

Economic Issues in a Designing a Global Agreement on Global Warming

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Abstract

Addressing global warming involves not only understanding the science of climate change but also designing effective economic instruments to provide appropriate incentives for nations to join agreements and for market participants. There are three major lessons from economics about climate-change policies. First, raising the price of carbon is a necessary condition for implementing policies in a way that will reach the multitude of decisions and decision makers over space, time, nations, and sectors. Second, universal participation at a harmonized level is a critical part of an efficient global-warming regime. There are extremely high costs of non-participation. Third, the cap-and-trade approach embodied in the Kyoto model is a poor choice of mechanism. It is completely untested in the international context; it has been unable to attain anything close to universal participation; it loses precious fiscal revenues; it leads to volatile prices; and it is an invitation to rent-seeking. It is unlikely that the Kyoto model, even if strengthened, can achieve its climate objectives in an efficient and effective manner. A harmonized international carbon tax is likely to be a more effective mechanism for responding to the threat of climate change.

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Introduction

Climate change involves a tale of two cultures. The natural sciences are doing an admirable job of describing the geophysical aspects of climate change. The science behind global warming is well established. While the exact trajectory of climate change is imprecisely known because of cascading uncertainties from economic activity through emissions, the carbon cycle, and earth-ocean systems, economic analysis should take the scientific findings as inputs.

But designing an effective political and economic strategy to control climate change will require the second culture – the social sciences – to analyze how to harness our economic and political systems to achieve our climate goals effectively and at low cost. This second task involves a very different set of issues from the natural-science questions. It requires examining questions such as the impacts on the economy and on non-market activities, the costs of slowing or mitigating climate change, the strength and timing of emissions reductions with an eye to the costs and benefits of slowing climate change, the risks of asymmetric and irreversible damages, and the policy instruments for implementing such emissions reductions.

This discussion focuses primarily on the last of the issues described above – the design of policy instruments. That is, I will examine the question of how the goals of climate policy can be effectively and efficiently implemented on the national and sub-national scale. This topic is important because, in my view, the current approach embodied in the Kyoto Protocol (it will be useful to call it the “Kyoto model”) will not accomplish the goals of those who would like to slow climate change. As currently designed, it is both inefficient and ineffective and should be supplemented or replaced.

An Inconvenient Economic Truth

This analysis focuses on carbon dioxide (CO₂) as the most important greenhouse gas (GHG). The economics of climate change is straightforward. Virtually every human activity directly or indirectly involves the combustion of fossil fuels, producing emissions of carbon dioxide into the atmosphere. Emissions of carbon dioxide are externalities, i.e., social consequences that are not accounted for in the market place. They are market failures because people do not pay for the current and future costs of their emissions.

If economics provides a single bottom line for policy, it is that we need to correct this market failure by ensuring that all people, everywhere, and for the indefinite future face a market price for the use of carbon that reflects the social costs of their activities. Economic participants – thousands of governments, millions of firms, billions of people, all making trillions of decisions each year – need to face realistic prices for the use of carbon if their decisions about consumption, investment, and innovation are to be appropriate.

I will unpack this idea succinctly. Raising the market price of carbon provides strong incentives to reduce carbon emissions through four mechanisms. First, it provides signals to consumers about what goods and services produce high carbon emissions and should therefore be used more sparingly. Second, it provides signals to producers about which inputs (such as electricity from coal) use more carbon, and which inputs (such as electricity from wind) use less or none. It thereby induces producers to move to low-carbon technologies. Third, high carbon prices provide market signals and financial incentives to inventors and innovators to develop and introduce low-carbon products and processes which can eventually replace the current generation of carbon-intensive technologies. Finally, and most subtle of all, the use of carbon pricing economizes on the information requirements that market participants need to undertake each of these three tasks. Of course, placing a market price will not work magic. There remain many further externalities and market imperfections in energy and other markets. But without a strong price signal, there is simply no hope for making the vast number of decisions in a remotely efficient manner.

This is the inconvenient truth from economics: Raising the price of carbon is a necessary condition for implementing carbon policies in a way that will reach the multitude of decisions and decision makers over space, time, nations, and sectors.

