After Kyoto:
Alternative Mechanisms to Control Global Warming

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Abstract

This study reviews different approaches to the political and economic control of global public goods like global warming. It compares quantity-oriented control mechanisms like the Kyoto Protocol with price-type control mechanisms such as internationally harmonized carbon taxes. The pros and cons of the two approaches are compared, focusing on such issues as performance under conditions of uncertainty, volatility of the induced carbon prices, the excess burden of taxation and regulation, accounting finagling, and ease of implementation. It concludes that, although virtually all discussions about economic global public goods have analyzed quantitative approaches, price-type approaches are likely to be more effective and more efficient.

I. Introduction[1]

Almost a decade ago, the first international treaty on climate change, the Framework Convention on Climate Change or FCCC, was signed. Five years ago, the first serious implementing instrument was devised as countries agreed in the Kyoto Protocol to an international mechanism to bring emissions of greenhouse gases (GHG) under an international control regime. Last year, the Bush administration threw all these activities overboard when it decided not to seek ratification of the Kyoto Protocol. The other parties to the Kyoto Protocol

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have bravely decided to forge ahead even without the United States, but the current round of the Kyoto Protocol ("the 171 minus 1") is likely to accomplish little in terms of emissions reductions.

We stand today at an important crossroad with respect to climate-change policy. While the 171 minus 1 proceed to implement the current protocol, it is worthwhile considering whether the current design is likely to provide a viable long-term approach to this long-term problem. The fact is that alterative approaches have not had a serious hearing among natural scientists or among policymakers. The only live alternatives considered for the control of greenhouse gases were standard command-and-control regulation or a variant in which permits are exchangeable. What are some alternatives?

II. Alternative Approaches to the Control of Global Public Goods

Climate change is a member of a special kind of economic activity known as *global public goods.* Global public goods are public goods whose influences are felt around the world rather than in one nation, town, or family. What makes global public goods different from other economic issues is that there are at best weak economic and political mechanisms for resolving these issues efficiently and effectively.

It is customary to think of climate change as unique. In fact, dealing with global public goods has been an increasingly important feature of global affairs for centuries. Other important examples are national defense, public health, intellectual property rights, international trade, macroeconomic stability, fisheries, international environmental issues, endangered species, and transnational terrorism. We have only to think about Bosnia, nuclear proliferation, the AIDS epidemic, the decline of many ocean fisheries, the Asian financial crisis of 1997-98, September 11, and the threatening war in Iraq to realize how prevalent are global public goods. A little further reflection will indicate that nations have had only modest success in combining to deal with global public goods. On the other hand, we can look to regimes to manage international trade disputes (today primarily through the World Trade Organization) or the chlorofluorocarbon protocols to indicate that all is not hopeless.

A review of mechanisms for dealing with global public goods reveals a wide variety of instruments or techniques. A partial list is:

• Non-cooperative or laissez-faire approaches (as is currently taken for antibiotic resistance),

• Aspirational agreements (e.g., the FCCC) or non-binding voluntary agreements (e.g., the institutional regime created in the 1980s to clean up pollution in the North Sea),

• Specific and binding treaties – contracts between nations – which are the standard way to deal with international issues (currently in effect for the chlorofluorocarbons (CFCs) and many other global environmental agreements),

• Agreements embedded in broader arrangement (exemplified when Western nations forced developing countries to accept strong patent protection under the last multilateral trade negotiations),

• Limited delegations of regulatory or fiscal authority to supranational bodies (seen in some European activities such as the European Central Bank, in some powers of the WTO, and the international financial institutions such as the IMF).

This array of international institutions reminds us that, although climate change is a new problem, the problems of international political economy raised by climate change are quite ancient.

There are two major problems involved in dealing with public goods. First, we must find the level of "appropriate federalism." That is, it is necessary to locate the decision making at the political level that can internalize the spillovers. This is a particularly thorny problem for global public goods because global inefficiencies intrinsically need global decision making, or at least global negotiations. The second issue is the Westphalian dilemma. Under international law as it developed out of the 1648 Treaty of Westphalia and evolved in the West, obligations may be imposed on a sovereign state only with its consent. In other words, there is no legal mechanism by which disinterested majorities of countries can coerce free-riding countries into mechanisms that provide for global public goods.

These points are useful reminders that we must take entirely different approaches to global public goods from those taken to national public goods.

III. Mechanisms for Economic Public Goods

Looking at the varieties of global public goods, I want to focus on those that I will call *economic public goods*. These activities involve huge numbers of economic agents in a large number of countries and where the costs and benefits of action do not indicate any obvious focal policy or technological fix. The opposite of economic public goods is *focal public goods*, where good policies appear obvious or consensual (to most people), such as no AIDS, no smallpox, no financial collapses, no nuclear meltdowns, no trade barriers, and no Osama bin Laden.

With economic public goods, it is usually difficult to determine and reach agreement on efficient policies because they involve estimating and balancing costs and benefits, where neither is easy to measure and both involve major distributional concerns. Economic public goods include such examples as fisheries (where most everyone agrees that some fishing is tolerable, but the point of overfishing is difficult to calculate); pollution (where most everyone agrees that zero pollution is prohibitively expensive); a multitude of societal risks (where it is difficult to decide where to set the safety margin between zero risk and "low" risk), and climate change (where almost everyone agrees that the optimal abatement is neither zero nor 100 percent of emissions). There is a temptation to redefine economic public goods as focal public goods because that tremendously simplifies analysis and policy. For example, policies have pretended to adopt a complete phase out of CFCs in principle, although that is impossible in practice. Policies to prevent the extinctions of species generally avoid the vexing question of how to draw the line between species and subspecies as well as the intractable question of how far to lower the probability of extinction given that it clearly can never be zero.

For economic public goods, there are three potential approaches: command-and-control regulation, quantity oriented market approaches, and tax or price-based regimes. Of these, only the tradable-quantity and the tax regimes have any hope of being reasonably efficient, and I will therefore limit my discussion to those cases.

• *Quantitative limits.* Under a tradable quantity approach, an agreement proceeds by setting limits on emissions by different countries. The limits are partially or wholly transferable among countries. This is the approach taken under the Kyoto Protocol. This approach has very limited international experience under existing protocols such as the CFC mechanisms and somewhat broader experience under national trading regimes, such as the U.S. SO_2 regime.

• *Price or tax mechanisms.* A radically different approach is to use harmonized prices, fees, or taxes as a method of coordinating policies among countries. This approach has no international experience in the environmental area, although it has modest experience nationally in such areas as the U.S. tax on ozone-depleting chemicals. On the other hand, the use of harmonized price-type measures has extensive international experience in fiscal and trade policies, such as with the harmonization of taxes in the EU and harmonized tariffs in international trade.

IV. Major Issues in Any International Climate-Change Regime

Any climate-change regime must face three fundamental questions – the level of emissions reductions, the distributions of emissions reductions across countries, and the need for transfers to induce low-income countries to participate. Each of these issues is very contentious for climate change.

1. *What should be the overall level of emissions reduction?*

Because climate change is a global public good, the key environmental question is global emissions, and the key economic issue is how much global emissions should be reduced. The future trajectory of climate does not depend upon the exact source of greenhouse-gas emissions, only on the total.

Under a quantitative approach, the level of emissions (in covered countries) is in principle directly chosen. Under a price approach, the level of emissions is indirectly determined by the level of the tax or penalty on carbon emissions. However, for a quantitative approach, a market economy is likely to develop markets for emissions, and a market price will therefore emerge. An economist will naturally examine the price in either case, and the first question then will quickly be transformed into a slightly rephrased question: What is the level of the carbon price that is consistent with the regime?

In a world of certainty, either a quantitative or a price regime could target a given carbon price, but in practice the price is likely to be unknowable in advance in a pure quantitative system. The key economic question in either regime is whether the price is likely to be relatively high, say in the $100 per ton of carbon range, or relatively low, say in the $10 per ton carbon range.

This issue has been at the heart of the debate about the efficiency of the Kyoto Protocol. Several economic studies have found that the Kyoto Protocol will not only lead to high carbon prices but also to a highly differentiated and therefore inefficient allocation of abatement across countries.[2] To the extent that an economic rationale lies behind the U.S. rejection of the Kyoto Protocol, it comes from estimates that the U.S. will bear a disproportionate share of the burden of adjustment and that the costs to the U.S. of the Kyoto Protocol far outweigh the benefits. Figure 1 presents an estimate of the economic impact (costs, benefits, and net benefits) of the full trading version of the *original* Kyoto Protocol using the RICE-2001 model.[3] These estimates indicate not only that the U.S. bears a large fraction of the costs of implementing the protocol but also that the net economic impact upon the U.S. is negative even including the environmental benefits. Figure 2 shows, by comparison, how the costs are radically altered by the U.S. withdrawal.

