

ANALYSIS

Beyond Kyoto: A tax-based system for the global reduction of greenhouse gas emissions

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Received 19 January 2005; received in revised form 6 September 2005; accepted 8 September 2005

Available online 4 November 2005

Abstract

The Kyoto Protocol represents an initial step in terms of solving the problem of global climate change. However, as with most first steps, the Kyoto Protocol must be followed by a full journey in order to reach the desired goal of preventing catastrophic global warming. The Kyoto Protocol does not lead to the necessary decline in the atmospheric concentrations of greenhouse gases, particularly because emissions of developing countries are not specifically addressed in the Protocol. We suggest a new agreement based on carbon taxes as a possibility to build upon the Kyoto Protocol and eventually freeze atmospheric concentrations at a level that prevents catastrophic climate change.

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Keywords: Climate change; Pollution taxes; Economic incentives

1. Introduction

In March of 2001 the George W. Bush administration decided that the Kyoto Protocol did not further the interests of the United States, and abandoned the Kyoto Protocol process.¹ Chief among his objections was what his administration perceived to be a high

cost of complying with the provisions of the Protocol. While the Kyoto Protocol does not slow the accumulation of greenhouse gases in a way that will prevent catastrophic climate change, we disagree with his decision to abandon the process, and we disagree with his projection that the cost of meeting the Protocol is unwarrantedly high. Rather than abandoning the Kyoto Protocol, the Kyoto Protocol should be significantly augmented in order to generate a meaningful slowing and eventually cessation of anthropogenic climate change.

According to the IPCC, the stabilization of atmospheric concentrations of carbon dioxide at 450 ppm requires the reduction of emissions to 1990 levels

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¹ Environmental News Service, 2001, <http://www.rememberjohn.com/kyoto.html>.

within several decades, and continuous reductions in emissions quickly thereafter. Even a rapid stabilization at 450 ppm will generate temperature change of approximately 2 °C. and a sea level rise of 0.3 m. by 2100. (IPCC Synthesis report) As we will explain below, the Kyoto Protocol, without modification, cannot achieve the rather modest goal of achieving stabilization at 450 ppm. *The Kyoto Protocol is not a comprehensive program to reduce the threat of global warming. It is the beginning of a process and the development of a comprehensive system must begin immediately in order to achieve this relatively modest goal.*

The Kyoto Protocol requires Annex I countries (OECD countries and formerly communist Europe) to reduce their emissions to 6% below 1990 levels by 2010. However, this will not accomplish the goal of stabilization at 450 ppm for several reasons. First, Annex II countries (developing countries) have no limits placed on their emissions by the Kyoto Protocol. Since these countries include populous and rapidly industrializing countries such as China, India, Brazil and Mexico this has very important implications for future greenhouse gas emissions. If these four countries embarked on a development path that resulted in the same per capita emissions as the United States, the emissions from these four countries would exceed the emissions generated by the entire world in 2000. The implications of this statistic are incredible. Even if these countries only increased their emissions to half the US per capita level, the rest of the world (including the rest of the developing countries) would have to cut their emissions by 50% just for the global emissions to remain constant, which would still generate increases in atmospheric concentrations of carbon dioxide. Second, there are no provisions in the Kyoto Protocol for generating further reductions in emissions below the Kyoto limit. If developing country emissions are increasing and developed country emissions are stabilized, atmospheric carbon dioxide emissions will not stabilize, but increase at an accelerating rate.

The fundamental requirement for the stabilization of atmospheric concentrations of carbon dioxide is that the reductions in emissions of developed countries must exceed the increases in emissions in developing countries by a significant margin. *In order for this to occur, increases in emissions by developing*

countries must be slowed, and decreases in emissions by developed countries must be accelerated, beyond what has been stipulated in the Kyoto Protocol.

The importance of reducing the growth of developing country emissions highlights a critical equity issue. The developing countries view the global climate problem as a problem that was created by the industrialized countries, who fueled their industrial growth by burning fossil fuels and cutting temperate forests. They think it inherently unfair that the developing countries be asked to make substantial sacrifices in order to alleviate global warming. However, the growth of emissions of developing countries can be substantially slowed through the development of a new international emissions limitation treaty that provides incentives, but not limitations for developing countries. We propose a tax-based international system of emissions limitations which has the potential for generating appropriate incentives in an equitable fashion.

