ADDRESSING THE COSTS OF CLIMATE CHANGE MITIGATION*

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I. Introduction

Cost considerations are critical in the development of any mandatory program to reduce U.S. greenhouse gas (GHG) emissions. First, climate change policies impose costs through the development and introduction of new technologies, and through required changes in production by firms and in behavior of individuals. Climate change mitigation policies can also produce benefits, including stimulation of innovation, reduced emissions of traditional air pollutants, and improved energy security. Effective strategies to reduce mitigation costs are also essential for political agreement and to ensure that climate targets are achieved in practice.

This paper frames policies to reduce GHG emissions in terms of cost-effectiveness analysis, and only considers market impacts. Cost-effectiveness analysis takes a stated GHG reduction goal and compares policy approaches to meet this goal at the lowest cost. Although this paper does not cover the benefits of climate change mitigation policies, particularly in terms of avoiding non-market impacts, considerable work continues to be done to accurately depict and account for these impacts and consider these in conjunction with the costs of mitigation.[1]

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II. Key Cost Issues

An important backdrop to any discussions of crafting climate policy is the issue of timing: how much cost to incur now for future benefits and how to deal with limitations to our understanding of the mechanisms and impacts of human-induced climate change?[2] Any U.S. policy effort should provide for phased implementation in order to manage costs and incorporate new information.

With this overall milieu as a backdrop, policy-makers must consider three critical dimensions of cost to shape an effective national program to mitigate GHG emissions. The first is *aggregate* or *absolute cost*: that is, the cost implications for the U.S. economy as a whole. In fact, much of the economic analysis of climate change policy has taken a macro-economic perspective with results expressed in terms of losses or gains in U.S. gross domestic product (GDP). The second cost dimension is *relative cost*: that is, the distribution of cost (and possible benefits) between industrial sectors, different states or countries. The third cost dimension is *cost certainty*: that is, how confidently mitigation costs can be anticipated. The attractiveness of a national mandatory policy to reduce GHGs will hinge in part on its capacity to minimize concerns about these three critical dimensions: aggregate cost, relative cost and cost certainty.

A. Absolute Cost

The overall cost of GHG mitigation hinges largely on the stringency of the goal – which is a function of its magnitude, its timing, and the cost-effectiveness of the measures chosen to meet it. At the national level, the projected cost is most often analyzed and expressed as a change in GDP (although other measures of economic welfare [e.g., household consumption or employment] are also important for policy).

Absolute costs are best minimized by allowing flexibility as to where, when, and what type of mitigation action is taken. To minimize costs, abatement should occur where it is cheapest. Since changes in the climate reflect GHG concentrations (the long-term accumulation of emissions), the precise timing of emissions reductions can also be flexible. Several gases contribute significantly to warming – carbon dioxide (CO_2), methane, nitrous oxide, and a range of industrial gases (perfluorocarbons, hydrofluorocarbons, and sulfur hexafluoride). As these non-

CO_2 GHGs are more potent in warming terms[3] than CO_2 and have historically had no explicit price signal to minimize their use, considerable cost effective reductions exist[4], (CO_2 represents over 80% of U.S. GHG emissions, however, so an effective strategy must target both CO_2 and non-CO_2 emissions alike). In addition, a ton of CO_2 permanently sequestered in biological or geological processes yields the same climate benefit as abating a ton of CO_2 emissions, so a cost minimizing policy should include sequestration. Finally, if a reduction target is announced in advance, firms have more time to formulate and implement a cost-effective abatement strategy.

B. Relative Cost

In assessing the political acceptability of a U.S. GHG mitigation policy, aggregate cost may ultimately be less critical than relative cost – the distribution of costs. While the issue of relative cost in the U.S. is often portrayed as one of competitiveness among states (or countries), it operates principally at the sectoral level, arising when a sector faces climate-related costs different from those of its competitors in other sectors or geographical areas. Even if the impact on overall competitiveness is minimal, the concentration of costs in particular sectors (often concentrated in a few states), and resulting concern over competitive disadvantage is a powerful obstacle to the U.S. taking on a mandatory reduction target.