The question of the "right" or the "optimal" level of emissions reductions is undoubtedly the most difficult and controversial question in the economics of climate change. In a series of studies, my coauthors and I have estimated cost and damage functions and estimated "optimal" or cost-beneficial approach to climate change. Our latest estimates in the RICE-2001 model suggest that a carbon tax of $10 per ton carbon (in 2001 prices) – rising rapidly over time – would appropriately balance the costs and benefits of emissions reductions. This number is slightly above the number that would stabilize the concentrations of CO_2 at twice the pre-industrial level (that is, at 550 parts per million).

It is important to understand, however, that (unless some dramatic geo-engineering solution is undertaken) substantial global warming is inevitable. All

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[2] The best reference on economic studies of the economic implications of the Kyoto Protocol is "The Costs of the Kyoto Protocol: a Multi-model Evaluation," *The Energy Journal*, special edition, May 1999.

[3] A description of the RICE model and the updates to 2001 is contained in the Appendix.

policies that are under consideration today would allow substantial climate change. Indeed, even if emissions were cut by 50 percent today, models project that we will bequeath about 2 degrees C of warming to the future simply due to past emissions.[4]

According to the RICE-2001 model, global emissions under the revised Kyoto Protocol will be very close to "business as usual" – global emissions in 2010 are estimated to be 1.5 percent lower than a no-controls scenario if the new forestry offsets are ignored (see Figure 3) and around 0.8 percent of global emissions with forestry offsets (not shown).

The less ambitious emissions reductions will be reflected in lower carbon prices. Carbon prices in the implementing regions are projected to be sharply lower under the no-U.S. version compared to the original version, declining from around $55 per ton carbon in 2010 in the original version to around $15 in the no-U.S. version. (Of course, for the U.S. the decline will be from $55 to $0.) With the U.S. out of the picture, the price of permits in Europe falls dramatically as required emissions reductions decline. Figure 4 shows the overall level of emissions estimated carbon prices in Europe for variants of the Kyoto Protocol as well as for the current estimate of the "efficient" or "optimal" carbon price. Even for Europe, the carbon price in the most recent version is close to the efficient price; the price in the uncontrolled regions is, of course, zero.

2. *What should be the distribution of emissions or emissions reductions among countries?*

While the global climate does not care who does the emissions reductions, people and countries definitely do care. The burden of reducing costs has several dimensions: What should be the relative distribution of reductions among high- and low-income countries, among high-emitting and low-emitting countries, and among countries that are vulnerable to the consequences of climate change and those who are relatively less vulnerable?

The economic approach to these questions leads to a simple and unambiguous answer: emissions reductions should be done in the most efficient

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[4] If emissions were immediately cut by 50 percent and held there indefinitely – an ambitious target – global mean temperature would still rise about 2 degrees C above pre-industrial level by 2150 according to most models.

way and the burden of reducing emissions should be shared in a fair way. The first half of this statement refers to the distribution of actual emissions reductions (which is question 2) while the second half refers to burden sharing (which is discussed in question 3 below).

Under the economic approach, emissions reductions will be efficient if the marginal costs of emissions reductions are equalized with appropriate discounting across space and time. The spatial component of efficiency is that the marginal cost of reductions should be equal across all countries and industries. The temporal component is more complicated. To a first approximation, intertemporal efficiency requires that the price or marginal cost of emissions reductions grows over time at a rate equal to the "real carbon interest rate," which is approximately equal to the real interest rate less the disappearance rate of CO_2 from the atmosphere. Most analyses focus only on the spatial component, which is always necessary for efficiency, and ignore the temporal component because it requires a complicated intertemporal optimization.

The Kyoto Protocol is defective on both efficiency criteria because it omits a substantial fraction of emissions (thus failing the spatial criterion) and has no plans beyond the first period (thus not attending to the temporal dimension). Indeed, the two largest emitters (the U.S. and China) are not even included in the current protocol, and a third (Russia) has agreed to join only because it is the recipient of massive transfers. Figure 5 shows the most recent estimates of the abatement costs under different trading regimes for the original Kyoto Protocol using the RICE-2001 model.[5] Because it limits trading to a small part of the world and ignores the intertemporal dimension, the Kyoto Protocol is an extremely costly treaty and makes only modest progress in slowing global warming.

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[5] These show the discounted costs of abatement using a real discount rate that begins at about 5 percent per year today and falls to around 3½ percent per year in a century.

3. *Should there by income transfers from high-income to low-income countries?*

All studies show that it is efficient for low-income counties to participate in emissions reductions, and indeed some of the most economical emissions reductions will probably come in low-income countries. In both quantity-type and price-type mechanisms, it will be both necessary and fair for high-income countries to provide assistance to low-income countries if the latter are to be expected to take measure to reduce emissions. The transfer mechanism under a quantity approach takes place through the allocation of baseline emissions. Under a fiscal mechanism, transfers would be direct monetary transfers or transfers tied to projects and would therefore be much more visible. Whatever the mechanism, some form of transfer will be necessary.

This set of concerns has been another obstacle to ratification of the Kyoto Protocol in the United States. Both the FCCC and the Kyoto Protocol exempt the developing countries, even relatively affluent ones, from obligations for emissions reductions. It is obviously crucial to have a mechanism whereby countries "graduate" into a set of obligations that are commensurate with their abilities to pay – in a way that is similar to the ability to pay principles of an income tax system.

The Kyoto Protocol has an arbitrary allocation of transfers. Because it generally used 1990 emissions as a base year when setting targets in 1997, those countries which had high emissions in 1990 (such as the former Soviet Union) will be advantaged while those who have grown rapidly (such as the United States) will be disadvantaged. Moreover, since developing countries are omitted, they are completely overlooked in the transfers. Although there have been few public pronouncements on the subject, it is inconceivable that the United States would agree to the enormous resource transfers to Russia and other countries that are envisioned by the Kyoto Protocol.[6] Therefore, while the quantity plan looks advantageous because it hides the transfers, when the time comes actually to purchase substantial emissions reductions from Russia, the political glue is likely to come unstuck rapidly.

[6] Estimates of transfers vary considerably across models. For example, in the RICE-2001 model, transfers from high-income countries (principally the U.S.) to Russia and other eastern European countries are estimated to be around $40 billion per year in 1990 prices.

V. Sketch of a Price-Type Approach to Climate Change

Price-type approaches or hybrid approaches have been discussed in a handful of papers in the economics literature,[7] but much careful analysis remains to be done. I will highlight a few of the details.

For concreteness, I will discuss harmonized carbon taxes (HCT). Under HTC, there are no international emissions limits; rather, countries would agree to penalize carbon emissions domestically at an agreed-upon and harmonized "carbon tax." The carbon tax is determined by weighing environmental and economic objectives. This might involve aiming to limit GHG concentrations or keeping temperature changes below some level, or it might use some kind of cost-benefit approach.[8] Unlike the quantitative approach under the Kyoto Protocol, there are no country emissions quotas, there is no emissions trading, and there are no base period emissions levels. Because carbon prices will be equalized, the approach will be spatially efficient among those countries that have a harmonized set of taxes.

Details about burden sharing would require study and negotiations. It would be reasonable to allow participation to depend upon the level of economic development. For example, countries might be expected to participate fully when their incomes reach a given threshold (perhaps $10,000 per capita), and poor countries might receive transfers for early participation. The issues of sanctions, the location of taxation, international-trade treatment, and transfers to developing countries under an HCT are important details that are subject to discussion and refinement. My current my view is that there should initially be relatively modest sanctions for those who violate their commitments. If carbon prices are equalized across participating countries, there will be no need for

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[7] There are few serious discussions of the structure of a regime based on price-type instruments. Some examples are Richard Cooper, "Toward a Real Treaty on Global Warming, *Foreign Affairs*, vol. 77, no. 2, 1998, pp. 66-79;; William A. Pizer, "Prices vs. Quantities Revisited: The Case of Climate Change," Resources for the Future Discussion Paper 98-02 (revised), December 1998; David Victor, *The Collapse of the Kyoto Protocol and the Struggle to Slow Global Warming,* Princeton University Press, Princeton, NJ, 2001.