The High Cost of Non-Participation

Economics leads to a second important truth about climate-change policies. The analytical basis for an efficient global-warming policy is extremely simple. Because global warming is a global public good, everyone, everywhere must face the same price.

The difficulty arises because, for global public goods like global warming, there are widely disparate incentives to participate in measures to mitigate the damages. The differences reflect different perceptions of damages, income levels, political structures, environmental attitudes, and country sizes. For example, Russia may believe that it will

benefit from limited warming, while low-lying countries may believe they will be devastated. Within the United States, some regions are energy exporters and resist measures to tax carbon fuels, while others are environmentally oriented and have already enacted local legislation to limit carbon emissions.

Current international agreements differentiate among countries in their responsibilities to undertake measures to limit emissions. Under the Kyoto Protocol, Annex I countries must limit their emissions, while non-Annex I countries have a variety of non-binding commitments as well as the ability to participate in the “clean development mechanism.” Moreover, while some countries have implemented strong internal mechanisms to control emissions, these often cover only a limited part of national emissions. For example, the European Trading Scheme covers only about half of EU emissions.

A centrally important question is the extent of inefficiency inherent in the patchwork nature and incomplete participation that characterizes the current international control regime. New evidence from economic studies suggests that the costs of non-participation are much higher than was earlier thought.²

We can simplify the discussion by considering a “participation function.” The participation function is a mathematical representation of the cost of partial participation. This approach assumes that a subset of countries has harmonized emissions reductions, while the balance of countries undertakes no emissions reductions. This assumption is approximately the structure of the current Kyoto model. Using this stylized assumption, we can estimate the costs of incomplete participation.³

² The results on non-participation are from William Nordhaus, *A Question of Balance*, Yale University Press, 2008, Chapter 5. The book is available on-line in a pre-publication version at nordhaus.econ.yale.edu/Balance_prepub.pdf. A more complete discussion of the costs of non-participation have been prepared in William Nordhaus, “The Role of Universal Participation in Policies to Slow Global Warming,” May 15, 2009, Paper prepared for The Third Atlantic Workshop on Energy and Environmental Economics, Organized by Universidade de Vigo, A Toxa, Galicia, Spain, 4-5 July 2008.

³ Here are the technical details of these estimates. The approach assumes that the mitigation cost functions are log-linear functions of output and the emissions-control rate. Only a fraction of countries participates in the climate agreements, where this group has a fraction of emissions equal to $\pi(t)$. Under the assumptions in the text, the

The results are very sobering. Annex I countries including the United States constituted about 66 percent of global CO₂ emissions in 1990. With a 66-percent participation rate, the cost of incomplete participation is 2.1 times the cost with complete participation. However, by 2010, the participation rate (with the U.S. withdrawal and the increasing share of developing countries) is estimated to be about 33 percent. The cost with incomplete participation is estimated to be 7.4 times the cost of the same global emissions reduction with complete international participation (see Figure 1).

We have also estimated the required participation to attain ambitious targets, such as the 2 °C target proposed by some European countries. Our work indicates that it will be necessary to attain close to universal participation by the middle of the 21st century to make this target.

One response to the criticism about non-participation is that the cap-and-trade system under the Kyoto Protocol actually extends participation through the clean development mechanism (CDM). I fear that the emissions reductions from CDM will prove to be minimal. There is no way of verifying that the projects in fact reduced emissions in the host countries, yet CDM has been a major source of accounting emissions reductions. By one reckoning, most of the emissions reductions in EU-ETS have come from CDM. According to a World Bank staff report, the CDM has produced 280 million tons of offsets of CO₂ for the EU whereas emissions reductions for the first

total cost function is $C(t) = Q(t)\alpha(t)\mu(t)^\beta \pi(t)^{1-\beta}$, where aggregate cost is $C(t)$, $Q(t)$ is total output, $\mu(t)$ is the aggregate emissions-reduction rate, α is a cost parameter, and β is the degree of convexity of the abatement cost function. Note that the costs are a function of the participation rate to the power $(1-\beta)$, which is the convexity of the marginal cost function.