Relative cost issues arise across different dimensions. First, even if two states or sectors have comparable commitments to reduce emissions, variations in their underlying economic and energy structures and in their implementation strategies may yield significant differences in the relative cost of compliance. A second set of competitiveness concerns arises between U.S. industrial firms and competitor firms in developing countries that have not taken on a comparable commitment. Relative costs influence not only the political viability of a climate change mitigation policy, but also its environmental effectiveness. This is usually illustrated by the notion of emissions leakage; for example, under a GHG constraint with associated higher energy costs, some energy-intensive industries could locate new plants or shift existing production overseas.[5]

Finally, the distribution of costs within the U.S. could significantly influence its willingness to adopt a national GHG reduction policy. Fossil fuel energy producers, energy-intensive industries, and workers in these industries are likely to bear a larger share of the burden of an emissions mitigation policy. In contrast, suppliers of energy-efficient and renewable energy technologies, or forestry and agricultural firms that engage in carbon sequestration may benefit from such a policy. The effectiveness of these various actors in influencing the U.S.'s climate change policy can determine in part the path the U.S. will follow. The design of a national mitigation program can ease or exacerbate relative costs, but it is unlikely that there exists an approach that would preserve the current market status of the most heavily carbon-exposed industries.[6]

C. Cost Certainty

A third, and related, issue that complicates the design of GHG mitigation policy is cost certainty. Economic models rely heavily on assumptions about key drivers[7] to overcome key uncertainties, and as such provide a range of costs of GHG reductions[8], and insights into where the actual cost will lie in this range. Long-term emissions forecasts reflect uncertainties over population growth, economic output, energy endowments and their prices, technological change, and land use activities – not to mention geopolitical changes.[9] Uncertainties over future emissions trends are important because the level of effort required to meet a given target must be measured from a presumed baseline of "business as usual" emissions growth.

There are significant uncertainties as well over the likely social and economic responses to a given GHG mitigation policy. For instance, the costs will depend in large part on how easily consumers and producers can substitute away from carbon-intensive activities. The more flexible and responsive firms and consumers are, the lower the costs.[10] The rates of technological change and diffusion are also critical, and difficult to predict. Assigning a price to GHG emissions stimulates the development and diffusion of lower emitting technologies.

Certainty is also crucial to firms that must implement the GHG reductions. Firms would prefer to delay investing resources that are largely irrecoverable (for example, large energy equipment that has lifetimes of years or decades), and to gain new information that can allow for a better-informed decision in the future. [11] However, the magnitude of these investments under more or less stringent policies must be weighed against irreversibilities from the impacts of various degrees of climate change, including the very real possibility of loss of species or destruction of cultures in at-risk geographic locations.[12] The pre-announcement of policy would help to reduce the costs associated with taking action.

Reducing the uncertainty in costs of meeting a given GHG mitigation target will contribute greatly to the political acceptability of such a policy and the likelihood of compliance.

III. Cost Comparison of Policy Options

A. Emissions Trading

A tradable emissions allowance program is a quantity-based mechanism that can ensure that all emissions sources and sectors face the same marginal cost of reduction. This is achieved through purchase of low-cost credits or banking of early abatement. The SO_2 Acid Rain program has demonstrated that cost-effective reductions can be achieved in practice.

An abundant literature supports the cost-minimization advantage of GHG trading.[13] In practice, savings may be diminished by imperfect information, transaction costs in setting up trades between firms, and any lost mitigation opportunities from the omission of various sectors, technologies, greenhouse gases or international offsets from the trading program. Despite these limitations, it is widely agreed that emissions trading is among the most effective means of minimizing the aggregate cost of GHG reductions.

Emissions trading also helps address relative cost. By ensuring that all sources have access to the same least-cost abatement opportunities, emissions trading reduces the competitive disadvantages that sources may face. This also reduces leakage by lowering incentives to relocate. In addition, certain design features of a U.S. trading system can help address relative cost impacts. For example, allocating emissions permits to adversely affected industries can alleviate much of the impacts on these carbon intensive sectors.[14] Another option is to recycle revenues from auctioning some or all emissions allowances to finance transition assistance for workers and communities dependent on energy-intensive industries, provide compensation for consumers facing increased energy prices, or to offset existing taxes on labor or capital inputs. In fact, if the existing taxes are economically inefficient, the emissions trading system may result in a "double dividend," yielding both emissions reductions and economic savings.

One concern with a quantity-based emission trading system is that if it is designed inflexibly, then supply side constraints and external economic factors can lead to spikes in the price of permits, with resulting negative impacts on both the trading scheme and the economy.[15] The next section discusses some options to hedge against cost uncertainty.

