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38 Choosing Price or Quantity Controls for Greenhouse Gases

William A. Pizer

To control emissions of greenhouse gases (GHG), there are two basic forms of economic incentives that can be used: taxes on emissions of these gases (a price instrument) or an emissions-trading system (a quantity instrument). The analysis suggests that, in principle, the tax instrument is much superior to an emissions trading system for controlling GHG. However, existing policies are leaning strongly towards systems of emissions trading. Such systems can be made more efficient by allowing a "safety valve" in the form of a relatively high tax that can be paid on excess emissions in the event that allowance prices in the trading market become very high.

Much of the debate surrounding climate change has centered on verifying the threat of climate change and deciding the magnitude of an appropriate response. After years of negotiation, this effort led to the 1997 signing of the Kyoto Protocol, a binding commitment by industrialized countries to reduce their emissions of carbon dioxide (CO_2) to slightly below 1990 recorded levels. Without approving or disapproving of the response effort embodied in the Kyoto Protocol, I believe that an important element has been ignored. Namely, should we specify our response to climate change in terms of a quantitative target?

The appeal of a quantitative target is obvious. A commitment to a particular emissions level provides a straightforward measure of environmental progress as well as compliance. Commitment to an emissions tax, for example, offers neither a guarantee that emissions will be limited to a certain level nor an obvious way to measure a country's compliance (when other taxes and subsidies already exist). Yet, this concern points to an important observation.

Quantity targets guarantee a fixed level of emissions. Emission taxes guarantee a fixed financial incentive to reduce emissions. Both can be set at aggressive or modest levels. Aside from the appeal of the known and verifiable emissions levels that quantity targets can ensure, might there be other important differences between price and quantity controls? Economists

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would say "Yes." With uncertain outcomes and policies that are fixed for many years, it is important to carefully consider both the costs and benefits of alternate price and quantity controls to judge which is best. My own analysis of the two approaches indicates that price-based greenhouse gas (GHG) controls are much more desirable than quantity targets, taking into account both the potential long-term damages of climate change and the costs of GHG control. This can be argued on the basis of both theory and numerical simulations. On the basis of the latter, I find that price mechanisms produce expected net gains five times higher than even the most favorably designed quantity target.

To explain this conclusion, I first characterize the differences between price and quantity controls for GHGs. I then present both theoretical and empirical evidence that price-based controls are preferable to quantity targets on the basis of these differences. Finally, I discuss how price controls can be implemented without a general carbon tax. This point is particularly salient for the United States, where taxes are generally unpopular. The "safety valve," as it is often called, involves a cap-and-trade GHG system accompanied by a specified fee or penalty for emissions beyond the initial cap.

How Do Quantity- and Price-Based Mechanisms Work?

A quantity mechanism—usually referred to as a permit or cap-and-trade system—works by first requiring individuals to obtain a permit for each ton of CO_2 they emit, and then limiting the number of permits to a fixed level. (CO_2 emissions from fossil fuel sources constitute the bulk of GHG emissions and are the general focus of most policy discussions. However, the arguments made in this context apply equally well to the regulation of GHG emissions more broadly defined.) This kind of system has been used with considerable success in the United States to regulate sulfur dioxide and lead. The permit requirement could be imposed on the individuals who release CO_2 into the atmosphere by burning coal, petroleum products, or natural gas. However, unlike the emissions of conventional pollutants, which depend on various other factors, CO_2 emissions can be determined very accurately by the volume of fuel being used. Rather than requiring *users* of fossil fuels to obtain permits, we could therefore require *producers* to obtain the same permits. This method has the advantage of involving far fewer individuals in the regulatory process, thereby reducing both monitoring and enforcement costs.

One key element in a permit system is that individuals are free to buy and sell existing permits in an effort to obtain the lowest cost of compliance for themselves, which in turn leads to the lowest cost of compliance for society. In particular, when individuals observe a market price for permits, those who can reduce emissions more cheaply will do so to sell excess permits or to avoid having to buy additional ones. Similarly, those who face higher reduction costs will avoid reductions by buying permits or by keeping those they already possess. In this way, total emissions will exactly equal the number of permits, and only the cheapest reductions are undertaken.

