRARY/NPDBooks/Pigou/pgEW1.html; Internet.

[8]Ibid.

[9]Ibid.

[10]Ibid.

Focusing on the marginal differences between those who are "internal" to a transaction and those who are "external" to a transaction, Pigou observed that a simple tax could drive marginal private costs to rise and meet marginal social costs. This observation is one of Pigou's main contributions to economics as he was the first to suggest that governments can use policy tools to force economic actors to take into account society's costs when making decisions, or "internalize" externalities. The tax for this purpose is named the Pigovian tax in his honor. With pollution as one of the most widely cited examples of a negative externality, there is an argument that economists have been indirectly considering the impacts of pollution since 1920, and the literature largely evolves from Pigou's early ideas.

In 1968, J.H. Dales was the first to propose a market in pollution rights in his work *Pollution, Property & Prices*.[11] Under Dales' method, now referred to as cap-and-trade, the government decides on an optimal allowable level of pollution. It then treats the right to pollute as a property right and distributes these rights either through a grand-fathering of permits to current polluters or by auction. Once distributed, the permits trade freely with the expectation that holders will sell their permits if they can reduce their pollution for less than the market price and that polluters will purchase permits if their costs of abatement are higher than the market price. In the end, each actor seeks his own optimal path, which should create the optimal solution for society when all of these choices are aggregated. Later, economists argued that permit trading is a viable and preferable alternative to other control methods.

[11]JH Dales, *Pollution, Property, and Prices* (Toronto: University of Toronto Press, 1968).

In 1985, Bruce Ackerman and Richard Stewart argued in their article *Reforming Environmental Law* that tradable permits were a preferable policy option to command-and-control regulation, which they say "wastes tens of billions of dollars every year, misdirects resources, stifles innovation, and spawns massive and often counterproductive litigation."[12] Even though command-and-control policy is still used today, it is widely regarded as inefficient, and the government is moving toward policies that either tax externalities or implement tradable permit systems.

Policy Options

Thus, in the case of climate change, economic theory proposes two policy choices worth considering for implementation:

- **Taxation**
  Also referred to as a "charge system" or called "controlling by price"
- **Cap-and-trade**
  Also called "permit trading," "emissions trading," or "controlling by quantity."

Policy Choice Symmetry in Theory

A great deal of economic research has been devoted to comparing the taxation and cap-and-trade systems of regulating externalities. In his 1992 article, *The Symmetry between Controlling Pollution by Price and Controlling It by Quantity*, John Pezzey argues,

> "Under ideal conditions, controlling excessive pollution or congestion of a scarce public or common property resource by using a price-based instrument such as a fee or charge can be made symmetrical, in terms of short-run efficiency, long-run

[12]Bruce A. Ackerman, and Richard B. Stewart, "Reforming Environmental Law," *Stanford Law Review* 37, no. 5 May 1985 [journal on-line]; available from http://links.jstor.org/sici?sici=0038-9765%28198505%2937%3A5%3C1333%3AREL%3E2.0.CO%3B2-9; Internet; accessed 17 March 2007.

efficiency,' and political acceptability, to using a quantity-based instrument such as a marketable license or permit."[13]

Under his assumptions, he is entirely correct, but the true question for policy makers is whether or not those assumptions hold in reality.

As Pezzey admits, the assumptions under which this model holds "constitute perfect competition in its fullest sense."[14] This model, while academically sound, makes several impractical and unlikely assumptions. Among them:

- Firms…own different sets of fixed factors like enterprise and therefore have different marginal cost schedules for effluent control. Perfect information [about these differences] is freely available to all firms and to the pollution control authority
- Transaction costs are zero
- A perfect [pollution] authority, whose sole objective is to maximize public welfare, is assumed
- Time-dependent phenomena such as uncertainty and technical innovation in pollution control are ignored
- The "charge rate," or tax, does not vary from firm to firm or with time
- The baseline effluent right, which is initially given as a property right to each existing firm by the authority, may vary from firm to firm but does not vary over time

It is worth analyzing these assumptions in a real world context, for as the assumptions fail, the theoretically equivalent systems of taxation and emissions trading become fundamentally asymmetric for the purposes of policy adoption.

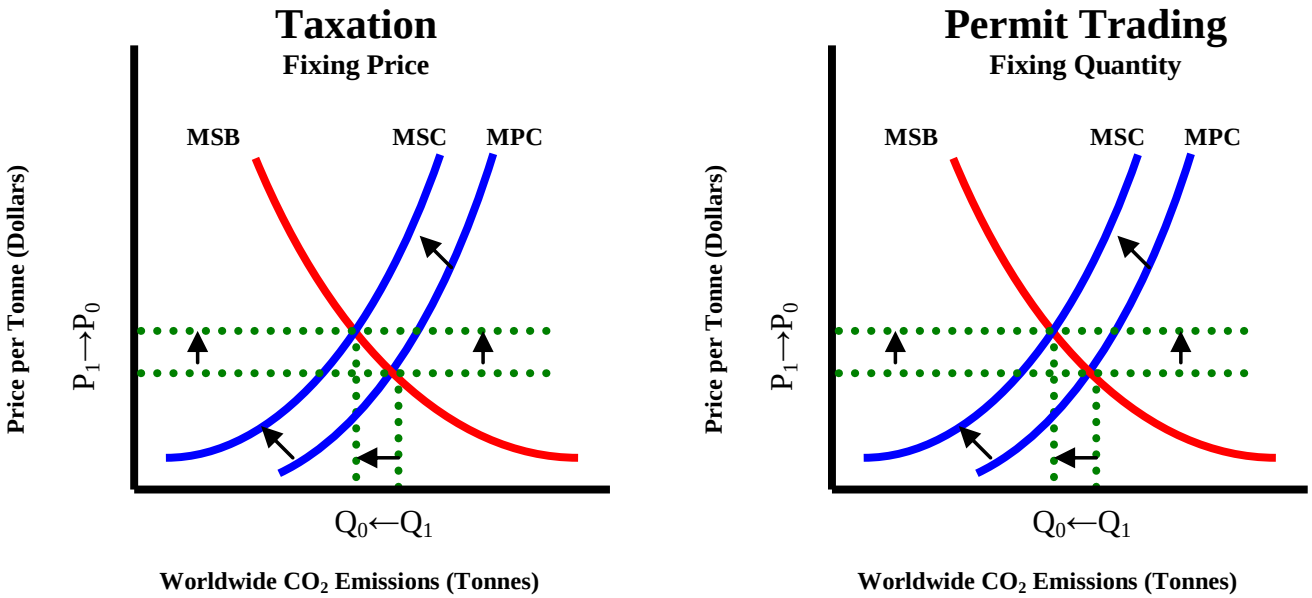
[13]John Pezzey, "The Symmetry between Controlling Pollution by Price and Controlling It by Quantity," *The Canadian Journal of Economics* 25, no. 4 November 1992: 983-984 [journal on-line]; available from http://links.jstor.org/sici?sici=0008-4085%28199211%2925%3A4%3C983%3ATSBCPB%3E2.0.CO%3B2-I; Internet; accessed 18 March 2007.