For our estimates, we have used cost functions as synthesized by the Mitigation Report of the IPCC Fourth Assessment Report (Intergovernmental Panel on Climate Change, *Climate Change 2007: Mitigation, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, "Technical Summary," p. 77, available at <http://www.ipcc.ch/ipccreports/ar4-wg3.htm>). The high cost of non-participation arises because the estimated marginal cost of abatement highly convex, which a convexity parameter estimated to be $\beta = 2.8$. That is, marginal abatement cost increases very sharply at higher levels of emissions reductions. More details are provided in reference 2 above.

budget period are only 130 million tons of CO₂. We see many firms springing up to provide CDM credits. We may be heading down the road to another set of opaque instruments that are the environmental equivalent of mortgage-backed securities.⁴

It is clear that non-participation will be an issue under any international agreement on climate change, whether the agreement follows the Kyoto model or one based on carbon taxes. The unfortunate feature of the Kyoto model is that it pretends to solve the problem of bringing developing countries into the regime, whereas in fact we have no idea of the actual emissions reductions that have been achieved in developing countries under the CDM. There is no future to this illusion.

The second bottom line from economics is this: Universal participation at a harmonized level is a critical part of an efficient global warming regime. There are extremely high costs of non-participation. A rough estimate is that the penalty from exempting half the global emissions from an agreement will increase costs by around 250 percent.

Harmonized Carbon Taxes

Perhaps the most controversial policy question in the design of economic systems to control global warming involves the decision whether to rely primarily on quantity-based or price-based constraints. More specifically, the question concerns the relative advantage of a cap-and-trade system (such as is embodied in the Kyoto model), or a carbon tax system (such as is used for limiting gasoline or cigarette consumption).

The quantity-type system of the Kyoto model is well-known. I will describe briefly that carbon tax approach. This is more precisely defined as a *system of harmonized domestic taxes on carbon emissions*. Under this approach, countries would agree to penalize carbon emissions at an internationally harmonized “carbon price” or “carbon tax.” Conceptually, the carbon tax is a dynamically efficient Pigovian tax that balances the marginal social costs and marginal social benefits of additional emissions. The

⁴ For trends in CDM, see Karan Capoor and Philippe Ambrosi, *State and Trends of the Carbon Market 2008*, World Bank, Washington, D.C., May 2008. An analysis of the shortcomings is contained in David G. Victor, 2009, “Global Warming Policy After Kyoto: Rethinking Engagement with Developing Countries,” PESD Working Paper #82, available at pesd.stanford.edu.

carbon price might be determined by estimates of the price necessary to limit GHG concentrations or temperature changes below some level thought to be “dangerous interference.” From a conceptual point of view, the tax (or price on carbon) should be equal in all countries and sectors. In reality, as with any system, reality will depart from the ideal, but it is useful to keep the conceptual ideal in mind when designing the system.

An important feature of the system is that the revenues would be collected and retained domestically. It would naturally fit into the domestic fiscal system and should be seen as an alternative mechanism for collecting the revenues needed by all countries. They are not an attempt to provide revenues for other worthy causes. They are primarily designed to raise the price of carbon, with countries retaining the right to use the revenues according to domestic priorities.⁵

All this leaves the appropriate carbon tax as an open question. I have studied this question in a series of modeling exercises. Figure 2 provides an estimate of the social cost of carbon in the latest DICE model (2007 vintage) as well as the estimated uncertainty bounds.⁶ The major point to note, robust across almost all models and vintages, is that the social cost of carbon and the appropriate carbon tax will rise sharply in the years ahead – at a rate of about 4 percent per year over inflation.

Comparison of Carbon Taxes and Cap-and-Trade

The debate about the relative merits of cap-and-trade versus carbon taxes has moved from the academic journals to legislatures and scientific congresses. It is not a simple matter, but I believe that the difficulties of the Kyoto model approach are

⁵ A more complete discussion of a carbon tax is contained in Richard N. Cooper, “Toward a Real Global Warming Treaty, *Foreign Affairs*, March/April, 1998 and Gilbert E. Metcalf, “Designing a Carbon Tax to Reduce U.S. Greenhouse Gas Emissions,” *Review of Environmental Economics and Policy*, forthcoming 2009; and Gilbert E. Metcalf, *A proposal for a U.S. carbon tax swap: An equitable tax reform to address global climate change*, Discussion Paper 2007–12. Washington, DC: The Hamilton Project; and in Nordhaus, *A Question of Balance*, op cit.