A price mechanism—usually referred to as a carbon tax or emissions fee—requires the payment of a fixed fee for every ton of CO_2 emitted. Like the permit system, this fee could be levied upstream on fossil fuel producers or downstream on fossil fuel consumers. Either way, we associate a positive cost with CO_2 emissions and create a fixed monetary incentive to reduce emissions. Such price-based systems have been used in Europe to regulate a wide range of pollutants (although the focus is usually revenue generation rather than substantial emissions reductions).

Like a tradable permit system, price mechanisms are cost-effective. Only those emitters who can reduce emissions at a cost below the fixed fee or tax will choose to do so. Because only the cheapest reductions are undertaken, we are guaranteed that the resulting emission level is obtained at the lowest possible cost.

The important distinction between these two systems is how they adjust when costs change unexpectedly. A quantity or permit system adjusts by allowing the permit price to rise or fall while

Update

Much has happened in the arena of climate change policy since this article was first published in 2001. The Kyoto Protocol entered into force at the beginning of 2005, despite the withdrawal of the United States and Australia. More importantly, various nations have begun designing and implementing domestic policies using both price and quantity instruments. The European Union has already begun its greenhouse gas Emissions Trading Scheme (ETS), New Zealand has introduced a carbon tax starting in 2007, and Canada is establishing a trading program for Large Final Emitters (LFE) of carbon dioxide. While the E.U. ETS is a pure quantity policy and the New Zealand carbon tax a pure price policy, the Canadian LFE is a hybrid with a targeted reduction through the trading program and a safety valve to limit costs. In the United States, a group of nine northeastern states are negotiating the Regional Greenhouse Gas Initiative to cap and reduce emissions from power plants through a quantity-based regional trading program. At the national level, Senators McCain and Lieberman have introduced a proposal for a trading program with a further proposal from Senator Bingaman for a safety valve to supplement trading. In the midst of all these domestic developments, international discussions are commencing on what to do "post-Kyoto" from 2013 onward. In particular, these negotiations must focus on whether there will be a continued international focus on quantitative targets.

holding the emissions level constant. A price or tax system adjusts by allowing the level of total emissions to rise or fall while holding the price associated with emissions constant. Ignoring uncertainty and assuming that we know the costs of controlling CO2, both policies can be used with the same results. Consider the following example:

Suppose we know that with a comprehensive domestic CO_2 trading system in place in the United States by 2010, a permit volume of 1.2 gigatons (billion tons) of carbon equivalent emissions (GtC) will lead to a $100 permit price per ton of carbon. (U.S. emissions of carbon from fossil fuels were estimated at 1.5 GtC for 1998.) In other words, faced with a price incentive of $100 per ton to reduce emissions, regulated firms in the United States will find ways to reduce emissions to 1.2 GtC. Then, the same outcome can be obtained by imposing a $100 per ton carbon tax.