[14]Ibid., 984.

Informational Requirements and Challenges

On the most basic microeconomic level, taxation and cap-and trade initially seem to require the same information.

Figure 1: Theoretically Taxation and Permit Trading both Cause Marginal Private Cost (MPC) to Rise and Equal Marginal Social Cost (MSC)



In the ideal world, as seen in Figure 1, the assumed welfare maximizing pollution authority aggregates a Marginal Social Benefit curve (MSB), based on the benefits firms and society receive from varying levels of pollution, and a Marginal Social Cost curve, based on the total costs society incurs as a result of polluting at a given level. The MSB could also be called the "demand" for pollution or the Marginal Social Cost of Abatement curve; the MSC could also be called the "supply" of pollution. At the intersection of these curves, where the MSB equals MSC, the pollution authority determines the socially optimal level of pollution, Q_0, and the corresponding socially optimal price, P_0. This analysis requires that the central authority can accurately create the MSB and MSC

curves. In theory, this process is always assumed possible, but in practice it is likely a fatal leap of faith.

Aggregating the Marginal Social Cost Curve

Although economists readily assume that perfect information is available to policy makers, this is not the case in reality. Accurately estimating the marginal social costs of carbon emissions is a daunting and perhaps unachievable task. Academic studies in this area have varied widely in their findings, and the sheer number of variables and assumptions required to calculate a value makes the variability in these findings unsurprising. Further, even with perfect information, aggregating an MSC requires value judgments. The necessity of discussing these judgments in a policy debate will likely slow the legislative process, delaying progress on the time sensitive issue of climate change, and pose significant risk to politicians who will be forced to navigate the veritable ethical minefield of quantifying value judgments for the purposes of policy decisions.

In his 2005 article, *The Marginal Damage Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties*, Richard S.J. Tol points out the difficulty and complexity of aggregating the impacts of climate change when he writes, "[a] key challenge when assessing the impacts of climate change is the need to reduce the complex pattern of local and individual impacts to a more tractable set of indicators, so that impacts in different regions, sectors or systems can be summarized and compared in a meaningful way."[15] One key aspect of comparable figures is a common unit, and for

[15]R.S.J. Tol, "The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," *Energy Policy* 33 2005: 2064 [journal on-line]; available from

this analysis dollars or some other unit of currency are the preferred choice. Yet, Tol also admits that "[u]sing a monetary metric to express non-market impacts, such as effects on ecosystems or human health, is more difficult" and "can be controversial…"[16]

There are several controversial issues regarding quantitative monetary metrics and the estimates that result from them. Although climate change is a global issue, its impacts are local. Effects of global warming primarily relate to weather variability and extremes, which have subsequent consequences for local populations and economies. Naturally, local governments are interested in climate change's probable impacts on their societies, but even the best climate models, which are fairly accurate on a global scale, are relatively poor at such a local scale.[17] In a 1997 article entitled *Uncertainties in Projections of Human-Caused Climate Warming***,** J. D. Mahlman of the National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory concluded that "our confidence in predictions on these smaller scales will likely remain relatively low." He reasoned that improvements would only come with "[m]uch greater fidelity of calculated local climate impacts," requiring "large improvements in computational power and in the physical and biological sophistication of the models."[18] Local impacts are just one of the uncertainties in these calculations.

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http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V2W-4CJCVJ8-2&_user=30681&_coverDate=11%2F30%2F2005&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000000333&_version=1&_urlVersion=0&_userid=30681&md5=b9bf5c65b659c44422696eb851753dae#bib61; Internet; accessed 15 February 2007.

[16]Ibid., 2065.

[17]J.D. Mahlman, "Uncertainties in Projections of Human-Caused Climate Warming," *Science*, 21 November 1997, 1416 [magazine on-line]; available from http://www.sciencemag.org/cgi/content/full/278/5342/1416; Internet; accessed 20 March 2007.

[18]Ibid.

Supposing that extreme weather events and significant changes in weather patterns are a major result of global warming, social costs must account for the loss of human lives and, potentially, the loss of entire societies. This task poses the enormous ethical and economic question of whether all human lives around the world are equally valuable. Further, what is the appropriate discount rate for human lives globally? Should people in nations with a lower life expectancy and a lower general earning potential be valued using a higher discount rate to account for the riskiness of their futures? How would these discounted values be converted into a common currency for comparison purposes? Are current forward rates the appropriate conversions, and if they are, how do the values change as currencies fluctuate? If a country's floating currency falls in the marketplace, do the true values of global warming's impacts on it change along with the monetary proxy? Are people and nations worth less as their currency depreciates? What is the value of an island culture and its history or the value of a unique island species should they all be lost to a devastating hurricane? Tol recognizes the difficulty of accounting for these and other issues when he writes, "[a]ggregating impacts requires an understanding of (or assumptions about) the relative importance of impacts in different sectors, in different regions and at different times."[19] Further, these issues are not purely economic; this type of policy "involves value judgments."[20] Of course, comparing impacts "is simplified if impacts can be expressed in a common metric, but even then aggregation is not possible without value judgments" because of the environmental and

[19]Tol, The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," 2066.

[20]Tol, The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," 2066.

ethical issues involved.[21] These value judgments will have to be part of the debate about global warming if the MSC plays a vital role in policy decisions. These debates, much like those over other ethical and moral issues such as abortion and welfare, will likely be very slow to produce consensus, if consensus is even possible. Further, politicians will find themselves making value judgments under a media microscope, creating a politically treacherous situation that most policy makers would likely prefer to avoid if at all possible. Aside from the decision making process, one must also consider the quality of the informational inputs to the debate.

Other important factors to consider are the quality of information available and the extent to which correlations between events caused by climate change are understood. Assessing a global problem includes a thorough analysis of all nations, and "[w]hile our understanding of the vulnerability of developed countries is improving—at least with respect to market impacts—good information about developing countries remains scarce."[22] Further, "[n]on-market damages, indirect effects, horizontal interlinkages, and the socio-political implications of change are also still poorly understood," seriously compromising the value of quantitative estimates and the weight they should carry in a carefully considered analysis.[23] In one example, severe weather events could cripple a fragile government, leading to the rise of a dictator. The probability of this effect

[21]Tol, The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," 2066.

[22]Tol, The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," 2067.

[23]Tol, The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," 2065.

obviously varies over time with the stability of governments, economic conditions, general preparedness and weather event location.