⁶ The estimates are from William Nordhaus, *A Question of Balance*, Yale University Press, 2008, Chapter 7, available online at nordhaus.econ.yale.edu/Balance_prepub.pdf.

insufficiently appreciated.⁷ I will sketch why price-type approaches such as a harmonized carbon tax have superior efficiency and distributional properties.

To begin with, tax systems are mature and universally applied instruments of policy. Countries have used taxes for centuries, and their properties are well understood. Every country uses taxes, has an administrative tax system, has tax collectors, and needs revenues. By contrast, there is no experience – as in zero – with international cap-and-trade systems. Just as it would be irresponsible for military planners to use a completely untested weapon to defend against grave threats, it would be similarly perilous for the international community to rely on an untested system like international cap-and-trade to prevent dangerous climate change.

A related point is that quantitative limits have proven to produce severe volatility in the market price of carbon under an emissions-targeting approach. The volatility arises because of the inelasticity of both supply and demand of permits. I have reviewed the history of the market prices of tradable permits for both the SO₂ trading system in the U.S. and for the CO₂ system in the EU. These prices show an extremely high level of volatility. The SO₂ trading regime is a useful laboratory experiment because it has a relatively stable set of rules, is a mature system, and has almost two decades of experience. Figure 3 shows a comparison of the volatility of SO₂ prices with two other important prices, oil and stocks. Using the most recent data, we see that the prices of U.S. SO₂ emissions allowances has been almost three times as volatile as stocks, and more than half again as volatile as oil. The volatility of CO₂ allowances in the EU ETS is similarly large: in the period from October 2008 to February 2009 alone, ETS carbon prices varied between €9 and €24 per ton of CO₂ (see Figure 4).

⁷ There has been extensive discussion of the relative merits of cap-and-trade systems versus carbon taxes. The discussion here draws upon Chapter 8 in *A Question of Balance* as well as the author's article, "To Tax or Not to Tax: Alternative Approaches to Slowing Global Warming," *Review of Environmental Economics and Policy*, 2007 vol. 1, no. 1, pp. 26-44. The alternative point of view has been elaborated in Robert N. Stavins, "A U.S. Cap-and-Trade System to Address Global Climate Change," Hamilton Project Discussion Paper 2007-13, October 2007 and Nathaniel O. Keohane, "Cap and Trade, Rehabilitated: Using Tradable Permits to Control U.S. Greenhouse Gases," *Review of Environmental Economics and Policy*, 2009, vol. 3, no. 1, pp. 42-62.

It should be emphasized that the volatility of allowances is not due primarily to policy errors. It is inherent in this kind of instrument. The high level of volatility is economically costly and provides inconsistent signals to private-sector decision makers. Clearly, a carbon tax would provide consistent signals and would not vary so widely from year to year, or even day to day.

In addition, a tax approach can capture the revenues more easily than quantitative approaches can, and a price-type approach will therefore cause fewer additional tax distortions. The tax approach also provides less opportunity for corruption and financial finagling than do quantitative limits, because the tax approach creates no artificial scarcities to encourage rent-seeking behavior.

Carbon taxes have the apparent disadvantage that they do not steer the world economy toward a particular climatic target, such as a CO₂-concentration limit or a global temperature limit. This suggests that a carbon tax cannot ensure that the globe remains on the safe side of “dangerous anthropogenic interferences” with the climate system. This advantage of quantitative limits is in my mind largely illusory. We do not currently know what emissions would actually lead to the “dangerous interferences” – or if there are “dangerous interferences” – or even what global climate change will be implied by a system such as the Kyoto model. We might make a large mistake – either on the high or the low side – and impose much too rigid and expensive, or much too lax, quantitative limits. In other words, whatever initial target we set is almost sure to prove incorrect for either taxes or quantities. Moreover, the current system, or even the modifications that have been proposed, does not come close to being efficient or attaining the strict environmental goals because of the high levels of non-participation.