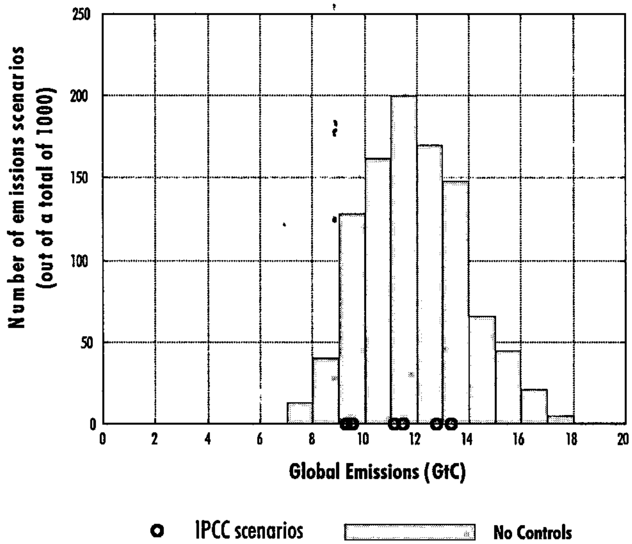
Uncertainty about Costs

In reality, we have only a vague idea about the permit price that would occur with emissions of 1.2 GtC or any other emission target. These costs are hard to pin down for three reasons. First, little evidence exists concerning reduction costs. There are no recent examples of carbon reductions on a substantial scale from which to base estimates. In the 1970s, energy prices doubled and encouraged increased energy efficiency, but these events occurred in a context of considerable uncertainty about the future and alongside many other confounding factors (such as increased environmental regulation). Alternatively, engineering studies provide a bottom-up approach to estimating costs. However, comparisons of past engineering forecasts with actual implementation costs suggest that forecasts are inaccurate at best.

A second source of uncertainty arises because we need to forecast compliance costs in the future. This task involves difficult predictions about the evolution of new technologies. Proponents of aggressive policy argue that reductions will be cheap as new low-carbon or carbon-free energy technologies become available. Proponents of more modest policies argue that these are unproven, pie-in-the-sky technologies that may never be practical.

Finally, it is impossible to know how uncontrolled emission levels will change in the future. That is, to achieve 1990 emission levels in 2010, it is unclear whether reductions of 5%, 25%, or even 50% will be necessary. The Intergovernmental

Figure 1: Distribution of Emissions in 2010



Panel on Climate Change (IPCC), the international agency charged with studying climate change, gives a range of six possible global emission scenarios in 2010 that include a low of 9 GtC and a high of 13 GtC. My own simulations suggest a broader possible range, 7–18 GtC.

The low end of both ranges reflects the possibility that population and economic growth may slow in the future and the energy intensity of production may fall. The high end reflects the opposite possibility, that growth remains high and energy intensity rises. Figure 1 shows the distribution of uncontrolled emissions arising from my simulations of 1,000 possible outcomes in 2010 alongside the six IPCC scenarios. (For details about the model, see Pizer in Suggested Reading.)

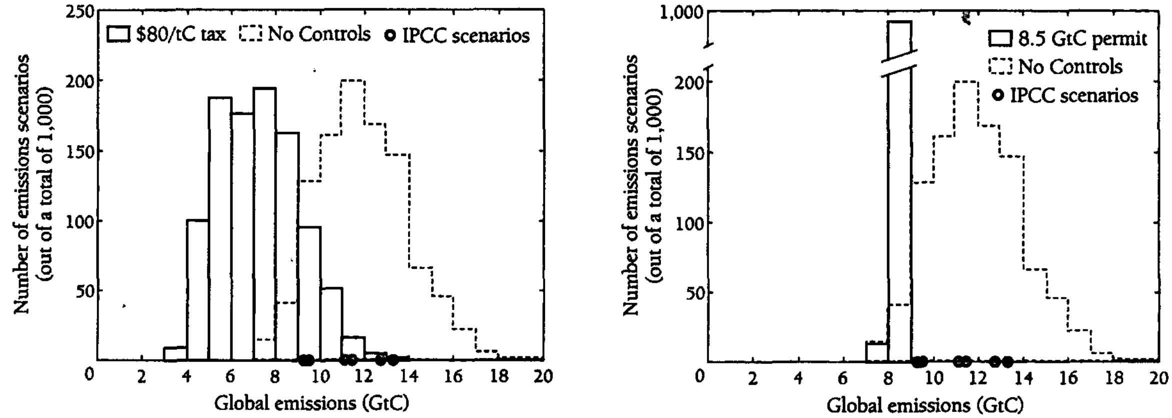
In summary, we have only vague ideas about the cost of alternative emission targets for two important reasons. First, there is little historic evidence about costs. Second, as we examine policies 10 or more years in the future, it is unclear how baseline emissions and available technologies will change between now and then. Figure 1 indicates that global emissions could be anywhere from 7 to 18 GtC in 2010. The cost associated with a target of 8.5 GtC (1990 level) will be uncertain because the necessary reduction is uncertain—somewhere between 0 and 10 GtC—and because costs are difficult to estimate, even knowing the reduction level.