2. An international system based on per unit carbon taxes

The proposed tax system is based on creating economic incentives for both developed countries and developing countries to reduce their emissions below what they would otherwise be, both in the present and the future. The tax would be placed on all non-renewable carbon emissions, and the carbon dioxide equivalent of other greenhouse gases such as methane and chlorofluorocarbons. Carbon in biomass fuels such as biodiesel and alcohol would not be taxed. Although the combustion of these fuels releases carbon into the atmosphere, the growth of the next cycle of the biomass crops pulls the carbon back out of the atmosphere, resulting in no increase in atmospheric concentrations of carbon dioxide. In contrast, the combustion of fossil fuels releases carbon that plants pulled out of the atmosphere millions of years ago. One of the most important impacts of a carbon tax is that it will encourage switching from fossil fuels to biomass-based fuels and other alternatives.

In the proposed system, both developed and developing countries would face taxes so that global incentives would be created to reduce carbon emissions. One way of helping to ensure the participation of developing countries would be to have a lower tax

per unit carbon in developing countries in comparison to developed countries. This would help to alleviate fears about impacts on economic growth and would also help address the equity issue. In addition, a proportion of the tax revenue raised in developed countries would go into a general development fund to be used by developing countries for any development purpose (not constrained to projects which would reduce greenhouse gas emissions). The remainder would stay within the developed country and could be used for any purpose which the developed country chose, including reducing income taxes, value added and/or corporate taxes. As long as these types of tax reductions are not related to the amount of carbon that an individual or firm emits, then these other tax refunds will not erode the incentive properties of the pollution tax. In contrast, all the tax revenue raised within a developing country would stay within the developing country and could be used for any purpose, including development (health, technology transfer, education, infrastructure, etc.) or reduction of existing taxes. It should be noted that these carbon taxes should be imposed on top of existing fuel taxes in the various countries; otherwise the taxes will not give any additional incentive to reduce greenhouse gas emissions.

There are several important technical issues involving the taxes that need be addressed. First, the taxes should be imposed gradually over time, to reduce the potential for macroeconomic shocks. If the schedule of tax increases is known for ten or twenty years into the future, when households and firms buy durable goods, vehicles or other forms of capital, they will make their decisions incorporating the knowledge that the cost of emissions will increase substantially into the future. Second, the taxes should be in real terms to be inflation proof. In the case of developed countries, the taxes could be designated in a bundle of developed country currencies, to prevent swings in the value of currency from affecting the impact of the tax. However, such a provision could create great difficulties in developing countries, if a situation such as the Mexican peso crises, the Asian financial crises or the 1998 devaluation of the Brazilian real developed. If developing country currencies fell significantly, and developed country currencies remained at previous levels, the tax could lead to further macroeconomic shocks within developing countries. For this reason, the developing

country tax should be defined in terms of a bundle of developed and developing country currencies, or there should be some other type of mechanism to keep currency-related changes in the tax within limits to prevent swings in currency values from creating further economic shocks through the carbon tax system.

The tax system can help address the important equity issues that separate countries. In particular, the provision that a portion of the tax revenues collected in developed countries be used to create an unrestricted development fund could help ensure developing country participation, particularly because the tax system does not impose limits on developing countries. Moreover, the tax differential between developing countries and developed countries will help developing countries to compete with developed countries in international trade.

The tax system can further address equity issues by creating tax differentials among developed countries or tax differentials among developing countries. For example, one definition of equity would be that a country's fair share of the burden of reducing greenhouse gas emissions is proportional to its contribution to the accumulation of these gases in the atmosphere. This could be accomplished by weighting a country's per unit tax by the ratio of its per capita emissions to the per capita emissions averaged across other countries in the corresponding group. Eq. (1) reflects such a weighting system.

$$W_i = \frac{\frac{CO_{2i}}{Pop_i}}{\frac{1}{n} \sum_{j=1}^n \frac{CO_{2j}}{Pop_j}} \quad (1)$$

Similarly, another conception of a fair burden for reducing greenhouse gas emissions is proportional to a country's ability to make sacrifices. In this case, a corresponding index could be developed by making the weight equal to the ratio of the per capita income of a particular country to the average per capita income of the countries in its group.