There are even more factors that must be considered to aggregate a marginal cost curve, but are not well understood. Tol notes that "[u]ncertainty, transient effects, and the influence of change in climate variability are other factors that deserve more attention."[24] Hurricanes Katrina and Rita, which displaced populations from storm battered areas to cities such as Houston, illustrated the enormous local impacts of transient effects. Houston's leaders and citizens alike quickly found their educational system and other local resources under a significant strain as the population ballooned, crime rose, and the makeup of its population drastically changed in a span of a week. Had the hurricanes hit a part of Florida rather than closer to New Orleans, none of these effects would have happened in Houston, and it was not clear until just before the hurricanes hit land where they would go. Perhaps the only certainty when predicting the effects of climate change is that the outcome will largely depend on randomness.

Randomness not only plays a role in the outcomes caused by global warming, but also in their costs over time. Tol briefly discusses the case of malaria in his study, acutely noting that the world's risk from climate change may substantially vary over time. Malaria, for instance, has been a serious health issue in warmer climates for centuries. As the world warms, malaria will certainly become more prevalent as the mosquitoes that carry the disease do not die out during the cold season. It appears on the surface that the spread of malaria is a certain cost of global warming, but how much of a cost, the distribution of that cost and how that cost will vary based on human action is a

[24]Tol, The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," 2065.

very difficult question to answer. Tol astutely points out that humans might reduce the impact of malaria through "a successful effort to develop a malaria vaccine."[25] Conversely, the same efforts could exacerbate the problem as "[a] less successful effort could introduce antibiotic-resistant parasites or pesticide- resistant mosquitoes, increasing vulnerability to climate change."[26] Another outcome, which Tol does not discuss, is the possibility that humans are able to rid the world of malaria through a technological or medical breakthrough.

Thus, outcomes depend on whether or not humans respond to certain issues, the effectiveness of their responses, currently unknown (and potentially not even considered) advances in technology and a strong element of randomness. Malaria, just one small issue in the totality of global warming, could have no impact, some impact, or a significant impact depending on these outcomes. Expanding this analysis across a broad range of issues reveals that randomness plays a complex and powerful role in each issue's ultimate marginal costs to society as they relate to climate change. Extrapolating further indicates that Pezzey's assumption of ignoring "time-dependent phenomena such as uncertainty and technical innovation" is indeed problematic and impractical given the actual conditions faced in the world.[27] Without this assumption, we see that the MSC is extremely difficult to calculate and not static in nature, but rather dynamic.

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[25]Tol, The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," 2066.

[26]Tol, The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," 2066.

[27]Pezzey, The Symmetry between Controlling Pollution by Price and Controlling It by Quantity," 984.

An element of randomness does not only have the potential to determine the magnitude of an impact as in the case of the spread of malaria; Tol notes a 1999 study by Mendelsohn and Neumann, which found that a "potentially negative impact can become positive under a suitable development path or vice versa."[28] That is to say, impacts which are perceived as negative today may actually become positive as technology or our understanding of our surroundings evolves over time. Even without this effect of uncertainty, and assuming that one could even identify all of the variables to include in a calculation, randomness and the shear number of factors to consider would make it difficult to determine an accurate range for the marginal social cost of carbon emissions, much less an exact figure that could be used as a tax rate.

Given all of the above uncertainty and the hundreds or thousands of additional questions that would require thorough research to aggregate an accurate curve, it is very unsurprising that Tol's study attempting to aggregate estimates of the marginal costs of carbon dioxide emissions found extremely varied results. Out of "one hundred and three estimates of the marginal damage costs of carbon dioxide emissions…gathered from 28 published studies," Tol finds that the "mode is \$2/tC, the median \$14/tC, the mean \$93/tC, and the 95 percentile \$350/tC."[29][30] His study, however, is not just a pure aggregation of the estimates, but also an analysis of the quality of the estimates. Naturally, he finds that differences in assumptions about the discount rate and about each country's weighting in the value estimates are the largest determinates of the marginal

[28]Tol, The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," 2066.

[29] \$/tC stands for dollars per tonne of carbon dioxide emitted.

[30]Tol, The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," 2064.

costs as well as the variability among the findings. When he adjusts for what he considers "better" methods, the "better" studies "yield lower estimates with smaller uncertainties than do studies with worse methods.[31]

Under these "better" conditions, Tol finds that when using "a social rate of discount of 4–5% - close to what most western governments use for most long term investments - the combined mean estimate is $16/tC, not exceeding $62/tC with a probability of 95%,"[32] This finding hardly represents an exact figure, and might even exclude important unpublished findings. To his credit, Tol notes that his study might not include all of the estimates found through research because "referees may have blocked publication of results that are too far out of the consensus range.[33] But supposing that his decisions are correct, that he has properly identified the "better" methods without bias, and that his aggregation includes all of the valid research, these estimates still represent an enormous range for the purposes of setting a tax. Were lawmakers forced to choose a tax based on this data, there would not be a sound framework for them to go about choosing a number in this range.

All of these noted problems associated with creating an accurate and politically acceptable MSC suggest that a policy option which can function without such a curve is preferable. Initially, this type of policy seems like an enormous departure from the earlier discussed equivalent models, but using as part of a policy solution an MSC that is

[31]Tol, The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," 2072.

[32]Tol, The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," 2073.

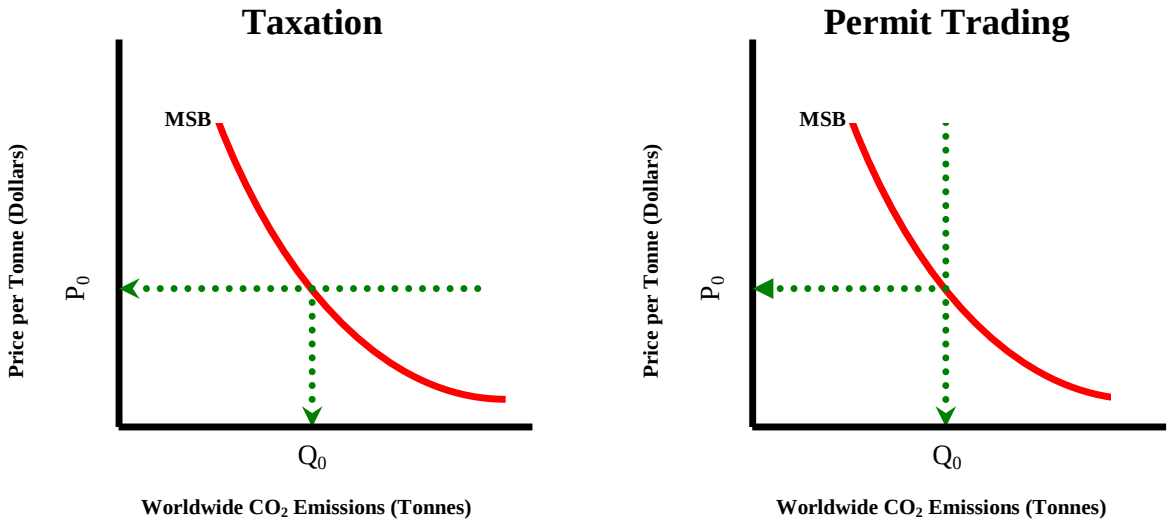
[33]Tol, The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," 2072.

surely inaccurate or whose assumptions might make it politically impractical is ill-advised and foolish if an acceptable system can be created without the monetarily and politically costly exercise of aggregating an MSC.