Effects of Price and Quantity Controls with Cost Uncertainty

When the cost of a particular emission target is uncertain, price and quantity controls will have distinctly different consequences for the actual level of emissions as well as the overall cost of a climate policy. Even if both policies are designed to deliver the same results under a best-guess scenario, they will necessarily behave differently when control costs deviate from this best guess. These differences arise because a price policy provides a fixed incentive (dollars per ton of CO_2 emissions), regardless of the emission level, and a quantity policy generates whatever incentive is necessary to strictly limit emissions to a specified level.

Figure 2 illustrates these differences by showing the emission consequences in 2010 associated with two policies that are roughly equivalent under a best-guess scenario: a quantity target of 8.5 GtC

Figure 2: Effect of Price and Quantity Controls on Emissions in 2010



Two policies are roughly equivalent under a best-guess scenario: a carbon tax of $80/ton (left) and a quantity target of 8.5 GtC (right).

and a carbon tax of $80/ton. Using the same 1,000 emission scenarios shown in Figure 1, simulations are used to calculate the effect of these two policies for each outcome. With a carbon tax, emissions are below 8.5 GtC in more than 75% of the outcomes. In other words, on average the carbon tax achieves more reductions than a quantity target of 8.5 GtC. Sometimes, the reductions are much more; emissions may be as low as 3 GtC. Yet, the carbon tax fails to guarantee that emissions will always be below any particular threshold.

The quantity target, in contrast, never results in emission levels above 8.5 GtC. Because some emission outcomes in the absence of controls were rather high, on the order of 18 GtC, we would expect that the cost of this policy could be quite high. At the other extreme, the quantity policy would be costless if uncontrolled emissions were unexpectedly low.

These data suggest that the cost associated with quantity controls will be high or low depending on future reduction costs as well as the future level of uncontrolled emissions. In contrast, price controls create a fixed incentive to reduce each ton of CO_2 regardless of the uncontrolled emission level. Therefore, costs under a carbon tax should fluctuate much less than costs under a quantity control.

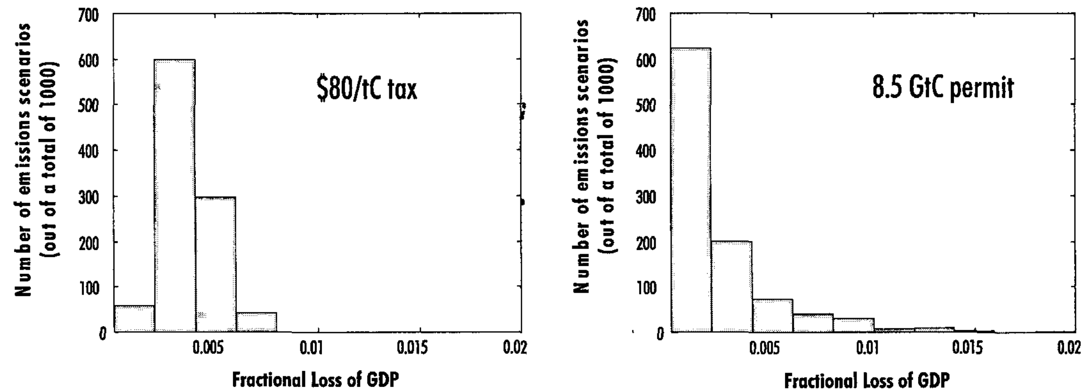
Figure 3 shows the estimated cost consequences of both policies. The range of costs associated with the quantity target is quite wide, as we suspected. The estimates extend from 0 to 2.2% of global gross domestic product (GDP), almost four times higher than the highest cost outcome under the carbon tax. In fact, the cost associated with emission reductions under a carbon tax are concentrated entirely in the range 0.2–0.6% of GDP. Because the carbon tax always applies the same per ton incentive to reduce emissions, the cost outcomes are more narrowly distributed than those occurring under a quantity target.

Choosing between Price and Quantity Controls

So far, the discussion has been limited to the different emission and cost consequences of alternative price and quantity controls. Choosing between them, as well as choosing the appropriate stringency of either policy, requires making judgments about climate change consequences as well as control costs. To understand when one policy instrument probably will be preferred to the other, it is useful to consider two extreme cases.