[8] There are many studies linking carbon taxes to different objectives. For example, Nordhaus and Boyer, *Warming the World, op. cit.* examine the carbon taxes associated with temperature, concentrations, and emissions limits as well as those that maximize net economic benefits.

tariffs or border tax adjustments among participants. I emphasize that much work would need to be done to flesh out these arrangements, but they are familiar terrain because countries have been dealing with problems of tariffs, subsidies, and differential tax treatment for many years.

Hybrid approaches

The literature on regulatory mechanisms entertains a much richer set of approaches than the polar quantity and price types that are examined here. Discussion of climate-change policy considers one specific hybrid which might be called "prices in quantity clothes" – ones which put price ceilings and floors on the price emissions-trading permits.[9] This was considered and rejected by the Clinton Administration in its preparation for the negotiations for the Kyoto Protocol. Another approach focuses on creation of durable property rights.[10]

The present discussion focuses on pure strains of the two systems partially to keep the analysis within manageable limits. Additionally, we must recognize the tendency of mixed systems to revert to their archetype. For example, even though the Kyoto Protocol was designed as a system with complete trading within the Annex I countries, there were strong pressures to limit trading. For example, the Europeans have advocated limiting trades by the United States (because that country would not be curbing its immoral gas-guzzling excesses and would instead be buying its way out of its obligations); and, as I discuss below, I suspect there would be strong reservations about the enormous transfers to Russia and Eastern Europe (because they would be getting undeserved and perhaps dangerous windfalls). The lesson from foreign-trade barriers, where price and quantity limits have a much longer history, is that the quantity limits through quotas are extremely durable as quantity constraints, while tariffs usually remain as revenue instruments.

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[9] Warwick J. McKibbin and Peter Wilcoxen, "A Better Way to Slow Global Climate Change," Brookings Policy Brief No. 17, Washington, D.C., 1997.

[10] One proposal is that countries are allocated property rights in emissions and climate-change policy then involves purchasing these rights from countries. See David F. Bradford, "Succeeding Kyoto," Working Paper, Princeton University and NYU School of Law, June 14, 2001

VI. Comparison of Price and Quantity Approaches

Quantity approaches have a strangle hold on most environmental policies today, and policies toward global warming are no exception. Policymakers, environmentalists, and economists are so accustomed to quantity constraints in environmental policy that the fundamental advantages of price-type approaches have been largely overlooked. I begin with a catalogue of major advantages of price-type systems and then discuss their disadvantages.

Major advantages of price-type approaches

1. The most fundamental defect of the Kyoto Protocol is that the policy lacks any connection to ultimate economic or environmental policy objectives. The approach of freezing emissions at a given historical level for a group of countries is not related to any identifiable goals for concentrations, temperature, costs, or damages. Nor does it bear any relation to an economically oriented strategy that would balance the costs and benefits of greenhouse-gas reductions.

It is not inevitable that quantity-type arrangements are inefficient. In principle, they might be designed to choose an emissions path that meets some well-defined and well-designed economic and environmental objectives. However, in practice, quantity approaches tend to be technologically oriented. Price-type systems such as taxes have a mixed record of efficiency. Nevertheless, in the long sweep of fiscal history, particularly in foreign trade interferences, countries have moved from the most inefficient forms of taxation to ones that are relatively more efficient.

2. One key difference between price and quantity instruments concerns the structure of the uncertainties — and uncertainty is clearly a central feature of climate-change policy. If the curvature of the benefit function is small relative to the curvature of the cost function, then price-type regulation is more efficient; conversely, if the benefit functions are highly nonlinear while the cost functions are close to linear, then quantity-type regulation is more efficient.

While this issue has received little attention in the design of climate-change policies, it would appear that the structure of the costs and damages in climate change gives a strong presumption to price-type approaches.[11] The reason is that the benefits are related to the stock of greenhouse gases, while the costs are related to the flow of emissions. This implies that the marginal costs of emissions reductions are highly sensitive to the level of emissions, while the marginal benefits of emissions reductions essentially invariant to the current level of emissions reductions. The key point is that where the damages are caused by stock externalities (as is the case for climate change because damages are a function of the stock of greenhouse gases), then the damage function is likely to be close to linear with respect to current emissions. Abatement costs, by contrast, are likely to be highly nonlinear as a function of emissions. This combination of relative nonlinearities means that emissions fees or taxes are likely to be much more efficient than quantitative standards or auctionable quotas when there is considerable uncertainty.

Figure 6 provides some data on the impact of data revisions on different approaches. This shows the impact of relatively modest changes in the input data between the 1999 version and the 2001 version of the RICE model.[12] The changes in the target carbon prices for the Pareto (optimal) run were very small, while the changes in estimated carbon prices for the Kyoto Protocol were approximately a factor of two *in only two years*.[13] The uncertainty and high variability of the price of carbon permits under the Kyoto Protocol reflects the reality that targets must be agreed upon long before they are imposed upon countries. The consequence of this fact is that any approach that links emission limits rigidly to forecasts will have great uncertainty about the price level.

3. Closely related to the second point is that quantity-type regulations are likely to show extremely volatile prices for the trading prices of carbon emissions. Carbon prices are likely to be extremely volatile because of the

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[11] This point has been discussed by Pizer, *op. cit.* and William Pizer and Richard Newell, "Regulating Stock Externalities under Uncertainty," December 1998, Resources for the Future Discussion Paper 99-10, December 1998.

[12] These revisions primarily reflect changes in carbon intensity and GDP projections for the major countries.

[13] Similar results occurred in earlier versions of the RICE and DICE models.

complete inelasticity of supply of permits in the quantity case along with the presumption of quite inelastic demand for permits in the short run.[14]

We can judge the potential volatility of prices in a quantity-type system from the recent history of the sulfur-emissions trading program. This is analogous because the supply is virtually fixed and the demand is inelastic because of the low substitutability of other inputs for sulfur in the short run. Both programs build in some banking features, which can in principle moderate price volatility. The history of the SO_2 program shows extreme volatility of the prices — varying by 50 percent or more from one year to the next. Figure 7 shows that sulfur prices are much more volatile than consumer prices or even the stock market prices.[15]

Such rapid fluctuations would be extremely undesirable, particularly for an input (carbon) whose aggregate costs might be as great as petroleum in the coming decades. An analogous situation occurred in the U.S. during the "monetarist" period of 1979-82, when the Federal Reserve targeted quantities (monetary aggregates) rather than prices (interest rates). During that period, interest rates were extremely volatile. As a result, the Fed changed back to a price-type approach after a short period of experimentation. This experience suggests that a regime of strict quantity limits might become extremely unpopular with economic policymakers as price variability caused significant changes in price levels and import and export values.

4. A fourth advantage of tax mechanisms is the strong fiscal-policy preference for using revenue-raising measures rather than quantitative or regulatory measures. When prices are raised and real incomes are reduced by regulations, this increases the inefficiency losses from the overall tax system — this is the "double burden" of taxation that is misnamed as the "double

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[14] To some extent, the volatility can be moderated by banking and borrowing. However, borrowing and banking require durable long-term agreements about allocations, which are much more difficult to impose under international law than under most national legal systems because most treaties allow countries to withdraw and there is no supranational mechanism for enforcing property rights. It is highly unlikely that any program would allow borrowing. Moreover, note that there is substantial banking allowed under the U.S. SO_2 program.

[15] An interesting feature of SO_2 prices is that they appear to have a strong negative correlation with energy prices.

dividend" from green taxes.[16] If the carbon constraints are imposed through taxes that are then rebated in taxes that have approximately the same marginal deadweight loss as the carbon taxes, then the overall efficiency loss from taxation will be unchanged. If the constraints under a quantity-based system are brought about in ways that do not raise revenues – such as by allocation – then the conventionally calculated abatement costs will underestimate the economic costs and the efficiency losses from the price-raising elements should be added to the abatement costs.[17]

While it is possible that emissions permits will be auctioned (thereby retaining the revenues and removing the double burden of taxation), history and current proposals suggest that most or all of the permits are likely to be allocated at zero cost to "deserving" parties, or will be distributed to reduce political frictions. In the cases of SO_2 allowances and CFC production allowances, *all* the permits were allocated to producers. The point here is that using tax approaches rather than quantity-type approaches will help promote a more efficient collection and recycling of the revenues from the carbon constraints.