Policy Viability without a Marginal Social Cost Curve

Can policy survive without an MSC? Figure 2 illustrates the policy choices without an MSC.

Figure 2: Without the Marginal Social Cost (MSC) Curve, Policy Makers Must Fixed Price or Quantity and Try to Estimate the Other



The first thing one observes when the MSC disappears, it that there is no longer an intersection of two curves to indicate the socially optimal quantity of pollution and price. One of the assumptions with the theoretical model is that governments will impose policies aimed at the socially optimal level of pollution. The reality of carbon emissions is that there are two optimal levels: an environmentally optimal level and an economically optimal level. The environmentally optimal level is the one at which carbon emissions no longer perpetuate global warming. In fact, this level might even

lower the level of carbon in the atmosphere over time so that the earth cools, reversing the century or so of warming that has already occurred. The economically optimal level is the one at which the marginal costs of reducing emissions equal the marginal benefits of those reductions under current environmental and technological conditions. The environmentally optimal level is actually far below the economically optimal level because current technology would not allow for the drastic reductions necessary to meet the environmental optimum without significant economic shock. The staged tightening of emissions caps in Europe already suggests that policy makers abroad realize that moving toward the environmental optimum will be a lengthy process, and certainly not an overnight change. Ideally, an upcoming policy choice would regulate emissions to somewhere near the economic optimum, perhaps slightly lower as an incentive to encourage innovation in carbon emissions abatement technology.

Moreover, today's policy makers should aim to create United States standards that are on par with the European Emissions Trading Scheme as a means of reducing international animosity and ensuring that domestic industry is not at a competitive disadvantage internationally. Creating a policy so parallel to Europe's would essentially solve the problem of the optimal emissions level by setting it equal to already established European standards. From a political perspective, adopting a policy which is equivalent to one already practiced in the developed world would appear to be more feasible than convincing industry or the public that the United States should take a more aggressive path; meeting the status-quo is always more practical politically than suggesting policy choices that would place the nation at some type of disadvantage. Of course, adopting

standards equivalent to Europe's would also eliminate the European Union's argument that the United States is soft on climate change.

Under the scenario where the United States adopts European reduction guidelines, policy makers would still have the option of choosing taxation or permit trading as the policy method. In the case of taxation, the pollution authority would need to aggregate an MSB curve and determine the tax rate, P_0, which would accomplish the policy goal of reducing emissions to Q_0. In the permit trading case, the government would merely assign the desired number of permits and let the market determine the optimal price, P_0. Under Pezzey's assumptions, these two choices are still theoretically symmetrical, but taxation requires the aggregation of an accurate MSB curve, whereas the permit trading scenario does not. Thus, if it is possible to aggregate an accurate MSB curve, these policy choices remain equivalent.

Aggregating the Marginal Social Cost of Abatement Curve

Although the MSB or Marginal Cost of Abatement curve does not involve value judgments as does an MSC, this curve is still subjective, incredibly complex and difficult to calculate with precision. In reality, costs of abatement are fundamentally project specific and highly localized, especially as abatement becomes more difficult, and decisions will vary from firm to firm based on internal frameworks and constraints. There are a variety of factors that influence marginal abatement costs at the project level, including the industry outlook, prevailing interest rates, the lending environment, capital constraints, alternative project availability, internal rate of return requirements,

commodity prices, freight rates, foreign exchange rates, site location and the demand for abatement technology. Planning in light of many of these variable factors requires a degree of subjectivity as forecasts for any of these variables will likely vary depending on their source. Further, decisions must take into account risk in relying on these forecasts as the future often differs from today's expectations. Many of these variables are also firm specific, depending on a firm's size, financial strength, geographic project portfolio distribution and risk tolerance. Accounting for these differences among firms, it is possible, and perhaps even likely, that two firms faced with an identical project might make different abatement decisions. Because many of these factors are highly subjective and proprietary for each firm, it is impractical to assume that a central pollution authority attempting to aggregate a Marginal Cost of Abatement curve would have perfect information. Even with proprietary financial metrics, a central authority might not be able to predict the creative solutions considered and implemented by firms with a financial incentive to innovate.

Some local solutions are quite surprising, and might only occur to those intimately familiar with a given project. As such these opportunities would not be readily visible to centralized policy makers, eliminating the ability of a central authority to forecast the potential reductions and costs of these projects. BP's experience in its quest to reduce emissions is very telling about the informational and project specific issues involved with implanting a carbon emissions control policy.

In 1997, BP became the first major energy company to acknowledge the serious effect of global warming. In a speech at Stanford University in the spring, BP CEO Lord

Browne announced that the firm would reduce its greenhouse gas emissions.[34] By September, he announced in a speech to the German Parliament that the firm would aim to reduce its emissions by ten percent by 2010.[35] Realizing the drastic differences in the costs of abatement across its dozens of units around the world, BP designed and implemented an internal permit trading system aimed at centralizing "strategic choices (e.g. the setting of an emission cap) but decentraliz[ing] control over deployment" solutions such as the methods of abatement.[36] High level managers realized that they just did not have the level of accurate information they would need to make specific trade offs at a high level, and "even when BP made a commitment to measurement it took a long time to gather data at the resolution needed for most BUs [business units] to become aware of the practices and technologies that would need changing" to meet the targets.[37] BP's experience illustrates the enormous task of generating and aggregating data on abatement costs for just one firm, much less across an entire economy or the world. The data, which evolved over years, was not available at the time policy choices were made, and this is a vital observation for government officials considering policy options that might require this level of data at the onset for an efficient result. The data simply will not be available.

BP's experience also indicates how abatement decisions evolve as data improves and obvious abatement decisions disappear. The firm's most productive original

[34]Victor, David G., "BP's Emissions Trading System," *Energy Policy* 34 2006: 2100 [journal on-line]; available from http://www.law.stanford.edu/program/centers/enrlp/pdf/victor_and_house_bp_trading_2006.pdf; Internet; accessed 10 March 2007.

[35]Ibid.

[36]Ibid., 2101.