B. Variations on Emissions Trading

An emissions trading variant that may offer greater cost certainty would incorporate a "safety valve" mechanism to insure against unexpectedly high costs. This works through the release of as many additional permits as required when the trading prices reaches a predetermined threshold. This option would effectively put a ceiling on the price of traded allowances and thus provide an upper limit on the marginal cost of compliance. To act as an insurance mechanism, the safety valve price should be set well above the predicted marginal cost of complying with a policy's emissions commitments. However, if the safety valve price is set too low – i.e., well below the forecast cost of the quantity target – it could effectively convert the emissions trading system into a tax-based emissions regime, which would provide less incentive for R&D and technological diffusion and may not meet environmental objectives.

Another mechanism designed to reduce cost uncertainty in an emissions trading scheme is a "circuit breaker." This works by relaxing the overall cap in the trading scheme when the permit price reaches a predetermined level. For example, if the emissions cap is set to decline by 1% per year, if the circuit breaker is triggered for that year, the cap would stay constant, allowing additional permits to enter the system. When the permit price dropped below the threshold, the tightening of the overall cap would resume once more. A circuit breaker would provide an insurance mechanism against excessive cost, but to a lesser extent than a safety valve, as the permit price could still rise considerably, even with a relaxed overall cap.

A third option to reduce cost uncertainty is an "indexed" or a "relative" emissions target. This does not set an absolute emissions target at the start of the trading scheme, but instead adjusts the quantity commitment based on measures of economic performance (e.g., GDP) or other potentially relevant indicators (e.g., population).[16] If the U.S. economy grew faster than expected, then the indexing formula would increase the total quantity of emissions allowed. However, since a GDP-based formula includes only one factor influencing the effective stringency of an emissions commitment, it does not eliminate cost variability from other factors (e.g., weather, energy supply, or the rate of technological innovation). Indexing can address another risk raised by setting absolute emissions objectives years in advance, the creation of so-called "hot air" – a quantity target in excess of business-as-usual emissions even in the absence of any abatement efforts.[17] With an indexing approach, if the U.S. economy grows much slower than expected, the total quantity of emissions allowed would be reduced, thereby reducing or eliminating the prospect of a commitment becoming a hot air target.

All of the options discussed above for reducing cost uncertainty in an emissions trading scheme may involve a trade-off against environmental effectiveness.

A final variant of emissions trading is sectoral targets. These can be used to alleviate the relative impacts on different US economic sectors. Under a sectoral targets approach, the emissions cap is set in terms of industry-specific measures (e.g., tons per MWhr or tons per million dollars of output). This can allow a more precise indexing of required effort to reduce emissions. Sectoral targets can also facilitate direct comparison with equivalent sectors in other countries and hence reduce international competitiveness concerns. Sectoral targets can also allow policy-makers to impose more or less stringent targets to various parts of the economy. Although this is likely to introduce artificial inefficiencies into the trading system, in a practical sense, some sectors may be more important for, and amenable to, emissions mitigation in the near term.

Some of these variants on a standard emissions trading scheme can be combined (for example, sectoral commitments could be integrated with a safety valve).

C. Emissions Taxes

While emissions trading systems provide for greater certainty regarding the quantity of emissions reductions, an emissions tax provides greater certainty about the cost of GHG emissions reductions. By equating the marginal cost of emissions across all sectors, an emissions tax can result in least-cost abatement comparable to what would occur in theory under an emissions trading regime.

An emissions tax can thus minimize aggregate costs, and provide certainty on marginal cost, but at the price of uncertainty in emissions abatement and with few options to address the distribution of cost across sectors. As with an emissions trading scheme, revenues from the GHG emissions tax could be used to compensate adversely affected sectors or communities or to offset existing inefficient taxation.

However, governments could effectively circumvent the effect of an emissions tax by reducing other taxes affecting energy-related activities. And finally, political acceptability is likely to be a major obstacle, since the GHG tax combines both new taxes and fuel price increases.

D. Technology and Emissions Standards

An alternative or supplemental approach to emissions trading or emissions taxes could be standards for technologies or for emission rates. Some policy analysts suggest such standards would be much easier to administer and would allow easier evaluation of firms' compliance. However, a technology-based standard for specific sources of emissions, or standards based on emission rates for various processes or products (e.g., automobiles), would not likely compare well with alternative policies in terms of absolute, relative, or predictable costs. Imposing standards, even tailored to specific industries, would not achieve efficient emissions abatement because the technology would be very expensive for some firms and less expensive for others. A national body cannot implement technology standards in a manner that equates marginal costs among all affected firms, as even expert policy-makers cannot perform as well as the private sector under clear market signals. Further, the process of setting standards may risk regulatory capture – policy-makers with the mandate to design standards becoming strongly influenced by interest groups – resulting in greater disparities in abatement effort across industries, hence exacerbating the relative costs of the policy. Last, improving the emission rate of a technology or a process may provide an incentive to use that product more, hence diminishing the overall emissions savings. However, standards are an important potential tool to address energy use in applications where there are many users, and one way to overcome concerns about inflexibility is to design a tradable standards system or to allow for standards to be integrated with an upstream trading program.[18]