5. A fifth advantage of tax-type systems is central for any plan that is designed to be global in a world of imperfect governments. One of the overlooked problems with quantity-type systems is that they are much more susceptible to corruption than are price-type regimes. An emissions-trading system creates valuable tradable assets in the form of tradable emissions permits and allocates these to different countries. Limiting emissions creates a scarcity where none previously existed and in essence prints money for those in control of the permits. Such wealth creation is potentially dangerous because the value of the permits can be used for non-environmental purposes by the country's

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[16] See Lawrence Goulder, Ian Parry, and Dallas Burtraw, "Revenue-Raising vs. Other Approaches to Environmental Protection: The Critical Significance of Pre-Existing Tax Distortions," *RAND Journal of Economics*, Winter 1997, pp. 708-731 and Lawrence Goulder and A. Lans Bovenberg, "Optimal Environmental Taxation in the Presence of Other Taxes: General Equilibrium Analyses," *American Economic Review*, September 1996, pp. 985-1000.

[17] There are no well-accepted estimates of the efficiency losses from allocation as compared to taxes or auctioning emissions permits, but we can get an order of magnitude estimate. Using the United States in 2010 as an example, GDP in 2010 is about $15,000 billion (in 2002 dollars). Assume that an emissions tax of $100 per ton led to an emissions level of 1.5 billion tons of carbon. Then with a marginal deadweight loss per dollar of revenue loss of 0.4, the additional loss would be $60 billion per year on top of the abatement costs of about $15 billion for that year. There are clearly big stakes here.

leadership rather than to reduce emissions. It would probably become common practice for dictators and corrupt administrators to sell part of their permits, pocket the proceeds, and enjoy wine, partners, and song along the Riviera.

A few examples will show the perils in the quantitative approach. A Russian scientist recently reported that people in Moscow were already considering how to profit from the "privatization" of the Russian carbon emissions permits. Simulations suggest that tens of billions of dollars of permits may be available for export from Russia under the Kyoto Protocol. Alternatively, consider the case of Nigeria, which had emissions of around 23 million tons of CO_2 emissions in 1996. If Nigeria could sell its allowances under a "clean development mechanism," the allowances could easily sell for between $0.2 and $2 billion each year of hard currency. This is in a country whose non-oil exports in 1999 were around $600 million.

In addition, what of the "axes of evil," current and future? Presumably, there would be little inclination to transfer emissions permits to countries who harbor terrorists or weapons programs. If a dictator were willing to ruin his country to pursue his military and political goals, why would he not starve the population a little further to sell the emissions permits and get revenues for weapons programs?

To prevent unacceptable diversions of funds, any broad-based emissions-trading plan would undoubtedly lead to a major monitoring system and would probably get mired down in concerns about the diversion of funds to arms purchases, drugs, money laundering, terrorism, and weapons of mass destruction. It would be tempting to make receipt of any excess emissions permits conditional on "good behavior" with respect to terrorism, human rights, treatment of dolphins and turtles, child and prison labor, and other worthy causes du jour. Reducing emissions permits would be a tempting target for sanctions for countries which violate international norms. Of course, the more burdensome are the "ethical" restrictions on the sale of the permits, the less attractive participation becomes for countries, so the plan could easily founder.

A price approach gives less room for corruption because it does not create artificial scarcities and monopolies. There are no permits handed over to countries or leaders of countries, so they cannot be sold abroad for wine or guns. Any revenues would need to be raised by taxation on domestic consumption of fuels. In fact, a carbon tax would add absolutely nothing to the instruments that countries have today. The only difference would be the international approval of carbon taxes, which probably adds little to their acceptability in corrupt countries.

6. A sixth advantage of price-type regimes is that they can avoid many of the problems associated with setting the baseline emissions paths. Some of the flaws have become evident under as the Kyoto Protocol. Under the Kyoto Protocol, the targets were set thirteen years before the control period and used baseline emissions for from *twenty years* before the control period for most countries. Because of the time difference, base year emissions have become increasingly inappropriate as the economic and political fortunes of different countries have changed. The 1990 base year penalizes efficient countries (like Sweden) or rapidly growing countries (such as Korea and the United States). It also gives a premium to countries with slow growth or with historically high carbon-energy use (such as Britain, Russia, and Ukraine).

The natural baseline, and one that would probably be chosen were it feasible, is the zero-restraint level of emissions. That level is in practice impossible to calculate or predict with accuracy. Problems would arise in the future as to how to adjust baselines for changing conditions and to take into account the extent of past emissions reductions.

Under a price plan, the baseline is a zero-carbon-tax level of emissions. Countries' efforts are then judged relative to that baseline. It is not necessary to construct a historical base year of emissions. Countries are not advantaged or disadvantaged by their past policies or the choice of arbitrary dates. Moreover, there is no asymmetry between early joiners in Annex I countries and late joiners such as developing countries.[18]

7. A final concern arises in the wake of the recent revelations of financial finagling in the world largest and, it used to be said, most transparent market economy. A cap-and-trade system relies upon accurate measurement of emissions by all relevant parties. If firm A (or country A) sells emissions permits to firm B (or country B), where both A and B are operating under emissions caps, then it is essential to monitor the emissions of A and B to make sure that their

[18] Under the Kyoto Protocol, Annex I countries have a fixed 1990 base, while late joiners have no base or, implicitly under article 12, a base emissions trajectory which is their uncontrolled emissions.

emissions are in fact within their specified limits. Indeed, if monitoring is ineffective in country A but effective in country B, a trading program could actually end up raising the level of global emissions because A's emissions would be unchanged while B's would rise.

It was generally supposed that monitoring would be relatively straightforward in countries with strong legal and enforcement systems such as the United States. This was probably naïve and overly optimistic. The accounting scandals of the last year have not been limited to dollar scandals, but these have also spilled over into emissions markets. They are not yet emissions scandals because the dollars involved has not crossed the nine-digit threshold of perception.

Some recent cases were described by Ruth Greenspan Bell:[19]

> PSEG Fossil LLC, the biggest player in [New Jersey's emissions trading system], apparently had not installed necessary pollution controls or obtained proper permits. The U.S. Justice Department discovered this and brought an enforcement action, which was resolved in the form of a consent decree. PSEG, without admitting any wrongdoing, agreed to stop selling its credits to other firms and to stay out of the trading system. When PSEG was forced to withdraw, its sheer size and status as one of the largest "suppliers" of credits in New Jersey brought that state's system close to collapse.
>
> [A]ccording to ... Electricity Daily, [authorities] are looking into charges that a Pasadena broker cheated several firms who paid for emissions credits that were never delivered.... A similar example from the United Kingdom was reported ... in an account of a government-sponsored auction in which participating companies bid by offering greenhouse gas reductions. An independent review by Environmental Data Services noted strong grounds to suspect that at least half of the claimed emissions reductions were not real, and blamed the inaccuracies on shortcomings in the Department of Environment, Food, and Rural Affairs regulatory controls and "poorly thought through rules."

If emissions finagling takes place in countries with relatively solid legal systems like the United States and the United Kingdom, it would be foolish to overlook the likelihood of emissions cheating in Russia, Ukraine, and many developing countries.

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[19] "Climate Change Monitoring: International Greenhouse Gas Emissions Trading," http://www.emissierechten.nl/climate_change__monitoring_inter.htm .

Such cheating will probably be endemic in an emissions-trading system that involves large sums of money. There are very poor intrinsic incentives for honesty in a cap-and-trade system. The purchasing unit gets a permit whether or not any true reductions take place by the selling unit. The incentives for tax cheating have been thoroughly studied and are quite different. Unlike the emissions-permit case, the recipient of the tax wants the payer to dispense the funds just as much as the taxpayer dislikes dispensing the funds. Tax cheating is a zero-sum game for the two parties, while emissions cheating is a positive sum game for the two parties. If tax evasion in the U.S. is in the order of 10 or 20 percent of taxes due, is there reason to believe that emissions evasion in Ukraine or Romania would be substantially less?

Some arguments against the price approach

No system is perfect. Three arguments against the price approach come up in discussions.[20] The first is serious, the second is actually an advantage of prices, and the third is incorrect.

1. The major problem with the price approach is whether it can be effectively administered. The issue has been analyzed by David Victor in his analysis of the Kyoto Protocol, and he writes as follows:

> The third objection, however, may be fatal to the carbon tax approach. Monitoring and enforcement are extremely difficult. . . . In practice, it would be extremely difficult to estimate the practical effect of the tax, which is what matters. For example, countries could offset a tax on emissions with less visible compensatory policies that offer loopholes for energy-intensive and export-oriented firms that would be most adversely affected by the new carbon tax. The resulting goulash of prior distortions, new taxes, and political patches could harm the economy and also undermine the goal of making countries internalize the full cost of their greenhouse gas emissions.[21]

These and other concerns with the feasibility of the carbon-tax approach will require serious analysis, but I will sketch the reasons why I believe they can be overcome.