[37]Ibid., 2109.

abatement decisions focused on venting and flaring, both processes that often needlessly emit large amounts of CO_2 and other greenhouses gases into the atmosphere.[38] BP not only found that it could reduce emissions by changing these practices, but that it could also add to shareholder value by trapping the gases, which it could later sell. As these simple projects disappeared, "energy efficiency projects (whose impacts on emissions are harder to measure and assess)" began to account for a large share of the firm's total emission reductions."[39] Eventually, the pressure to reduce emissions led to further creative and unexpected abatement solutions such as "powering down the dynamic positioning system on drilling ships (a system that used the engines to steady itself in shallow water) and using the anchors instead."[40] Although initial emissions reductions were predictable from a high level, true abatement challenges required intimate knowledge of individual processes and projects, knowledge specific enough that not even business units heads would have the familiarity with operations to think of these innovative solutions.

By distributing the abatement decisions to its business units, where decisions makers had better information and process knowledge, BP was able to meet "its 10% goal—seven years ahead of schedule."[41] Lord Browne also announced BP estimates that the firm saved over $650 million on an NPV basis "through decreased gas venting and flaring (gas which could then be sold) and through increased energy efficiency."[42] The

[38]Ibid.

[39]Ibid.

[40]Ibid.

[41]Ibid., 2100.

[42]Ibid., 2105.

creativity of these solutions and their specificity indicates that policy makers likely will not have the information to predict these types of solutions, now or well into the future, and this realization has very important policy implications for taxation, which requires the aggregation of a Marginal Social Cost of Abatement curve.

Given the specificity of this information and cost/benefit analysis scenarios that vary from project to project and from firm to firm, accurate aggregation of abatement costs by a central authority is highly unlikely. BP's experience clearly demonstrates the informational challenges associated with aggregating a Marginal Social Cost of Abatement curve, particularly the delay between the time a decision is made to reduce emissions and the time that sufficient data is available to make complex abatement decisions. Moreover, BP's operations are miniscule in relation to the size of the economy and the number of projects that would need to be accounted for by a central authority. Pezzey's assumption of perfect information being available to all firms and central pollution authority is clearly unrealistic in regards to the Marginal Social Cost of Abatement curve, and it is not the only assumption that fails in this respect.

When comparing taxation and permit trading as equivalent models, Pezzey assumes that the "charge rate," or tax, does not vary from firm to firm or with time."[43] In order for the tax or permit prices to remain efficient under this assumption, abatement costs cannot vary with time. Again, in reality, dynamic factors such as such as interest rates, foreign exchange rates, commodity prices, and technological innovation influence abatement costs. A simple example of dual-fuel power plants easily proves that constant abatement costs are not a realistic assumption.

[43]Pezzey, The Symmetry between Controlling Pollution by Price and Controlling It by Quantity," 984.

The spreads between petroleum and natural gas prices provide a salient example of dynamic abatement costs. Dual-fuel power plants have the choice of burning either petroleum products or natural gas, and their abatement costs vary with the relative prices of these fuels. Suppose that petroleum prices are relatively lower than natural gas prices per unit of heat output.[44] Petroleum, however, produces more CO_2 emissions than burning natural gas per unit of heat output. According to the Energy Information Administration, "petroleum-fired electricity generation averaged 1.969 pounds of CO_2 per kilowatthour, and natural gas-fired electricity generation [averaged] 1.321 pounds per kilowatthour" in 1999.[45] Based on these numbers, using petroleum produces 49% more CO_2 than using natural gas. Thus, the marginal cost of reducing emissions by switching to the cleaner, more expensive fuel is the difference between the two prices per unit of heat output divided by the amount of CO_2 emissions reduced as a result of the switching. Petroleum and natural gas prices, which are stochastic and vary over time, are inputs to the abatement cost calculation, and, therefore, abatement costs for this decision also vary over time.

Further, technical innovation reduces abatement costs over time. Given that firms will be forced to bear the social costs of pollution under emissions reduction legislation, it is only natural that demand for emissions abatement will rise, that this demand will lead to increased research and development, and that cheaper and more efficient emissions reducing technology will result. Indeed, in an article about abatement techniques at coal-

[44] Petroleum is currently more expensive than natural gas, but this relationship has shifted over time and petroleum has been relatively cheaper during certain periods. See 1993, 1998-99 periods.

[45]United States Department of Energy, "Carbon Dioxide Emissions from the Generation of Electric Power in the United States," July, 2000, Energy Information Administration (EIA), http://tonto.eia.doe.gov/FTPROOT/environment/co2emiss00.pdf (accessed March 1, 2007).

fired power plants, Nathaniel Keohane notes that "[b]y rewarding emissions reductions on the margin, taxes and tradable permit systems enhance the incentives for regulated firms to install lower-cost abatement technologies." [46] Broadening the reductions to cover a wider range of gases across a larger number of sectors expands demand for abatement techniques, increasing incentives to create this technology, and offering flexibility to "change tactics as our understanding of technologies and climate impacts evolves." [47] As technology evolves, marginal abatement costs change.

Variable inputs and technological change mean that the Marginal Social Benefit curve is constantly shifting. Experience with the US Clean Air Act shows that the United States government does a very poor job of estimating costs of abatement ahead of making policy decisions – possibly because it is impossible to aggregate data accurately and possibly because the costs are continually changing while policy makers suffer from the time lag inherent in the aggregation process. Prior to implementing a permit trading system for SO_2, the government forecasted a market price of $600/ton.[48] As the government's official estimate of abatement costs for the desired level of pollution, this figure would have been used as the tax rate under a tax system. In 1996, average successful bid prices at permit auctions were "around $65/ton - 10% of the original

[46]Keohane, Nathaniel O., "Environmental Policy and the Choice of Abatement Technique: Evidence from Coal-Fired Power Plants," May 24, 2005, http://www.som.yale.edu/faculty/nok4/files/papers/scrubbers.pdf (accessed April 12, 2007).

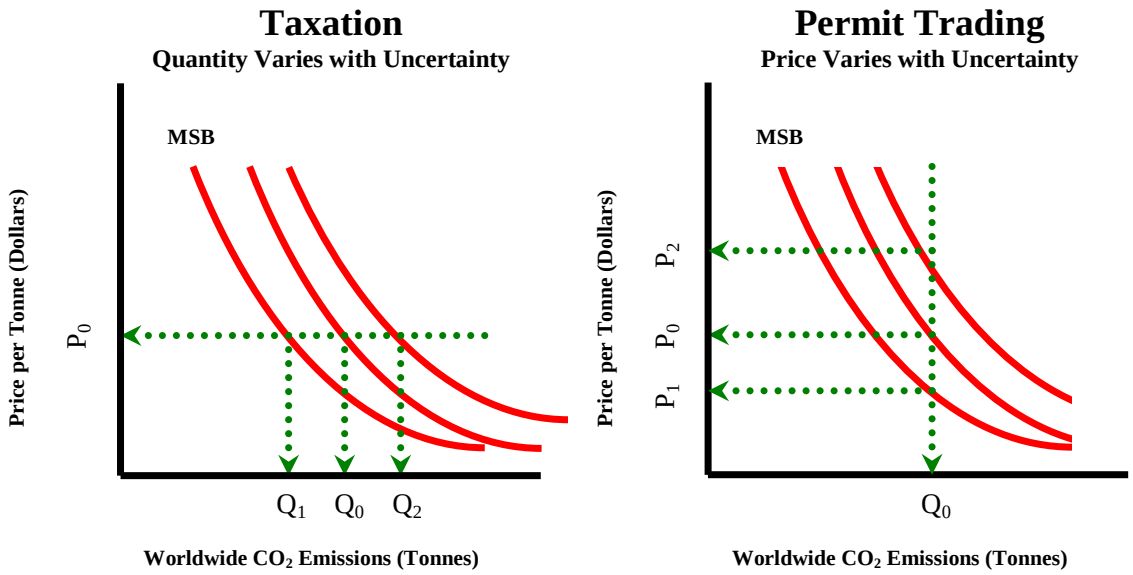
[47]Stephen H. Schneider, Armin Rosencranz, and Niles, eds., "Designing Global Climate Regulation," in *Climate Change Policy: A Survey* [book on-line] (n.p.: Island Press, 2002, accessed 20 February 2007), 151-187; available from http://eprints.law.duke.edu/archive/00001277/01/Stanford_Climate_Reader.pdf; Internet.