3. The advantages of a tax based system

Readers may find it strange that two economists are advocating a tax-based system, as many economists favor the "cap and trade" system. A tax system

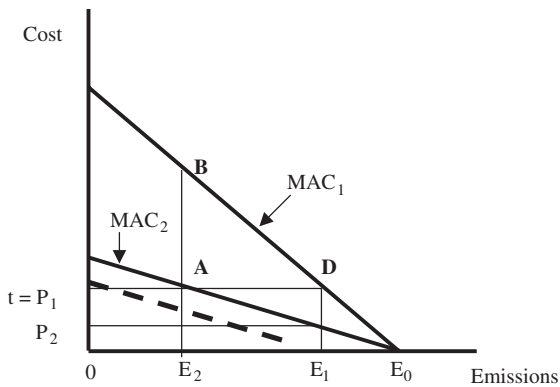


Fig. 1. Responses to taxes and credit systems.

carries four significant advantages in comparison to a cap and trade system. These are:

- A continuous incentive to reduce emissions even if the tax remains constant.
- Greater incentive for technological innovation in emissions reduction technologies.
- Easier inclusion of small polluters such as households in an incentive system.
- Greater likelihood of developing country participation.

However, before demonstrating why a tax system is preferable to a cap and trade system, it is beneficial to examine why economic incentives are preferable to command and control systems. This is not new information to those who study environmental economics. Command and control systems tend to exacerbate the costs of controlling emissions, because they do not give flexibility in making choices in how to reduce emissions. In contrast, economic incentives make it costly for polluters to emit, but leave them free to choose the least cost method of reducing pollution.²

The creation of a never-ending incentive to reduce emissions is an important advantage of the tax system over the cap and trade system. Quite simply, technological innovations that result in a downward shift of the marginal abatement cost function generate very different results within the two systems of economic incentives. A technological innovation within a cap

and trade system reduces the price of the marketable pollution permit, but has no effect on the level of emissions. This is illustrated in Fig. 1, where the unregulated level of emissions is E_0 and the emissions are reduced to E_1 by a tax equal to t , or a quantity of marketable permits equal to E_1 . In this case, the price of the permits will equilibrate at P_1 . Now, if technological innovation takes place, as depicted by the shift of the marginal abatement cost curve from MAC_1 to MAC_2 , emissions will fall to E_2 under the tax system. However, under the cap and trade system, emissions will remain unchanged at E_1 , as the technological innovation is reflected by the price decrease from P_1 to P_2 . As technology naturally evolves, emissions will fall under a tax system. However, under a cap and trade system, emissions will not fall until technology drives the horizontal intercept of the marginal abatement cost function to the left of the quantity of pollution permits, as in the dashed marginal abatement cost function in Fig. 1. Even in the case of this type of shift of the marginal abatement cost function, the reductions in emissions under a tax system would be greater than the reduction under a permit system.

Although both a tax system and a permit system allow firms to realize cost savings from technological innovation, the cost savings are greater in the tax system, giving an additional incentive for research and development into energy saving and emissions reducing technologies. This is illustrated in Fig. 2, where E_1 is the level of emissions before the regulation, and E_3 is the level of emissions after regulation. First, assume that E_3 is achieved with a cap and trade system. Then, the benefit to the firms of developing

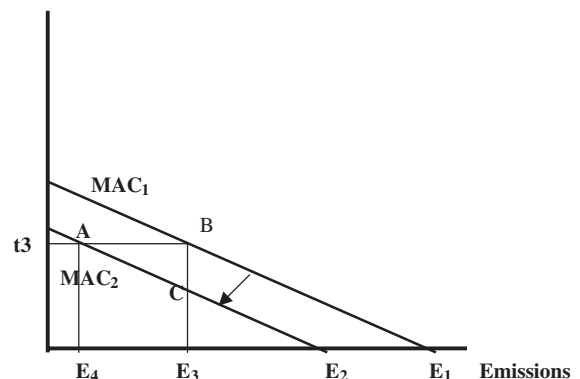


Fig. 2. Abatement cost savings with technological innovation.