This leads to a final point about the two systems. A carbon-tax model provides a friendly way for countries to join a climate treaty. Currently, countries joining the Kyoto limitations would need to enter into highly politicized and uncertain negotiations on the extent of their emissions reductions. Suppose you were a medium-sized open economy closely tied to the United States, Russia, or Europe and you were considering whether to join the Kyoto Protocol under the current model. You might be concerned about the long-term impacts of climate change and might even be eager to join the effort to ensure its success. But you would also be realistically wary of the heavy pressures that big countries can apply. Your emissions commitments are poorly defined under the Kyoto model. You and other newly-joining countries would be under pressure to make sharp reductions so that larger countries could make smaller ones.

This is a set of negotiations, under the current Kyoto model, that you would be reluctant to join if you could avoid it. So it is not a puzzle that countries have not been flocking to join the Kyoto Protocol since its original negotiations in 1997. Under the carbon-tax model, by contrast, countries would need only to guarantee that their domestic carbon price would be at least at the level of the international norm. If I were a small country – worried about climate change, eager to join the effort, but wary of the heavy pressures that big countries can apply – I would find the carbon-tax approach most attractive. It would not be a painless choice to agree to a minimum carbon price, but it would at least be a transparent and relatively straightforward one, and one in which countries contemplating joining would know what they were signing up for.

The Perils of the Current Cap-and-Trade System

The international community is making a huge wager on the Kyoto model. The wager is that the cap-and-trade structure contained in the Kyoto model will do the job of slowing global warming. The new United States administration advocated that the U.S. adopt this system as its contribution to solving the global problem, and the primary legislation in the U.S. Congress is firmly in the cap-and-trade camp.

But, as I have suggested above, the cap-and-trade approach is a poor choice of mechanism. It is untested in the international context; it has been unable to attain anything close to universal participation; and it has the inherent flaws just described. It is unlikely that the Kyoto model, even if strengthened, can achieve its climate objectives in an efficient and effective manner. To bet the world's climate system and global environment on an untested approach with such clear structural flaws would appear a dangerous gamble.

Given the advantages of tax-type systems, as well as the problems inherent in the Kyoto model, an important question is how to modify the Kyoto Protocol to include tax-type models. Some have suggested a hybrid approach that could combine the strengths of both quantity and price approaches. An example of a hybrid plan would be a traditional cap-and-trade system combined with a floor carbon tax and a safety-valve price. For example, the initial carbon tax might be \$30 per ton of carbon with safety-valve purchases of additional permits available at a 50 percent premium. These would be an improvement on a pure cap-and-trade system, but we would be wary that a faint-

hearted cap-and tax system would have low-or-non-existent floors and high-and-vanishing caps, in which case it would differ little from a cap-and-trade system.

One approach that might meet climate, economic, and political objectives more effectively would be to broaden the Kyoto treaty to allow countries to fulfill their treaty obligations if they have a domestic regime with a minimum carbon price attached to all emissions. This would require international negotiations about the minimum price and its trajectory, but such an approach would allow a much broader set of policy regimes.

In closing, I would emphasize to my natural-science colleagues how difficult it is to design durable and effective international economic systems. They are complex ecosystems, full of hidden prey and predators, with many unforeseen results. History is littered with failed institutions, from cholera conventions in the 19th century to disarmament pacts in the 20th century to international currency regimes stretching back for many decades. One need only look today at the wreckage of the current financial system to see the latest example of the effects of failed regulatory and risk-management design. So, if the Kyoto model turns out to be another failed model, it has lots of company. A carbon-tax system, or a hybrid carbon-tax and cap-and-trade regime, would be a natural evolutionary change from the current ineffective approach.

So, if the Kyoto model turns out to be another failed model, it has lots of company. But it would be better to recognize and change it now, rather than in one or two more decades of ineffective and inefficient efforts to slow emissions. The international community should move quickly to replace the current cap-and-trade structure by one in which the central economic mechanism is a tax on greenhouse-gas emissions.