[48]Raymond S. Hartman, Wheeler David, and Singh Manjula, "The cost of air pollution abatement," *Applied Economics* 29 1997: 759 [journal on-line]; available from http://taylorandfrancis.metapress.com/content/n0fqwchggymd0pma/; Internet; accessed 12 April 2007.

forecast, despite several years of intervening inflation"[49] This ten-fold discrepancy in previous experience is not a very promising indicator of the government's ability estimate abatement costs in the future, and implementing an economically efficient tax relies on the government's ability to specify an accurate tax rate. Even a range of values is unacceptable as any variation from the true cost will create inefficiency.

Given the difficulty of accurately aggregating dynamic, proprietary data, the stochastic nature of abatement costs in a world of variable inputs and technological change, and the government's poor track record in forecasting marginal abatement costs, evaluating the policy implications of failures in these estimations is a necessary step when choosing a policy option for climate change legislation.

Figure 3: Implications for Marginal Social Benefit (MSB) Estimation Errors



By the time of policy implementation, the MSB curve will likely shift from its estimated location during policy planning stages, either because of estimation errors or its dynamic nature. As mentioned earlier, taxation is also known as controlling by price

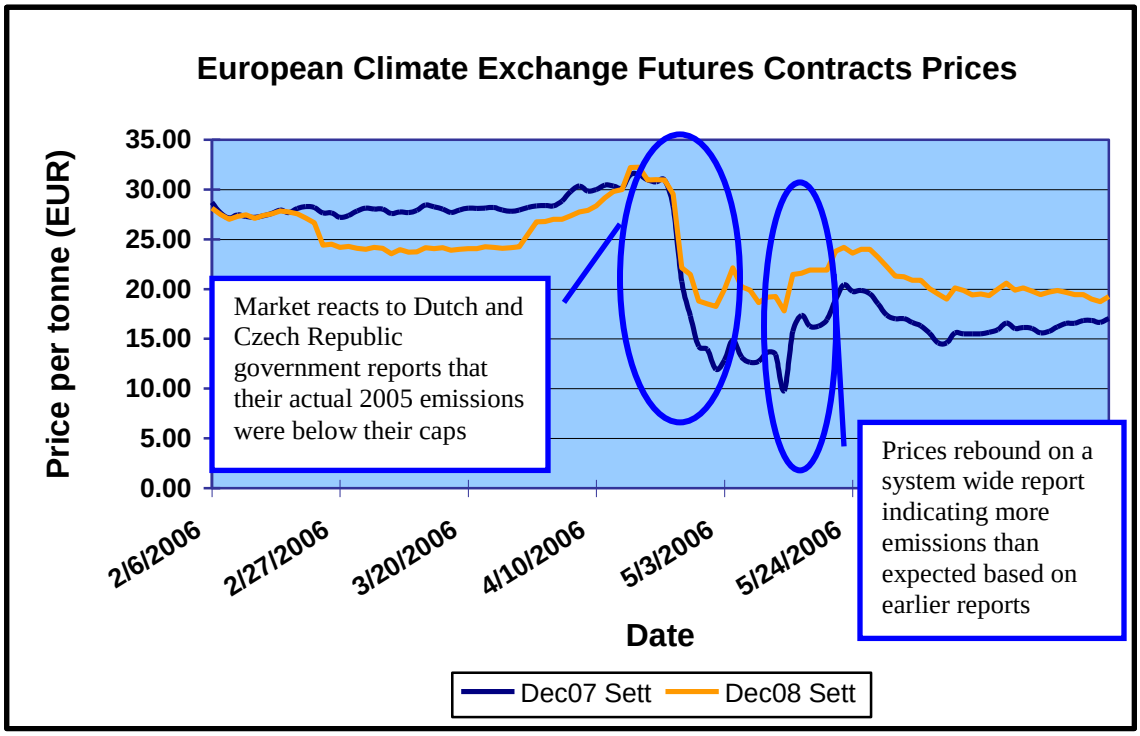
[49]Ibid.

because a central authority using this policy chooses a price for emissions that it hopes will reduce pollution to a desired level. As seen in Figure 3, this price remains constant as the MSB shifts, and the result is that the level of emissions changes from the desired level. Conversely, under the permit trading system, otherwise known as controlling by quantity, the central authority fixes the quantity of pollution and as the MSB shifts, the price fluctuates, but the amount of emissions remains at the optimal level.

These varying effects illustrate the asymmetry of these policy choices under uncertain conditions. It is important to remember that the ultimate goal of climate change legislation is to reduce pollution to a desired level at the most efficient cost. When assumptions falter, the taxation policy completely fails to regulate emissions levels as it sends a constant and invalid price signal to the market. The permit trading option, however, succeeds in accomplishing the policy goal while also sending an updated and accurate price signal to the market.

Further, the speed at which these price signals update differs dramatically depending on the policy choice with serious ramifications for efficiency.

Figure 4: European Climate Exchange Futures Price Reactions[50]



As seen in Figure 4, permit prices in the European Union Emissions Trading Scheme market fell more than 61% from €30.95 to €11.95 from April 24, 2006 to May 2, 2006. On April 24, 2006 the Dutch and Czech Republic governments published reports that their actual 2005 emissions were below their caps.[51] The market had been expecting a scheme-wide shortage of permits for 2005, and prices reacted immediately, falling over 61% in the following seven trading days as other nations reported similar results. Prices began to rebound on May 15, 2006, when the European Commission issued a system wide report indicating that total 2005 emissions were not as far below the caps as the

[50]European Climate Exchange, "Historical data - ECX CFI Futures Contract," April 24, 2007, http://www.europeanclimateexchange.com/index_flash.php (accessed April 24, 2007). From the homepage, go to Market Data, Historical Data, Futures.