First, imagine that there is a known climate

Figure 3: Distribution of 2010 Costs associated with Price and Quantity Controls



change threshold. When CO_2 emissions are below this threshold, the consequences are negligible. Above this threshold, however, damages are potentially catastrophic. For example, research suggests that the process by which CO_2 is absorbed at the surface of the oceans and circulated downward could change dramatically under certain circumstances. If we also believe that these changes will have severe consequences and that we can identify a safe emission threshold for avoiding them, then quantity controls seem preferable. Quantity controls can be used to avoid crossing the threshold, and in this case, large expenditures to meet the target are justified by the dire consequences of missing it.

Now, imagine instead that every ton of CO_2 emitted causes the same incremental amount of damage. These damages might be very high or low, but the key is that each ton of emissions is just as bad as the next. Such a scenario is also plausible, as indicated by a survey of experts including both natural and social scientists who do research on global warming. Their beliefs suggest that the damage caused by each ton of emitted CO_2 may be quite high but that there is no threshold: Damages are essentially proportional to emissions. Each additional ton is equally damaging, whether it is the first ton emitted or the last.

In this case, it makes sense to use a price instrument. Specifically, a carbon tax equal to the damage per ton of CO_2 will lead to exactly the right balance between the cost of reducing emissions and the resulting benefits of less global warming. Every time a firm decides to emit CO_2, it will be confronted with an added financial burden equal to the resulting damage. It will lead to reduction efforts as well as investments in new technology that are commensurate with the alternative of climate change damage. In this scenario, little emphasis is placed on reaching a particular emission target because there is no obvious quantity target to choose. This argument applies even if we are uncertain about the magnitude of climate damage per unit of CO_2.

Arguments for Price Policies

Given this characterization of circumstances under which alternative price and quantity mechanisms are preferred, we can make the argument for price controls. This argument hinges on two basic points. The first point is that climate change consequences generally depend on the stock of GHGs in the atmosphere, rather than annual emissions. GHGs emitted today may remain in the atmosphere for hundreds of years. It is not the level of annual emissions that matters for climate change but the total amount of CO_2 and other GHGs that have accumulated in the atmosphere. The second point is that although scientists continue to argue over a wide range of climate change consequences, few advocate an immediate halt to emissions. For example, the most aggressive stabilization target discussed by the IPCC is a 450-ppm concentration in the atmosphere (roughly 1,035 GtC), a level that we will not reach before 2030, even in the absence of emission controls.

If only the stock of atmospheric GHGs matters for climate change, and if experts agree that the stock will grow at least in the immediate future, then there is almost no rationale for quantity controls. The fact that only the stock matters should first draw our attention away from short-term quantity controls for emissions and toward long-term quantity controls for the stock. It cannot matter whether a ton of CO_2 is emitted this year, next year, or in 10 years if all we care about is the total amount in the atmosphere. Taking the next step and presuming that the stock will grow over the next few decades, this approach suggests that there is some room to rearrange emissions over time and that a short-term quantity control on emissions is unnecessary.

Quantity controls derive their desirability from situations where strict limits are important, when dire consequences occur beyond a certain threshold. Such policies trade off low expected costs in favor of strict control of emissions in all possible outcomes. However, under the assumption that it is acceptable to allow the stock of GHGs to grow in the interim, there is no advantage to such strict control. We give up the flexible response of price controls without the benefit of an avoided catastrophe.

Even for those who believe the consequences of global warming will be dire and that current emission targets are not aggressive enough, price policies are still better. An aggressive policy designed to stabilize the stock eventually does not demand a strict limit on emissions before stabilization becomes necessary. Additional emissions this year are no worse than emissions next year. Why not abate more when costs are low, less when costs are high—exactly the outcome under a price mechanism? When we eventually move closer to a point where the stock must be stabilized, a switch to quantity controls will be appropriate.