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[20] For a good summary of the case against tax approaches, see David Victor, *op. cit.*

[21] David Victor, *The Collapse of the Kyoto Protocol, op. cit.,* p. 86.

The major obstacle to enforcement is the measurement of "net carbon taxes." It might be difficult to measure the net level of carbon taxes in the context of other fiscal policies (such as fuel taxes and coal subsidies). For example, suppose that Germany imposed a $50 carbon tax, which would fall primarily on coal. It might at the same time increase its coal subsidies or reduce its gasoline taxes to offset the carbon tax, thereby reducing the level of net carbon taxes. Alternatively, Canada might argue that it has met its carbon-tax obligations by raising provincial stumpage charges on timber. How can the carbon tax be calculated in such circumstances?

This problem actually has two parts: first, we would need for each country a full set of the relevant taxes and subsidies (primarily those relating to energy taxes); second, we would need an appropriate methodology for combining the different numbers into an overall carbon tax rate.

The first issue – obtaining tax rates – is relatively straightforward for market economies. One of the proponents of the tax approach, Richard Cooper, describes the monitoring issue as follows:

> Monitoring the imposition of a common carbon tax would be easy. The tax's enforcement would be more difficult to monitor, but all important countries except Cuba and North Korea hold annual consultations with the International Monetary Fund on their macroeconomic policies, including the overall level and composition of their tax revenues. The IMF could provide reports to the monitoring agent of the treaty governing greenhouse gas emissions. Such reports could be supplemented by international inspection both of the major taxpayers, such as electric utilities, and the tax agencies of participating countries.[22]

Countries cannot easily hide their subsidies, for there are powerful environmental interest groups in most countries that monitor internal developments and would alert "the authorities" if countries instituted hidden carbon subsidies. Moreover, in transparent market democracies like the U.S., taxes and subsidies are part of the legislative process. On the other hand, countries with closed political systems might attempt to hide their subsidies. This problem would be particularly troublesome in non-market economies or sectors where fuels are allocated by quantitative measures rather than by the price mechanism.

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[22] Cooper, *op. cit.*

The second issue, calculating the effective carbon tax from the underlying data, is more complicated because it involves many technical economic issues. Calculations would require certain conventions about how to convert energy taxes into their carbon equivalent. Some of the calculations involve conversion ratios (from coal or oil to carbon equivalent) that underpin any carbon-based system, whether it be price-based or quantity-based. Others would use output data and input-output coefficients, which might not be universally available on a timely basis. On the whole, calculations of effective carbon tax rates are straightforward as long as they involve first-round or impact calculations (i.e., the rate of tax per unit of carbon emitted) and do not need to involve substitution effects.

To go beyond first-round calculations would require assumptions about supply and demand elasticities and cross-elasticities, might engender disputes among countries, and should be avoided if possible. The procedures would probably require mechanisms similar to those used in WTO deliberations, where technical experts would calculate effective taxes under a set of guidelines that would evolve under quasi-legal procedures.[23] Overall, measurement and calculation of effective carbon tax rates seems more tedious than insuperable.

2. An important issue involves the question of how to count initial carbon taxes. Some countries — particularly those in Europe — would claim that they already have high carbon-equivalent taxes because of high taxes on gasoline. They would argue for taking existing taxes into account before requiring them to undergo further obligations.

While this looks like a subterfuge, counting pre-existing taxes as compliance is not obviously wrong and easily seen to be so in the price framework. Therefore, the first step, and one absent from analysis of the Kyoto Protocol, would be a calculation of existing equivalent carbon taxes and subsidies. Our data suggest that, even without its CO_2 taxes, Europe is taxing carbon at a rate of approximately $100 per ton carbon more than the United States.[24] Given that disparity, it would make no economic sense to ask Europe to add, say, another $20 on top of its existing taxes with an equivalent expectation

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[23] There is a substantial body of work on "ecological" and "green" taxes. Some of the literature is accessible at www.globalpolicy.org/socecon/glotax/biblio/index.htm .

[24] See William Nordhaus and Joseph Boyer, *Warming the World: Economic Models of Global Warming*, MIT Press, 2000, and the associated data sheets.

for the U.S. Moreover, the fact that Europe might be overtaxing carbon today would never come up in the quantity-type approach. So perhaps this turns from disadvantage to advantage.

3. Environmentalists might worry that the price approach does not really "solve" the climate-change problem because it fails to limit emissions. This objection is akin to the fallacy that curing a sore throat requires injecting penicillin into the neck. It is misplaced because it forgets that the aim of policy is not to reduce emissions or get an agreement but to have a policy that minimizes the net damages of global warming. Adopting the Kyoto Protocol might turn out to be a Pyrrhic victory in which countries religiously meet their targets but there is virtually no impact on global temperature.

Policy should be aimed at balancing environmental and economic costs and benefits, not at limiting emissions. Emissions limitation is only an intermediate objective. It is preferable to steer policy toward the ultimate objectives of reducing concentration or temperature changes or limiting environmental damages rather than at intermediate and intrinsically unimportant objectives like emissions. A control mechanism should allow iterative adjustment and movement toward evolving goals, which can be accomplished using either prices or quantities. However, while either prices or quantities can be used as a control mechanism, emissions taxes are more efficient because of the relative linearity of the benefits with respect to emissions and the resulting high volatility of prices under an emissions-targeting approach. In other cases, quantities would be more appropriate, but in the case at hand – with a stock externality – using quantity controls only gives the appearance of being a more direct approach.

Non-economists will probably always be uncomfortable with using indirect instruments like prices, just as patients may wonder how little yellow pills can cure their disease. Nonetheless, the fact that prices are more indirect than quantity restraints should not prevent us from recognizing their great power as a coordinator and motivator.

VII. Conclusion

In sports, a score of 7-1-1 would suggest that prices are the clear victor over quantities. However, in economics, we do not simply count the arguments. They must be weighed in terms of their importance, validity, and practicality. The message I would convey is that a price-type approach to economic global public goods like global warming should be carefully considered. All evidence suggests that we are just at the beginning of dealing with this "great geophysical experiment." We will need to work together to protect the global environment just as much as to prevent tyranny, disease, poverty, and war. Nations that spend hundreds of billions of dollars developing new military weapons against unknown enemies can afford to devote a fraction of that to developing new weapons against a known enemy called global warming.

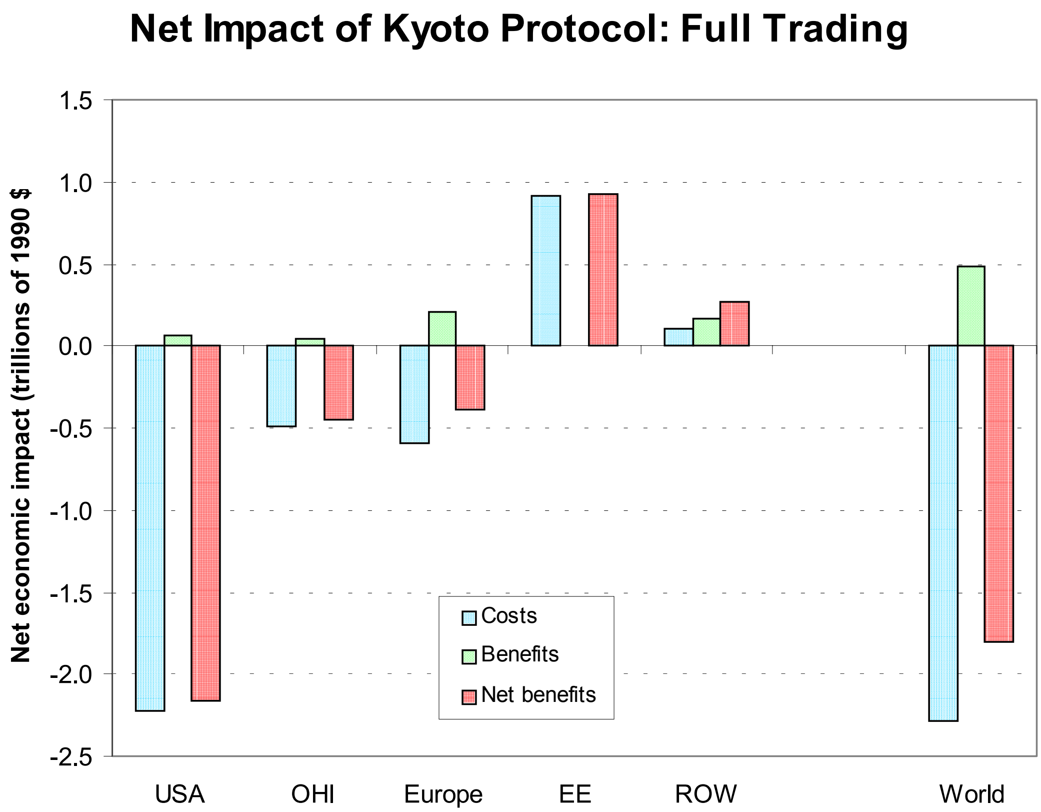

Figure 1. Costs and Benefits of the Original Kyoto Protocol

Figure shows the estimated costs and benefits of the original Kyoto Protocol in the RICE-2001 model for different regions. The figure shows the costs and benefits of the Kyoto Protocol (with full Annex I trading) for the major regions. *Costs* are production costs (measured negatively), *benefits* are the environmental benefits of reduced climate change, and *net benefits* are the difference between costs and benefits. All figures are relative to the no-control baseline.