[51]European Climate Exchange, "Carbon Sees Biggest Fall in 9 Months," April 24, 2007, http://www.europeanclimateexchange.com/index_flash.php (accessed April 24, 2007). From the homepage, go to News, Stories for April 25, 2006.

market anticipated based on earlier reports.[52] Although there is no parallel example of the speed at which a tax would react, there is no evidence to suggest that a legislative or regulatory process would react nearly as fast to changing market conditions. The Federal Funds Rate is perhaps the closest equivalent to a dynamic tax in the United States, and it is adjusted eight times per year at most. If information exists that is not accounted for immediately, there exists an economic efficiency, and in this regard a system of taxation will be less economical efficient than a permit trading policy because of the lag in policy response time. Efficiency under either policy, however, will require adjustment in the tax rate or permits prices over time, and firms require a mechanism by which they can mitigate this risk.

Risk Mitigation

As all of the previously presented evidence clearly shows, climate change is an incredibly complex issue and it involves a large degree of uncertainty at nearly every juncture. As a result, risk mitigation is enormously important to firms, and in some cases, the reason firms are asking the government to move forward with a climate control policy sooner, rather than later. Many projects that emit significant amounts of greenhouse gases, such as power plants, refineries, and other industrial projects, require massive, long-term capital investments. Firms considering these projects often hedge production inputs and outputs before embarking on the project as a means of ensuring that their profits will be sufficient to cover debt payments or meet a minimum required

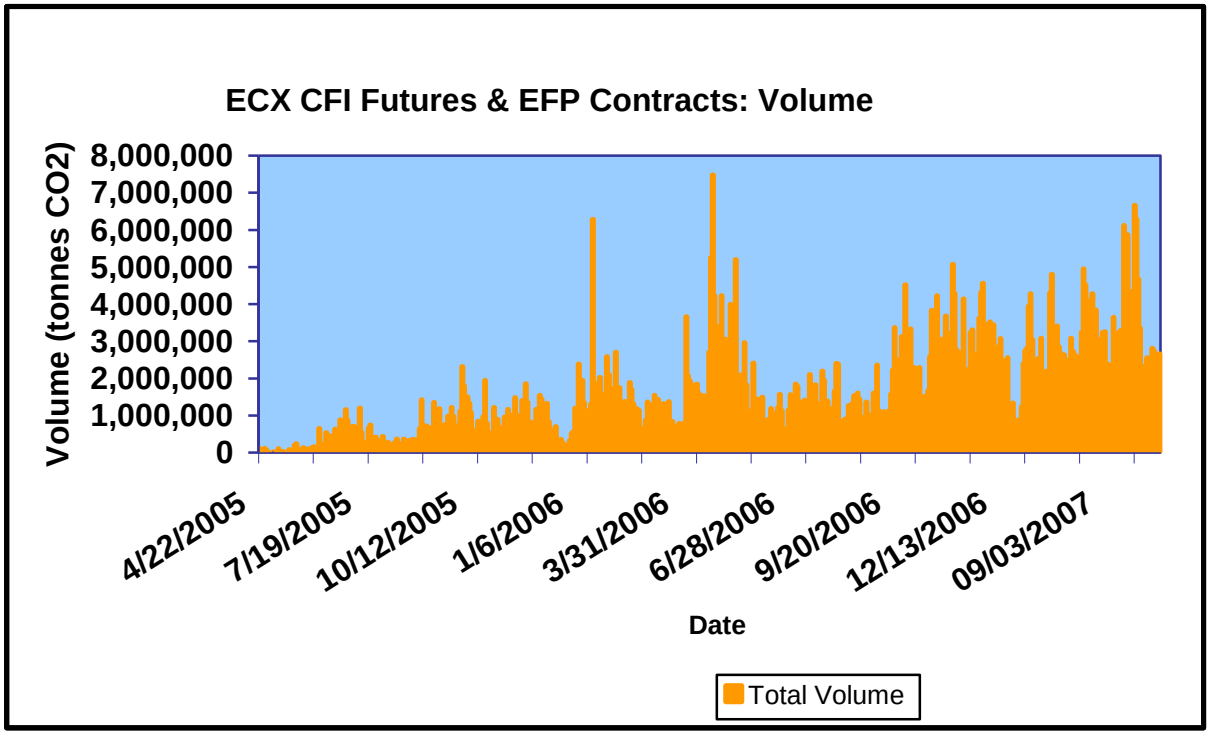
[52]European Climate Exchange, "EU Emissions Trading Scheme Delivers First Verified Emissions Data for Installations," May 15, 2006, http://www.europeanclimateexchange.com/index_flash.php (accessed April 24, 2007). From the homepage, go to News, Stories for April 15, 2005.

return. Of course, profitability figures rely on planners' abilities to account for all of the important decision variables affecting a project, and climate change legislation is currently a large unknown with the potential to turn presently attractive projects into sure losers overnight.

Currently, firms hedge vital exposures, such as commodity prices, through forward, futures and option markets. The creation of a permit trading system lends itself to the development of these markets for the purposes of speculation and risk mitigation. These markets allow hedgers, investors, and speculators to take directional views based on their expectations of or exposure to climate change, public policy, abatement decisions and technological advancements. European experience shows that these markets will develop quickly following the adoption of permit trading based legislation.