² This result is fully discussed in all environmental economics textbooks. See Fields, Kahn (2005) or Tietenberg, for example.

better abatement technology (represented by a downward shift of the marginal abatement cost function from MAC_1 to MAC_2) is equal to the area of trapezoid CBE_1E_2 , or the difference between the two marginal abatement cost functions for the amount of pollution they are abating ($E_1 - E_3$). Note that if E_3 is achieved by a tax equal to t_3 , firms have an even greater incentive to make the technological innovation. Not only do they receive the area of trapezoid CBE_1E_2 , but they will also receive the area of triangle ABC . The reason for this is that for the area between E_3 and E_4 , the cost of reducing emissions is smaller than the tax (with the new technology) thus firms will respond by lowering their emissions and achieving greater saving. In the context of global warming, where it is necessary to generate future reductions, the fact that taxes are superior to marketable pollution permits in generating technological innovation (in comparison to pollution taxes) is a significant advantage of the tax system over the cap and trade system.

Taxes are also preferable to a cap and trade system because it is difficult to include small polluters in a marketable pollution permit system, as transactions cost associated with monitoring and enforcement are simply too high. However, greenhouse gas emissions from small polluters are important. Whether it is a taxi driver in Mexico City or a young executive driving a Hummer in Atlanta, emissions of individuals contribute to the atmospheric concentrations of greenhouse gases. Under a permit system, this would need to be handled by a separate system of direct controls (such as the CAFE standards in the United States). However, systems such as the CAFE system, which specify technology requirements (in this case the fuel efficiency of engines) not only does not give the full range of incentives, but is associated with a perverse incentive known as the rebound effect.³ The decisions of an individual household concerning how much to drive its car, the level at which it sets its thermostat, the length of hot showers and similar decisions will be

completely unaffected by a cap and trade system, because transaction costs prohibit the inclusion of this type of activity in a trading system. Moreover, the use of direct controls to reduce emissions from this type of activity is likely to be both difficult and expensive. However, a tax system would give an individual household the appropriate incentives to modify these activities to reduce the household's total emission level. In fact, the lowest cost methods of reducing emissions are the simple adjustments that can be made by small polluters such as households, retail establishments, business offices, and the like.

4. Carbon sequestration

In addition to limiting emissions, a global climate treaty must provide new opportunities for carbon sequestration, as well as protecting carbon that is already sequestered. The Kyoto Protocol gives little incentive for new opportunities for sequestration, and no incentives for protecting existing sequestered carbon. New opportunities for sequestration may take place in reforestation, forest plantations, agricultural fields and pastures and other activities. Existing sequestration takes place in pristine forests, second-growth forests, wetlands, grasslands, and so on.

Under the Kyoto Protocol, there only very limited opportunities to receive credit for sequestration activities. In particular, neither changes in agricultural practices (enhancing soil carbon levels, manure handling, livestock feed management) nor the maintenance of existing forests receives credit. The exclusion of the agricultural activities is particularly disturbing because these are relatively low cost abatement activities. The exclusion of credit for the preservation of pristine forests is even more disturbing, because there exist few market incentives to maintain these important sources of biodiversity and other ecological services.

One could construct a differentiated plan for giving credit (by subsidy payment, carbon annuity⁴ or other mechanism) for carbon sequestration. If the nations of the world wish to place a high priority in protecting ecosystems that are both high in carbon sequestration

³ The rebound effect occurs when the energy efficiency of cars reduces the cost of operation, and individuals respond by increasing the number of miles that they drive, causing the emissions reductions of the energy saving technology to be dampened. In the case of automobile fuel efficiency in the United States, the rebound effect is estimated to be about 20%. Meaning that for a ten percent improvement in energy efficiency, emissions only fall by 8%.

⁴ See Caviglia-Harris and Khan, 2003.

and high in other ecological services, then the highest payment per ton of sequestered carbon would go to forests (and other ecosystems such as wetlands) that are important sources of the full suite of ecological services. Even though these forests do not provide new sequestration, recent research has indicated that the conversion of these forests to other land uses releases the carbon to the atmosphere much more quickly than previously thought.⁵ Therefore, it is imperative to maintain these carbon sinks intact as well as protect the production of the other ecological services. The economic value of carbon can be used as a means to provide an economic incentive for protecting these other important sources of ecological and social benefits.

The next highest payment for sequestration could go to the creation of new habitat in areas of prior degradation. This creates two major benefits in addition to carbon-sequestration. The first is recuperation of previously degraded areas and augmentation of the flow of ecological services from the areas. The second is the creation of a source of income that reduces the pressure to exploit the more pristine areas. These areas should not be forest monoculture, but would need to be biodiverse and generate a significant flow of ecological services in addition to carbon sequestration.