In addition to these theoretical arguments, integrated assessment models can provide support. To this end, I have constructed an integrated model of the world economy and climate based on the dynamic integrated climate-economy (DICE) model developed by William Nordhaus (see Suggested Reading). In contrast to the DICE model, I simultaneously incorporate uncertainty about everything from growth in population and energy efficiency to the cost of emission reductions, the sensitivity of the environment to atmospheric CO_2, and the damages arising from global warming.

The results of these simulations indicate the price-based mechanisms can generate overall economic gains (expected benefits minus expected costs) that are *five times higher* than even the most prudent quantity-based mechanism. These results are robust. Even allowing for catastrophic damages beyond 3°C of warming, price mechanisms continue to perform better. This robustness can be explained in two ways. First, the catastrophe—if it exists—is in the future. Before we reach that point, it is desirable to have some flexibility in emission reductions. Specifically, we will want to delay those reductions if the costs are unexpectedly high in the short run, provided those reductions can be obtained more cheaply in the future but before the catastrophe.

Second, unlike the stylized description in which climate consequences depended directly on CO_2 concentrations presented earlier, in this model, damages depend on temperature change. In reality, damages probably depend on an even more complex climatic response. Either way, the links between CO_2 emissions, concentrations, temperature change, and other climatic effects are not precisely known. Therefore, a quantity control on *emissions* is not equivalent to a quantity control on *climate change*. Both price and quantity controls will lead to uncertain climate consequences. Therefore, the advantage of the quantity control—namely, its ability to avoid with certainty the threat of climate catastrophe—is substantially weakened.

Combined Price and Quantity Mechanisms

Even if a carbon tax is preferable to a cap-and-trade approach in terms of social costs and benefits, this policy obviously faces steep political opposition in the United States. Businesses oppose carbon taxes because of the transfer of revenue to the government. Under a permit system, there is a hope that some, if not all, permits would be given away for free. Environmental groups oppose carbon taxes for an entirely different reason: They are unsatisfied with the prospect that a carbon tax, unlike a permit system, fails to guarantee a particular level of emissions. Such antagonism from both sides of the debate makes it unlikely that a carbon tax will become part of the U.S. response to the Kyoto Protocol.

However, the advantages of a carbon tax can be achieved without the baggage accompanying an actual tax. In particular, a combined mechanism (often referred to as a hybrid, or a safety valve) can obtain the economic advantages of a tax while preserving at least some of the political advantages of a permit system.

In such a scheme, the government first distributes a fixed number of tradable permits—freely, by auction, or both. The government then provides additional permits to anyone willing to pay a fixed ceiling or "trigger" price. The initial distribution of permits allows the government the flexibility to give away a portion of the right to emit CO_2, thereby satisfying concerns of businesses about government revenue increases. The sale of additional permits at a fixed price then gives the permit system the same compliance flexibility associated with a carbon tax.

With a combined price/quantity mechanism, it will be necessary to consider how both the trigger price and the quantity target should evolve over time. One possibility is to raise the trigger price over time to guarantee that the quantity target is eventually reached. A second possibility is to carefully choose future trigger prices as a measure of how much we are willing to pay to limit climate change. As we learn more about the costs of future emission reductions, however, this distinction between price and quantity controls will diminish. That is, after uncertainty about future compliance costs is reduced through experience, then price and quantity controls can be used to obtain similar cost and emission outcomes.

Operationally, when this safety valve is used in conjunction with international emissions trading, as the Kyoto Protocol allows, problems potentially arise. In general, there would be a need for either harmonization of the trigger price across countries or restrictions on the sale of permits from those countries with low trigger prices. Otherwise, there would be an incentive for countries with a low trigger price to simply print and export permits to countries with higher permit prices. This action would not only effectively create low trigger prices everywhere; it also would create large international capital flows to the governments of countries with the low trigger prices.

Instead of harmonizing trigger prices, the trigger price could be set low enough to avoid the need for international GHG trades. This may be a desirable end in light of concerns about the indirect economic consequences of large volumes of international GHG trade flows.

Finally, if we find it desirable to raise the trigger price rapidly, it will be necessary to limit the possibility that permits can be purchased now and held for long periods of time. Otherwise, there will be a strong incentive to buy large volumes of cheap permits now to sell them at high prices in the future. This problem is easily addressed by assigning an expiration date for permits as they are issued, for perhaps one or two years in the future.