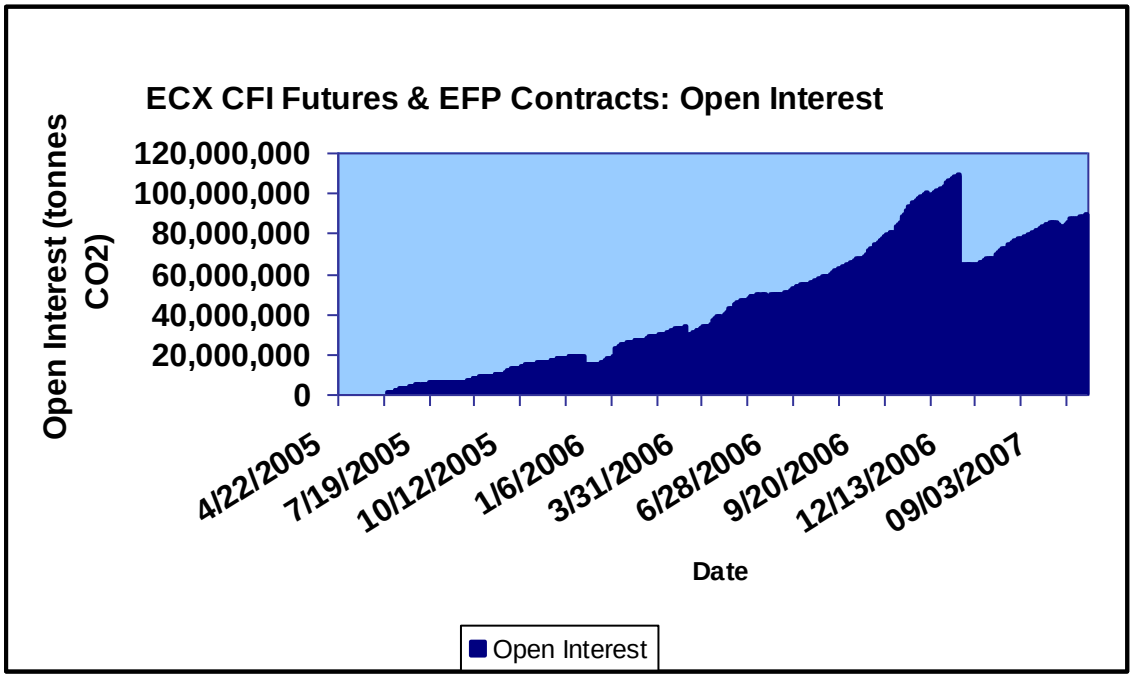
In just two short years since the beginning of the European Union Emissions Trading Scheme, markets in these products have materialized and grown substantially. The European Climate Exchange offers futures, options, and Exchange for Physical contracts. As Figures 5 and 6 illustrate, traded volumes and open interest in these instruments have steadily risen since the contracts began trading in 2005. These numbers, however, underestimate the true size of the permit trading market because they do not include over the counter (OTC) trades.

Figure 5: Rising Volumes on the European Climate[53]



[53]European Climate Exchange, Historical data - ECX CFI Futures Contract," http://www.europeanclimateexchange.com/index_flash.php.

Figure 6: Rising Open Interest on the European Climate Exchange[54, 55]



Unlike the permit trading system, which inherently includes a market mechanism that develops into a deeply liquid tool for price discovery, the taxation method does not include any such forum for risk mitigation. Without this marketplace, the only way firms can increase or reduce their exposure to climate change legislation is through changing production levels. Should a firm desire a means of reducing risk without changing production, it will have to search for and find a counterparty willing to write a financial contract based on changes in the tax rate. Presumably these products would come in the form of fixed for floating swaps or options on notional amounts of pollution. Because a marketplace is not a direct consequence of the taxation policy choice, however, these products will likely come in the form of custom-made structured products, which pose

[54]European Climate Exchange, Historical data - ECX CFI Futures Contract," http://www.europeanclimateexchange.com/index_flash.php.

[55] Note that the large drop in open interest is due to contract expiration.

several problems.

One major issue is that the burdens of climate change legislation, and, in turn, the risks associated with a given policy will primarily be borne by a few concentrated industries, including electricity utilities and oil refiners among others. A system that does not provide a mechanism by which these firms can spread this concentrated financial risk throughout the economy poses a danger to these industries and the future of climate change regulation. Should regulations prove too stringent and severely impact these industries, enough political pressure could build to repeal the legislation for fear of crushing an entire industry that is vital to the economy. Spreading financial risk across firms and throughout the economy reduces the risk of an acute financial meltdown in a heavily polluting industry, and, therefore, the chance of a policy repeal. Such a repeal would have devastating consequences for future policy as detractors would have a massive failure to cite every time a new debate about climate change legislation arises. Aside from concentrating risk and posing a threat to future legislative efforts, a system that does not include a market will make risk mitigation very expensive, inefficient, and time intensive.

Bespoke structured products have several disadvantages when compared to freely traded instruments. Firstly, they are extremely expensive in the sense of a very wide bid-ask spread because they lack liquidity. Often, these instruments must be bought from and sold back to the same counterparty as a result of their custom terms. As OTC instruments, they introduce an element of credit risk, which futures markets eliminate through clearinghouses. OTC products also require that counterparties identify themselves as part of the transaction process, whereas futures markets provide complete

anonymity, especially in an age of electronic trading. Smaller margin requirements and increased netting opportunities also reduce the cost of carrying exchange traded positions versus OTC products. In short, fungible permits in a market based system reduce transaction costs, increase liquidity, and reduce risk premia compared to OTC solutions. These effects lower the costs of complying with new policies and mitigating the risks of policy changes and failures. Market based policies also have the benefits of global integration.

The European Union has already adopted a system of permit trading and developed a market for this purpose. If the United States adopted a permit trading system, it would be possible to integrate both markets, massively increasing liquidity and developing an international price signal for carbon emissions. Eventually, it is conceivable that the carbon market, as a global market, could trade virtually around the clock as does the foreign exchange market. Establishing a broader market also has the potential to reduce volatility as regional shocks will become less consequential in relation to the market as a whole. Further, today's technology enables a completely electronic marketplace that can simultaneously operate around the world without costly duplication and can operate at virtually zero marginal cost per transaction. The extreme efficiency of this model promises to reduce transaction costs, and, thus, the overall cost of policy adoption. A highly integrated market is clearly the most efficient way to deal with risk mitigation on the global level, and international integration can only occur under a permit trading system.

Conclusion

Given mounting evidence about mankind's influence on global warming and the recent shifts in political sentiment toward action on the subject, it is necessary that the policy discussion shift away from the today's topics of economic equivalence under perfect conditions and toward a discussion that carefully considers which policy options are most suitable to reality. Today's political environment indicates that policy adoption is imminent; policy choices and their structures will have important economic, social, and political ramifications for decades or centuries to come.

The evidence presented here clearly shows that the assumptions that lead to equivalence between controlling by price and controlling by quantity in theory do not hold in reality. As uncertainty and a dynamic environment are taken into account, it becomes apparent that much of the aggregated information necessary to properly implement a system of taxation is not currently available and may never be available in a timely manner for policy decisions. Further, using this data relies on very controversial value judgments, which will slow the political process on a time sensitive issue.

The government's prior experience with estimating costs of abatement is telling of the issue's complexity and the inability of a central authority to calculate accurate figures. Using a permit trading policy not only eliminates the need for this costly, slow, and inaccurate information, it also provides a system under which the ultimate policy goal of controlling emissions is accomplished in spite of the uncertainty and randomness that will assuredly mark the implementation and functioning of a carbon controlling policy.

A permit trading policy also presents the opportunity for global integration, both in terms of an abatement schedule and a market. Pursuing a path similar to the European Union's should mitigate some of the risks of policy implementation as the United States has the benefit of several years of hindsight on the European experience when structuring its policy. A system that inherently creates a market is preferable for its advantages in risk mitigation. An internationally integrated policy ultimately reduces costs and volatility while ensuring a consistent global price signal for carbon emissions prices.

Climate change is a dynamic, global problem that requires a dynamic, global policy solution. Cap-and-trade is the best policy for this issue as it can be integrated globally, reacts quickly and will ensure the desired emissions reductions in the face of uncertainty.

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