The next level of sequestration credit would be for degraded areas that were converted into forest plantations. Lower credit is given because these areas are lower in biodiversity and other ecological services. The lowest level of credit is given for increases in carbon sequestration generated by the modification of existing agricultural activities.

It is important that no credit be given for carbon sequestration activities that destroy natural ecosystems. For example, no credit would be given for the conversion of wetlands into a eucalyptus plantation.

4.1. Political acceptability

Although the plan that is suggested above has the potential to address the problem of atmospheric accumulation of greenhouse gases, desirable properties are not all that is required. The plan must be politically acceptable as well. The enhanced prospects for developing country participation have already been discussed, with the absence of emission limits and the creation of a global development fund providing a significant inducement for developing country participation. However, what of political acceptability among voters and elected officials within both developed and developing countries? How will voters respond to a system which will clearly increase the price of energy use in the short run?

The idea of a tax may seem counterintuitive in a political environment where voters are crying about both the (perceived) high cost of energy and the percentage of income that is taxed. However, these potential objections could be easily dealt with by refunding all or a portion of the taxes to the citizenry. As long as the refund of the tax was carried out in a fashion that was unrelated to energy consumption or carbon emissions (such as a progressive tax refund or a lump sum distribution) the tax would still have the desired impact on carbon emissions.

Since the tax revenue will decline over time as emissions decline over time, a good potential use of the tax revenue may be investment or endowment purposes. For example, a country with failing infrastructure could use the revenue to replace degraded infrastructure or implement new infrastructure. Alternatively, a country such as the United States that was seeking to move its social security system from a “pay as you go” system, to an accrual-based system could use the carbon tax revenue to fund the transition and endow the social security system.

Another alternative would be to construct the system to return all the tax revenue to firms. A good example of how to do this is the tax system for nitrogen oxides in Sweden.⁶ Under this system (which applies to electric power generators), the firms pay a tax per ton of nitrogen oxides emitted. All of the money that is collected from this is returned to the firms, based on their share of electric power generation. For example,

⁵ Mayorga et al. (2005). This research indicates that when the carbon is transported from the land into the river system, the majority of the carbon is broken down from the organic cells that contain it, and it is respired to the atmosphere. Previously it was believed that much of this carbon was transported to the ocean where it was stored from long periods of time before release to the atmosphere. Therefore, it is now believed that there is little lag time between the destruction of forests (even when not burned) and the release of the carbon into the atmosphere.

⁶ See Blackman and Harrington (1999) for a complete discussion.

if a firm generates 5% of the total electricity production, it receives a payment equal to 5% of the total revenue that is collected. Firms that are exactly average in pollution per kilowatt hour of electricity generated pay no net taxes. Firms that are better than average in terms of pollution per kilowatt hour profit, and firms that are worse than average lose money under the system. This system generates additional incentives for pollution reduction by placing firms in competition with each other to improve their environmental efficiency.

Recent political events could make the system more politically acceptable as well. The Iraq war is perceived to be highly related to the oil that exists in Iraq. Many countries, especially the United States have relatively little diversity in their energy portfolio, relying primarily on oil. The absence of diversity implies high risk. The population is nervous about the political ramifications of this dependence on oil, and nervous about the price movement. For example, in the period spanning 2004 and 2005, prices increased from about thirty dollars per barrel to more than sixty dollars per barrel. Many would welcome the freedom from dependence on foreign oil, particularly if the process did not involve major changes in lifestyle. With biodiesel and other liquid fuels, the transportation and electric power generation systems in the United States and other countries would not require significant changes to convert to the new fuels.

This possibility of fuel switching is important to consider, because the cost of limiting emissions is often cited as a reason for opposition to the provisions of the Kyoto Protocol, let alone more aggressive limitations on emissions. In fact, the cost of emissions reductions to the US economy was the reason cited by President George W. Bush for pulling-out of the Kyoto Protocol process.

The evidence, however, does not support the Bush Administration position that the cost of reducing emissions is oppressive. Much of the evidence concerning the cost of reducing emissions has been synthesized in two IPCC reports.⁷ The IPCC reports

examine two general categories of cost of abatement studies, “Top-Down” studies and “Bottoms-Up” studies.