Source: The underlying model is described in William Nordhaus and Joseph Boyer, *Warming the World: Economic Models of Global Warming*, MIT Press, 2000, Chapter 8. Input data are revised to reflect changes in trends since 1999.

Note on regions:
"OHI" is other high-income countries, including Japan and Canada.
"Europe" is primarily the European Union
"EE" is Eastern Europe and the countries of the former Soviet Union
"ROW" is the rest of the world

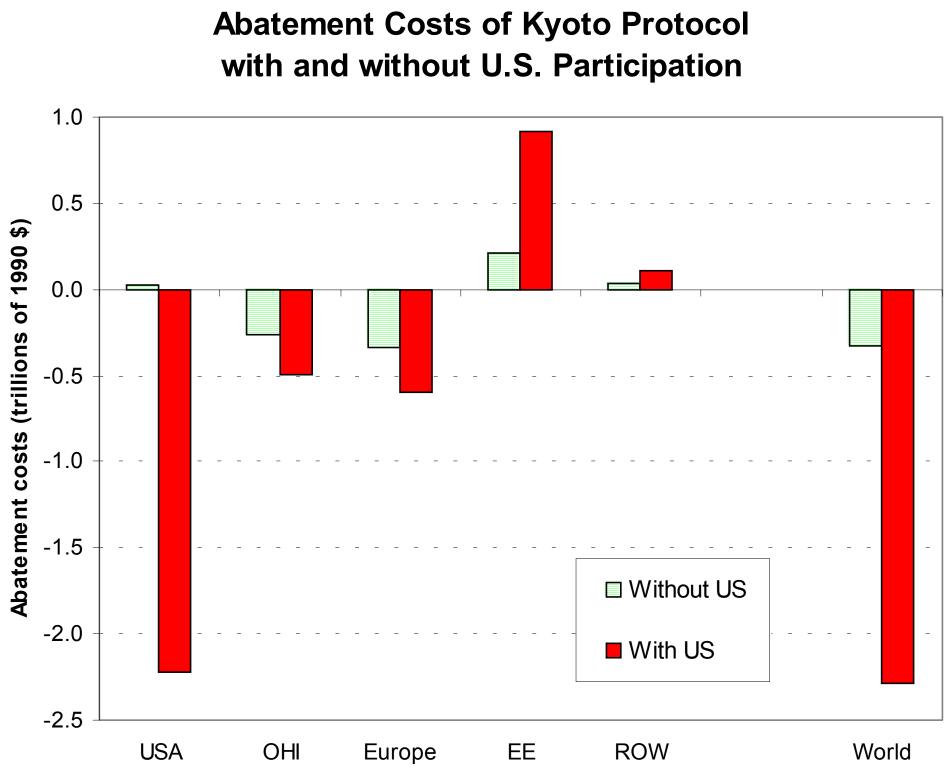

Figure 2. Abatement Costs of Kyoto Protocol without United States Participation

The burden of abatement would shift greatly if the U.S. were excluded from the Kyoto Protocol. Note that costs are measured negatively, as in Figure 1.

Source: See Figure 1

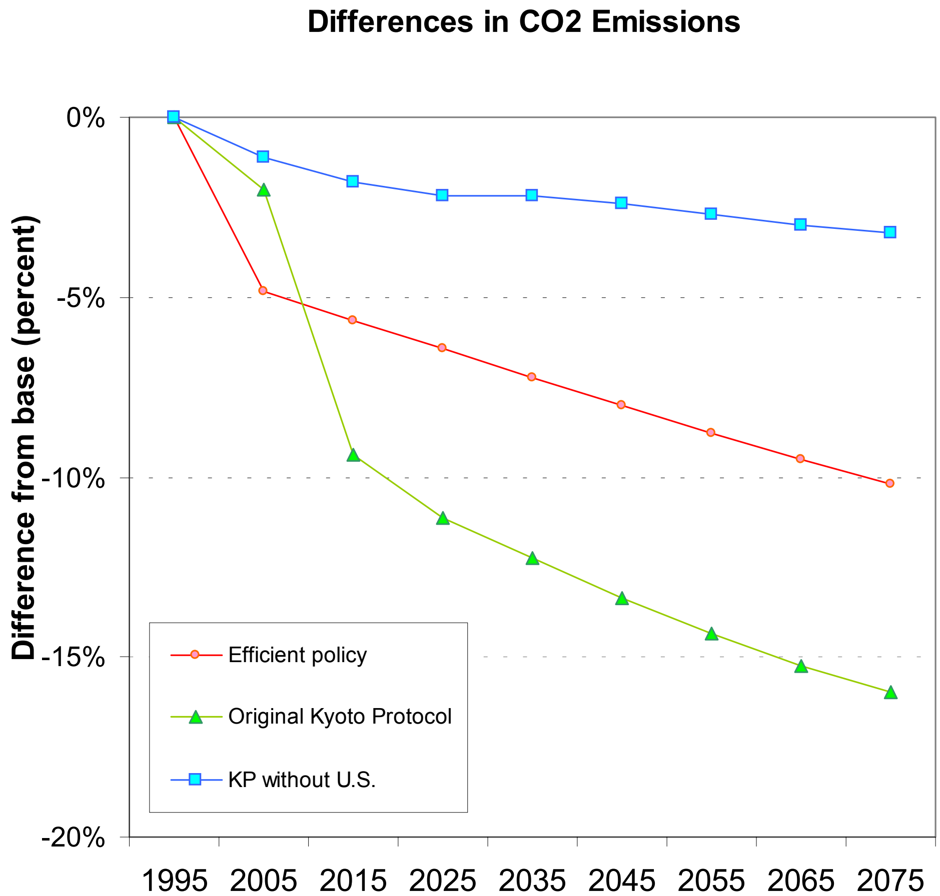

Figure 3. Estimated Emissions Reductions Under Different Scenarios.

Numbers are for total global industrial CO_2 emissions and measure the percent reduction relative to a "business as usual" path of no emissions reductions (or zero carbon prices). The "efficient policy" path is balances estimated costs and benefits of emissions reductions. The "Original Kyoto Protocol" shows the impact of the Protocol with U.S. participation. "Kyoto Protocol without U.S." shows the impact of removing the U.S. from the Protocol. The estimates are for the decades centered on the listed year. Estimates do not include reductions in targets due to new provisions regarding sinks and other technicalities contained in the most recent version of the Kyoto Protocol.