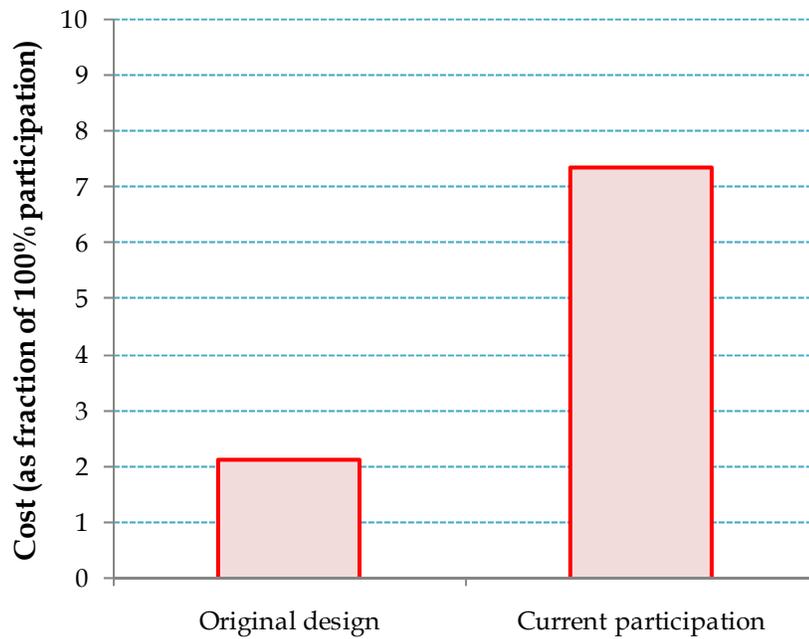


Figure 1. Penalty of non-participation in Kyoto Protocol

Because of sharply rising marginal costs of emissions reductions, there are severe cost penalties from non-participation. This figure shows the estimated cost penalty incurred in a regime with two groups, participants and non-participants. The current version of the Kyoto Protocol (Annex I without the United States) has a cost penalty of more than 600 percent over an efficient design with universal participation. (See text for sources.)