“Top-Down” studies are based on aggregate macroeconomic models such as the computable general equilibrium (CGE) models. CGE models look at how the various sectors of the economy are linked and compute how potential impacts on the economy (such as tighter environmental regulations or higher energy prices) ripple their way and impact the overall level of GDP. There are two major types of problems with these genera of models. First, within the CGE models, there is no mechanism by which environmental quality can have a positive impact on GDP. This is a serious omission, because the reduction of CO₂ emissions will be partially achieved in a way that reduces the emissions of other types of pollution, such as volatile organic compounds (VOCs), sulfur dioxide (SO₂), nitrogen oxides (NO_x), carbon monoxide (CO) and so on. For example, if reductions in CO₂ are achieved by utilizing more energy efficient capital, all types of emissions will fall as less energy is used. This reduction in other types of pollution would have a positive impact on GDP, reducing health care costs, prolonging the life of materials, increasing agricultural yields and so on. The other major problem with these types of models is that they impose the disturbance (such as restrictions on emissions or higher energy costs) on the economy, but do not allow the economy to adjust to the new conditions. They assume that economic activity will be conducted in the same way as in the past, without making adjustments. This implies greater cost estimates than if adjustments are allowed.

According to these two IPCC reports, the impact of stabilizing greenhouse gas emissions at 1990 levels that is forecast by the Top Down models is to reduce the GDP of OECD countries by 0.5% to 2% of the level it would otherwise attain. If full emissions trading were allowed⁸, the impact on GDP would be substantially lower (0.1% to 1.1%), according to these studies. However, because of the problems listed above, even the lower estimate of 0.1% to 1.1%

⁷ Inter-governmental panel on climate change, *climate change 2001: synthesis report* (2003). Inter-governmental panel on climate change summary for policymakers: the economic and social dimensions of climate change-IPCC Working Group III (Bruce et al., 1996). Both reports are available at www.ipcc.ch.

⁸ Note that pollution taxes would have the same cost-minimizing properties as marketable pollution permits.

should be viewed as an upper bound estimate, with the actual cost quite likely to be below this.

The IPCC studies report that the “Bottoms Up” studies show a much lower cost, and that the 1990 levels could actually be attained at “negative cost,” implying that production costs would actually be lowered through achieving the 1990 emissions levels. Bottoms-Up models look at engineering cost estimates of implementing the type of technologies that are necessary to achieve the target emissions levels and then compute how costs would change as a result of switching to these new technologies in response to the new regulatory or environmental regime.

The reason that achieving reductions consistent with 1990 emission levels actually lowers production cost has to do with the interplay between capital costs and operating costs. Although the initial capital costs of purchasing and installing more energy efficient capital can be significant, they are more than offset by the energy savings that results. This benefit occurs without a drastic movement away from fossil fuels. In addition, there are the benefits of reduced emissions of other types of pollution. Because these policies would result in an increase in social welfare independent of the benefits of reduced global climate change, Nordhaus (1994) refers to these types of policies as “no regrets” policies. No regrets policies are those policies that have non-climate related benefits, so we approve of them even if it turned out that scientists miscalculated and the impacts of potential global climate change were far less than expected.

A very important aspect of the over-estimate of costs comes from the assumptions in the top down models, which evaluate the constraints imposed by reducing emissions while assuming that no adjustments are made in the choice of technology. Past experience has shown that this type of estimation process leads to vast over-estimation of the costs of compliance with new emission standards. For example, the U.S. Environmental Protection Agency originally predicted the price of a sulfur dioxide permit to be \$1500 per ton, but revised this downward to about \$500 in 1990 as the Amendments were being acted upon. In actuality, prices started out around \$250–300 per ton in 1992, falling to \$110–140 in 1995 and bottoming-out around \$70 per ton in 1996, slightly less than five percent of

the original cost estimate. (Bohi and Burtraw, 1997).⁹

While this is not an indication that the cost of reducing greenhouse gas emissions will be an order of magnitude less than current cost estimates, it is an indication that we need to be careful when making CGE or engineering cost estimates, because these do not incorporate the full potential of adaptation possibilities and technological innovation.