Source: See Figure 1

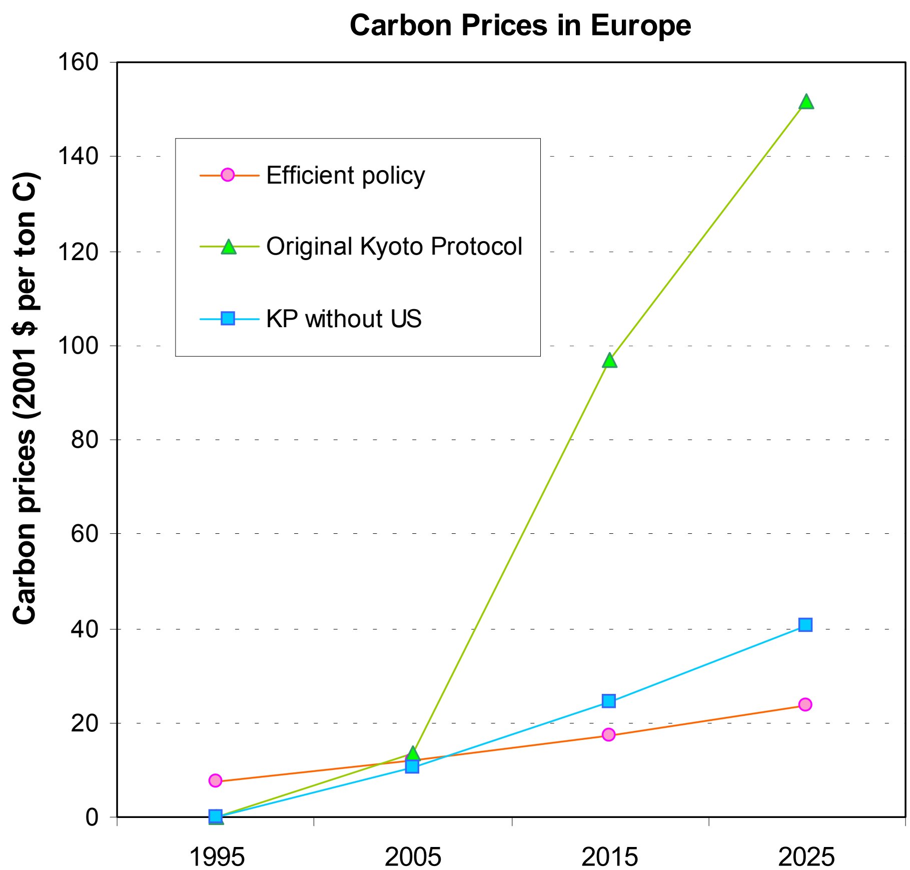

Figure 4. Carbon prices in Europe and Other Countries Implementing the Kyoto Protocol

The "efficient policy" path balances estimated costs and benefits of emissions reductions. The "Original Kyoto Protocol" shows the impact of the Protocol with U.S. participation. "Kyoto Protocol without U.S." shows the impact of removing the U.S. from the Protocol. The estimates are for the decades centered on the listed year. Estimates do not include reductions in targets due to new provisions regarding sinks and other technicalities.

Note: Emissions permits are "free" in developing countries under both versions of the Kyoto Protocol, and are "free" in the U.S. when it does not participate. Carbon prices are the estimated market price of permits to emit carbon dioxide measures in 2001 U.S. dollars per ton carbon. These results assume full trading.

Source: See Figure 1

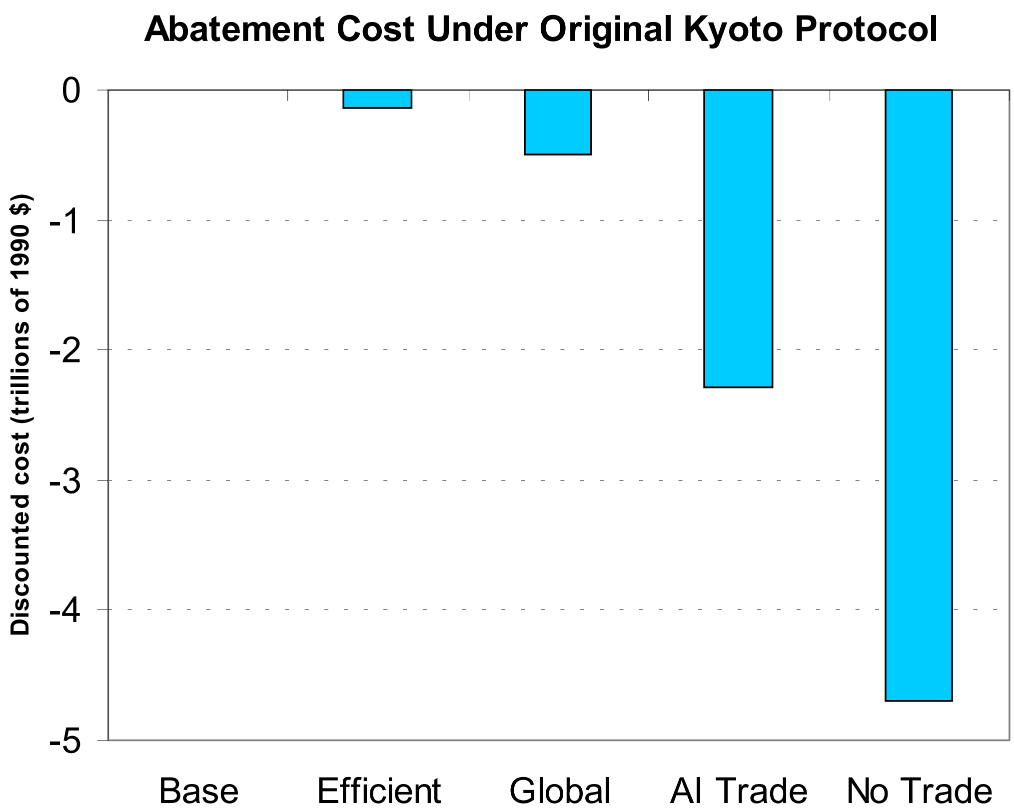

Figure 5. Abatement Costs under Different Implementation Strategies of the Kyoto Protocol in the RICE-2001 Model

The estimates are the discounted value of the costs of abatement and exclude any environmental benefits. Costs are discounted back to 1990 and are in 1990 U.S. dollars. The results use the RICE-2001 model. The *Base* case is with no restraints on emissions. The *Efficient* case is one that balances costs and benefits over time. *AI trade* is the basic Kyoto Protocol with full Annex I trading. *Global* is the case where the emissions under the AI Trade case are traded among all countries. *No Trade* allows no emissions trading among the four major regions of Annex I.

Source: See Figure 1

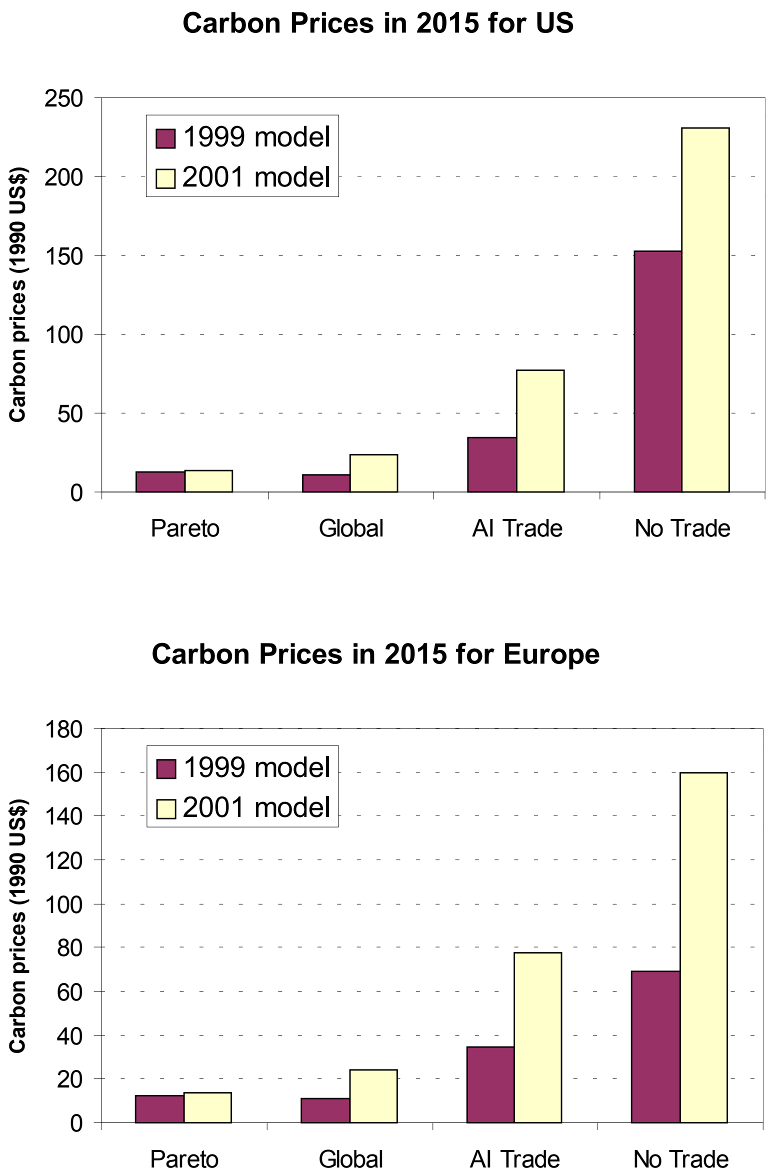

Figure 6. **Impacts of Model Revisions on Projected Carbon Prices for 2015**

These two figures show the impact of data revisions between 1999 and 2001 on the estimated prices of carbon trading permits for Western Europe and the United States for four different runs (in 1990 U.S. dollars). There is very little change in the carbon prices for the Pareto efficient run (from $12.71 to $13.82 per ton carbon). However, for the estimated prices under the Kyoto Protocol changes are substantial. The change in the price of permits for full Annex I trading was from $34 to $77 per ton carbon, while the price for permits in the no-trade runs in Western Europe was from $69 to $160 per ton carbon.