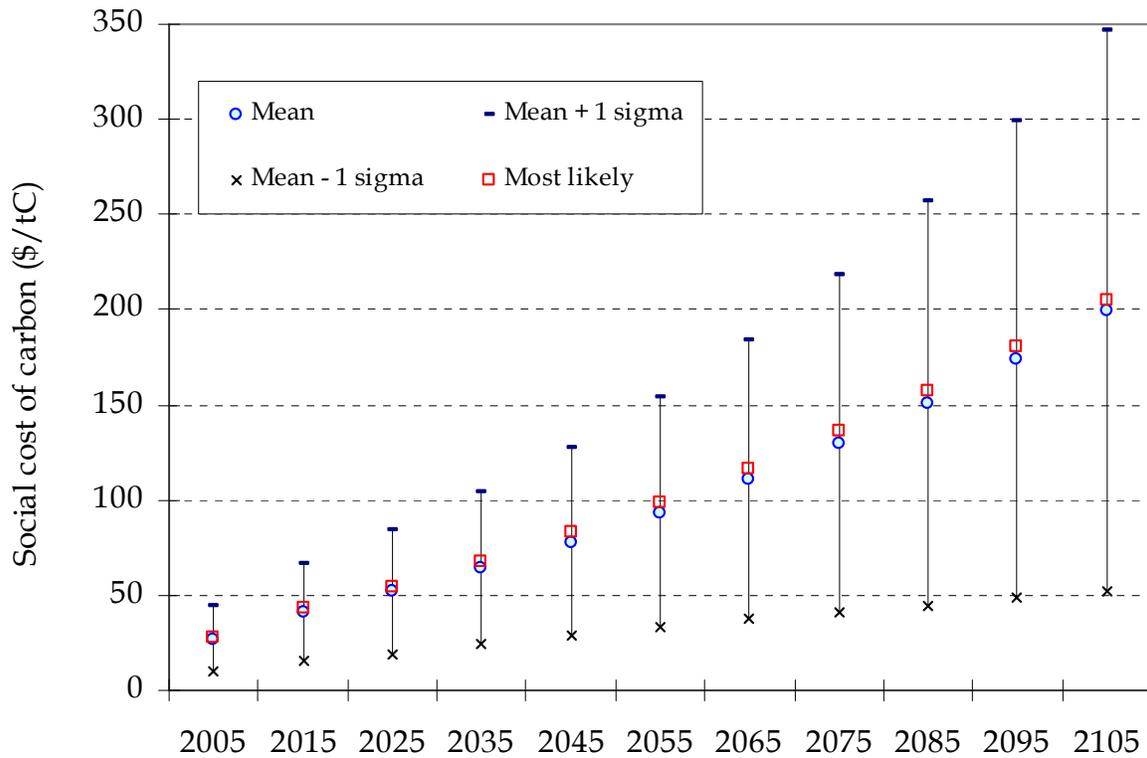


Figure 2. Central case and uncertainty bands for social cost of carbon

The figure shows the central case and the current uncertainty bands for the social cost of carbon (SCC) at different dates in the future. The square and circle in the center of the bars are respectively the certainty equivalent for the SCC and the mean SCC for the 100 runs in a Monte Carlo uncertainty analysis. This is for the base no-controls case for the DICE-2007 model. (Source: William Nordhaus, *A Question of Balance*, Yale University Press, 2008).

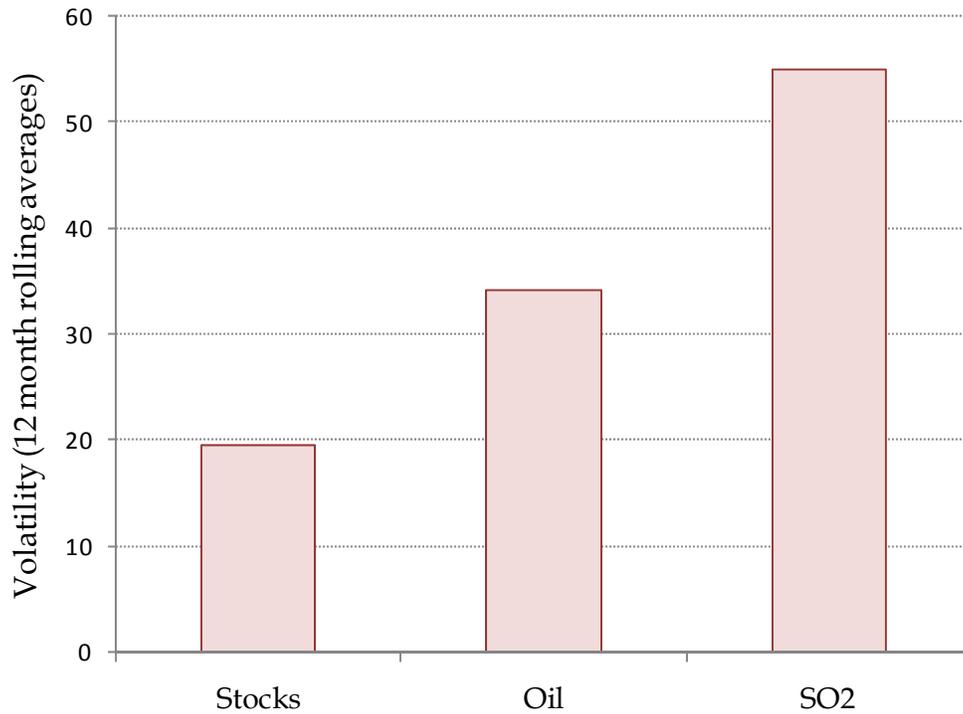


Figure 3. Prices of sulfur emissions allowances show high volatility

Cap-and-trade systems lead to high volatility of the prices of emissions, as is exemplified by SO₂ prices. This figure shows the estimated volatility of three prices over the 1995-2009 period. These are from left to right the stock price index for the Standard and Poor 500 (Stocks), the price of crude oil (Oil), and the price of U.S. SO₂ allowances under the U.S. acid rain program (SO₂). Volatility is calculated as the average absolute value of year-to-year changes. (Calculations by the author.)



Figure 4. Volatility of Prices under a Cap-and-Trade Regime

This figure shows the history of two contracts under the EU Emissions Trading Scheme. The volatility is representative of trading prices for allowances under cap-and-trade systems. (Source: Gilbert Metcalf, *A Proposal for a U.S. Carbon Tax Swap*, Hamilton Project.)