Building Domestic and International Support for a Price-Based Approach

Although the safety valve approach is potentially appealing to businesses concerned about the uncertainty surrounding future permit prices, environmental groups will be wary of giving up the commitment to a fixed emission target. Such a commitment is already an integral part of the Kyoto Protocol. However, a strict target policy ultimately may lack political credibility and viability. Although a low trigger price would clearly rankle environmentalists as an undesirable loosening of the commitment to reduce emissions, a higher trigger price could allay those fears while still providing insurance against high costs.

Perhaps more controversial than the concept of a safety valve is the fact that a hybrid policy requires setting a trigger price. It extends the debate over targets and timetables to include perceived benefits on the basis of the trigger price. Business interests undoubtedly will seek a low trigger price and environmental groups a high trigger price. I believe this conflict is desirable. The debate will focus on the source of disagreement between different groups—namely, the value placed on reduced emissions. Rather than leaning on rhetoric that casts reduction commitments as either the source of the next global recession (according to businesses) or the costless ushering in of a new age of cheaper and more energy-efficient living (according to environmentalists), it will be necessary to decide how much we are realistically willing to spend to deal with the problem.

Although seemingly provocative in its challenge of the core concept of targets and timetables embedded in the Kyoto Protocol, some concept of the safety valve is already part of many countries' notion of their commitments to the protocol. European countries that are likely to implement carbon taxes must have some idea how they will handle target violations if their tax proposals fail to sufficiently reduce emissions before the end of the first commitment period. Likewise, other countries that are considering either a quantity or command-and-control approach must envision a way out if their actual costs begin to surpass their political will to reduce emissions.

Among the many implicit safety valve possibilities, one could imagine a more flexible interpretation of existing provisions, such as the clean development mechanism or the use of carbon sinks. Alternatively, Article 27 specifies that parties can withdraw from the protocol by giving notice one year in advance. A country that foresaw difficulty in meeting its target in the first commitment period could serve notice that it wished to withdraw before the commitment period ended.

Therefore, flexibility in meeting current commitments already exists implicitly. Countries can choose to massage their commitments using existing provisions, violate their targets and risk penalties (which have yet to be defined), or simply withdraw. In these cases, however, the outcome and consequence are unclear. The advantage of a price mechanism is that it makes the safety valve concept explicit and transparent. Establishing a price trigger for additional emissions allows countries, and private economic decisionmakers in turn, to approach their reduction commitments with greater certainty about the future. This method not only improves the credibility of the protocol but also its prospects for future success in reducing GHG emissions.

Conclusions

The considerable uncertainty surrounding the cost of international GHG emission targets means that price- and quantity-based policy instruments cannot be viewed as alternative mechanisms for obtaining the same outcome. Price mechanisms will lead to uncertain emission consequences, and quantity mechanisms will lead to uncertain cost consequences. Economic theory as well as numerical simulations indicate that the price approach is preferable for GHG control, generating five times the net expected benefit associated with even the most prudent quantity control. The essence of this result is that a rigid quantity target over the next decade is indefensible at high costs when the stock of GHGs is allowed to increase over the same horizon.

Importantly, a price mechanism need not take the form of carbon tax. The key feature of the price policy is its ability to relax the stringency of the target if control costs turn out to be higher than expected. Such a feature can be implemented in conjunction with a quantity-based mechanism as a safety valve. A quantity target is still set, but with the understanding that additional emissions (beyond the target) will be permitted only if the regulated entities are willing to pay an agreed-upon trigger price.

This approach can improve the credibility of the protocol and its prospects for successful GHG emission reductions. The last point is particularly relevant for ongoing climate negotiations. Should the emission incentives and consequences remain ambiguous and uncertain, or should they be made explicit and transparent? Specifying a price at which additional, above-target emissions rights can be purchased provides a transparent incentive; the current approach does not. Although ambiguity may prove to be the easier negotiating route, it also may be a disincentive for true action.

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