Source: See Figure 1.

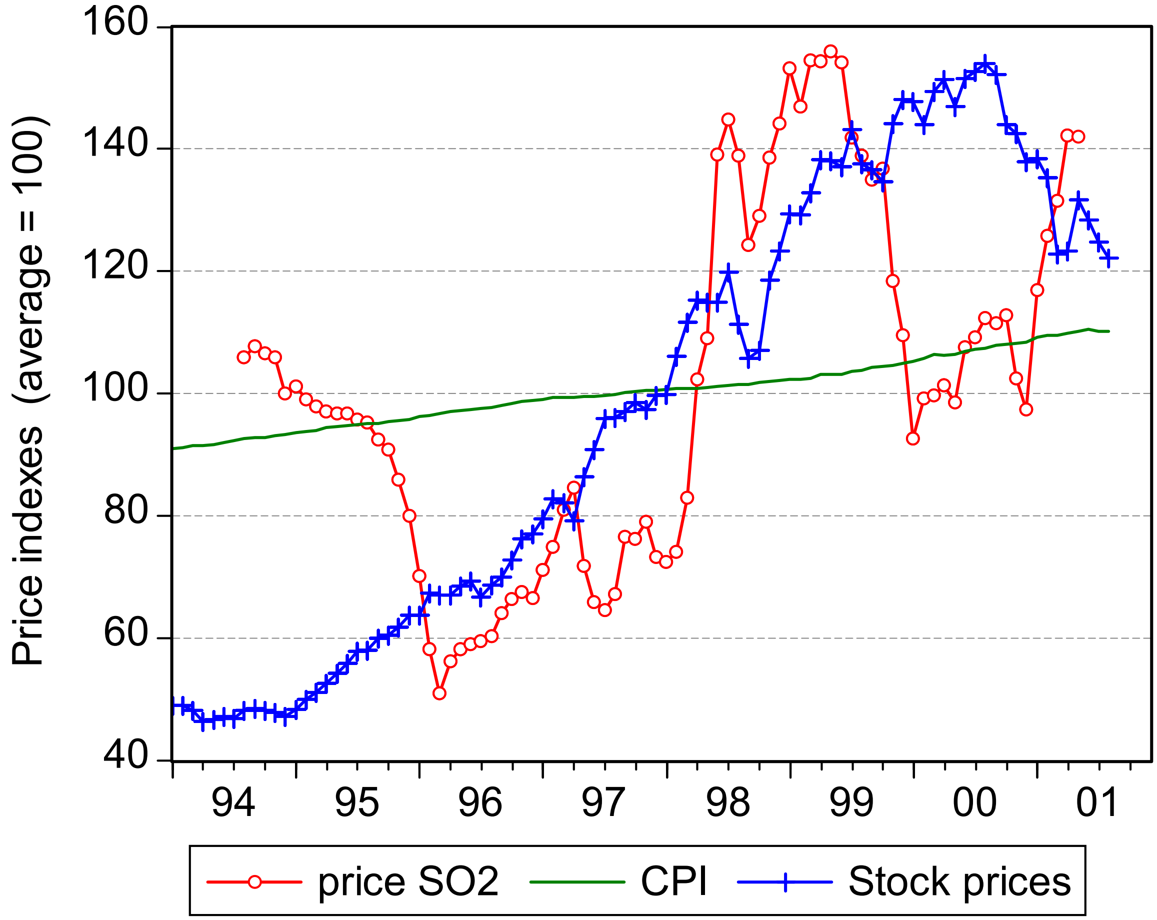

Figure 7. Prices of sulfur emissions permits are highly volatile, 1994-2001

One of the potential concerns with the current structure of the Kyoto Protocol is that it will induce great volatility in the prices of permits. The volatility can be seen in the history of SO_2 permit prices, which have been much more volatile than consumer prices or even stock prices.

Source: Oil prices and CPI from DRI. Price of SO_2 permits from Denny Ellerman with permission.

Appendix. The RICE model and Changes between RICE-1999 and RICE-2001 model

The RICE model (Regional Integrated model of Climate and the Economy) is an integrated or "end-to-end" model that analyzes the major economic tradeoffs involved in global warming. It uses the framework of optimal economic growth theory and incorporates emissions and climate modules to analyze alternative paths of future economic growth and climate change. This appendix provides a brief overview of the RICE-99 model and describes the changes incorporated in the RICE-2001 model. The RICE-99 model is fully documented in the published literature and on the Internet.[25]

In the RICE-99 model, the world is composed of eight regions (the U.S., Western Europe, other high-income countries, China, Eastern Europe and the former Soviet Union, middle-income countries, lower-middle-income countries, and low-income countries). Each region is assumed to have a well-defined set of preferences by which it chooses its path for consumption over time. The welfare of different generations is combined using a social-welfare function that applies a pure rate of time preference to different generations. Nations are then assumed to maximize the social-welfare function subject to a number of economic and geophysical constraints. The decision variables that are available to the economy are consumption, the rate of investment in tangible capital, and the climate investments, represented by reductions of emissions of greenhouse gases.

The model contains both a traditional economic sector, similar to that found in many economic models, and a geophysical module designed for climate-change modeling. Each region is endowed with an initial stock of capital and labor and an initial and region-specific level of technology. Population growth and technological change are exogenous in the baseline model, while capital accumulation is determined by optimizing the flow of consumption over time. The energy sector is modeled as producing and consuming "carbon-energy," which is the carbon equivalent of energy consumption and is measured in carbon units. Technological change takes two forms: economy-wide technological change and carbon-energy saving technological change.

The environmental part of the model contains a number of geophysical relationships that link together the different forces affecting climate change. These involve a carbon cycle, a radiative forcing equation, climate-change equations, and a climate-damage relationship. Endogenous emissions are limited to industrial CO_2, which is a joint product of carbon-energy. Other contributions to global warming are taken as exogenous. Climate change is represented by global mean surface temperature,

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[25] See Nordhaus and Boyer, *Warming the World*, *op. cit.* Full documentation is available on the Internet at www.econ.yale.edu/~nordhaus/homepage/ dicemodels.htm .

and the relationship between radiative forcing and climate uses the consensus of climate modelers and a lag derived from coupled ocean-atmospheric models. The economic impacts of climate change uses a willingness-to-pay approach and relies on detailed sectoral estimates for thirteen major regions of the world; the model includes both market and non-market impacts of climate change along with an estimate of the potential impact of abrupt climate change.

Changes are introduced into the RICE-2001 model only for the U.S. and Western Europe. For the U.S., recent data indicate an increase in long-term productivity growth and potential output. Consequently, the estimated rate of total factor productivity (TFP) growth has been increased from 0.38 percent per year to 0.98 percent per year in the first decade with declining changes in subsequent decades; part of this reflects changes in output measurement and part is genuine productivity acceleration. The initial increase in the efficiency of carbon-energy services was increased from 1.13 percent per year to 1.33 percent per year to reflect measurement changes in output. According to the baseline projections, U.S. industrial carbon emissions for the period centered on 2005 over that centered on 1995 are estimated to grow at 1.7 percent per year.

Similarly, trend output growth in Western Europe appears to have increased relative to earlier forecasts. We have therefore increased estimated TFP growth in Western Europe from 0.41 percent per year to 0.98 percent per year in the first decade, with appropriate adjustments thereafter. There is no apparent change in the efficiency growth of energy services in Western Europe, so that parameter was unchanged. All other parameters were kept at the levels assumed in the RICE-1999 model.

The recent apparent sharp decline in carbon dioxide emissions in China will have little effect on the analyses of the Kyoto Protocol in the RICE model because the model envisions sharp increases in energy efficiency in the baseline case. Holding Chinese emissions constant over the next century has virtually no effect on the optimal shadow prices.

The RICE-2001 model is available in a spreadsheet version on the Internet at www.econ.yale.edu/~nordhaus/homepage/ dicemodels.htm .