Endnotes

1. Avoided impacts from climate change include changes in resource productivity, damages to the human-built environment, human-health impacts, and notably damages to ecosystems, including loss of biodiversity and damage to aquatic ecosystems. Great uncertainties surround physical impacts of climate change, and valuation of these non-market impacts further depends on assessing thresholds (where impacts either accelerate or change course), low probability but high impact events (also known as climate surprises), existing vulnerabilities and the role of adaptation. For further discussion of benefits of GHG mitigation, see Smith J. (2003), *A Synthesis of the Potential Impacts of Climate Change on the United States*, Pew Center on Global Climate Change, Arlington, VA.

2. See Proceedings of Pew Center's Timing Workshop (www.pewclimate.org). October 2001.

3. As expressed in Global Warming Potential or GWP.

4. Expanding the coverage from energy-related CO_2 to all six GHGs lowers the GDP cost by over 30% for the US to meet its Kyoto objective through purely domestic measures. See Reilly J., H. Jacoby, and R. Prinn (2003), *Multi-Gas Contributors to Global Climate Change: Climate Impacts and Mitigation Costs of Non-*CO_2 *Gases*, Pew Center on Global Climate Change, Arlington, VA.

5. Of course, a host of factors are likely more important for plant location than energy costs -- including proximity to resources, access to markets, the available employment pool and government fiscal policies.

6. The role of existing carbon intensive sectors may hinge on the development of new technology, for example integrated gasification and sequestration technologies would allow coal-fired electricity to maintain market share in a carbon constrained economy.

7. See Weyant J. (2000), *An Introduction into the Economics of Climate Change Policy*, Pew Center on Global Climate Change, Arlington, VA.

8. For example, the range of marginal costs – the cost of removing the last ton – to achieve the Kyoto Protocol's targets ranged from less than $20 to more than $200 per ton of carbon. See Weyant J. and J. Hill (1999), *The Costs of the Kyoto Protocol: A Multi-Model Evaluation*, Special Issue of the Energy Journal.

9. An effort to project long-term emission trends yielded six illustrative scenarios, with global CO_2 emissions in 2100 varying by a factor of six and CO_2 concentration levels varying by a factor of two or more. See Nakicenovic, N. et al. (2000), *Summary for Policymakers: IPCC Special Report on Emissions Scenarios*, Intergovernmental Panel on Climate Change.

10. See Jorgenson D., et al (2000), *The Role of Substitution in Understanding the Costs of Climate Change Policy*, Pew Center on Global Climate Change, Arlington, VA.

11. See Lempart R. et al (2002), *Capital Cycles and the Timing of Climate Change Policy*, Pew Center on Global Climate Change, Arlington, VA.

12. This favors a far stronger environmental objective. See Arrow K., and A. Fisher (1974), *Environmental Preservation, Uncertainty, and Irreversibility, Quarterly Journal of Economics*, Vol. 88, pp. 312-319.

13. See Edmonds J. et al (1999), *International Emissions Trading and Global Climate Change: Impacts on the Cost of Greenhouse Gas Mitigation*, Pew Center on Global Climate Change, Arlington, VA.

14. See Burtraw D. et al (2002), *The Effect on Asset Values of the Allocation of Carbon Dioxide Emission Allowances*, Discussion Paper 02–15, Resources for the Future, Washington DC.

15. For example in the California RECLAIM program – See Ellerman D., P. Joskow, and D. Harrison (2003), *Emission Trading in the U.S. - Experience, Lessons and Considerations for Greenhouse Gases*, Pew Center on Global Climate Change, Arlington, VA.

16. An example of an intensity target is the U.S. voluntary goal of reducing its ratio of GHG emissions to GDP to 151 million metric tons per million dollars by 2012 (from the 2001 ratio of 183).

17. For example the contraction of the Russian economy following the demise of the Soviet Union has led to considerable amounts of Russian "hot air" credits in the Kyoto trading system.

18. See Nordhaus R. and K. Danish (2003), *Designing a Mandatory Greenhouse Gas Reduction Program for the U.S.*, Pew Center on Global Climate Change, Arlington, VA.