It seems rather paradoxical that the consensus of the economic modeling is that emissions reductions can be achieved at low cost or cost savings, yet the perception of excessive cost tends to be the focus of those opposed to global climate treaties. There are three reasons for this. First, there is uncertainty about the costs and some people may anticipate that the actual costs will turn out to be greater than anticipated. Furthermore, the proposal of something more ambitious than the Kyoto Protocol would swell people’s perceptions of the uncertainty. Second, the costs occur predominantly in the short run, as energy inefficient capital is replaced with more energy efficient capital and as alternative fuel sources replace conventional fuel sources. Although the cost savings would then come in over the next several decades as less energy would need to be purchased, people and politicians tend to focus on the short run. Finally, some sectors of the economy will be hurt more drastically than others. For example, the fossil fuel industry is a certain loser (unless they switch to the production of alternative fuels) if we require the reduction of emissions, particularly if the changes spur the development of alternative sources of power such as biomass fuels, wind and solar energy. Other sectors of the economy will benefit, but those who are likely to be hurt are certain to vigorously promote the idea that emission limitations are too costly to implement. However, it should be noted that the health of a nation’s oil industry and the health of the national economy are not one and the same.

A tax is more conducive to solving the political acceptability problem associated with uncertainty about costs, because a tax creates an upper bound to

⁹ The 2003 auction had a market clearing price of approximately \$170 per ton.

the social costs of attaining a given level of emissions. The idea that a tax can ameliorate the uncertainty associated with the cost of abatement is an often overlooked corollary to Weitzman's (1974) important article, as the focus of the economics profession has been on the ability of marketable pollution permits to reduce the uncertainty in terms of achieving the target level of pollution. However in the current political climate where there is such fear of excessive abatement costs and corresponding impacts on the macro-economy, an international agreement based on taxes as a system of compliance may be more feasible in a political sense, because taxes set a ceiling on the cost of compliance.

5. Other environmental considerations

The potential problem of converting natural habitat into engineered ecosystems for the storage of carbon has been mentioned above, but it is not the only potential environmental problem that the proposed system must be designed to prevent. In particular, if the carbon tax results in a massive shift from fossil fuels to biomass fuels produced from energy crops, there is great potential for environmental harm. For example, there is already great economic pressure to convert rainforest into soy bean fields. This pressure would be intensified with carbon taxes, as biodiesel is an ideal fuel for transportation and electric power generation. In addition to protecting against the loss of habitat, there would be potential problems with ground and surface water as run-off, agrichemical applications and other pollutants were generated on these energy farms. It is important that if the carbon tax is put in, that other policies or incentives are developed to encourage farmers to use best practice agricultural technologies in the production of these crops. In addition, the economic pressure of a carbon tax could lead to incentives to dam the few free flowing rivers that exist in developed countries and create additional incentives for the construction of hydroelectric facilities in developing countries. All of these reactions to a carbon tax have the potential to harm the environment, but good environmental policy can prevent significant declines in these facets of environmental quality. It

should be emphasized, however, that without these additional policies for environmental protection, the policies designed to protect us from global warming could lead to a different type of environmental tragedy.

6. Conclusions

It is difficult to construct conclusions about a proposed system for limiting greenhouse gas emissions, when the system has not yet been implemented. However, several things are clear. First, the Kyoto Protocol, ratified or unratified, is not going to significantly slow global warming, as it does not encourage emissions reductions for developing nations and it has no provision for reducing developed country emissions below 94% of 1990 levels. Therefore, new potential systems must be discussed. Second, a tax-based treaty has the potential for providing incentives for the type of reductions in emissions that are needed, giving developing countries an incentive to constrain the growth of emissions (without placing formal limits on their emissions) and providing both developed and developing countries an incentive to continue to reduce emissions in the future. Moreover, the tax system provides unique opportunities for addressing equity issues between developed and developing countries, as well as among developed countries and among developing countries. Although many implementation issues remain to be resolved, it is important to immediately make progress in going beyond the Kyoto Protocol to obtain the type of emissions reductions necessary to protect the global climate. An international treaty based on per-unit carbon taxes has greater potential to achieve this than systems based on either direct controls or cap and trade incentives.

Acknowledgements

The authors would like to acknowledge colleagues at Washington and Lee University, Universidade Federal do Amazonas, and Universidade Estadual do Norte Fluminense and an anonymous reviewer for helpful comments. Any remaining errors are the responsibility of the authors.

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