Global Warming Policy: A Public Finance Perspective

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The scientific evidence on how man-made emissions of greenhouse gases affect global climate is not yet conclusive, but in spite of this, many policy-makers have proposed various policies to reduce these emissions. Carbon dioxide is the single most significant man-made greenhouse gas. One of the most common policy prescriptions for slowing greenhouse gas emissions is a carbon tax: a tax on fossil fuels in proportion to the amount of atmospheric carbon dioxide that is released when they are burned. It differs from other broad-based energy tax proposals, such as President Clinton's recent proposal for a BTU tax, in the relative burdens that it places on coal, oil, and natural gas.

Enacting a carbon tax is only one of many possible policy responses to the possibility of global warming. Such responses can be divided, following Nordhaus (1991), into three broad categories: amelioration, abatement, and prevention. Ameliorative actions focus on offsetting the effects of a warmer climate if and when they occur. They include migration, increased use of air conditioning in regions that are affected by global warming, and shifting patterns of industry and land use in particular areas. The second group of policies, which focus on abating the effects of global warming as they occur, might include painting roof-tops and highways white, to reflect more incoming sunlight back into space, or chemical modifications to the oceans to encourage CO_2 absorption. Finally, the third group of policies focus on preventing the build-up of greenhouse gases before they can affect global climate. The carbon tax is an example of such a preventive policy.

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Global climate change is a slow process, at least relative to many other phenomena studied in economics. Most of the consequences of global warming occur in the middle of the next century, at the earliest. This time profile of benefits has an important implication for comparisons of the three classes of policy responses described above. Since the benefits of all three types of policies accrue in the distant future, but the costs of preventive policies are incurred now, the benefit-cost ratio for prevention policies is more sensitive to the discount rate than the benefit-cost ratio for either abatement or amelioration policies. At high discount rates, prevention policies look relatively unattractive. Nevertheless, preventive policies have received nearly all of the attention in global warming policy discussions. Part of their appeal derives from a concern with worst-case scenarios. Because atmospheric carbon dioxide has a long half-life, reducing emissions today provides a margin of insurance against future discoveries of adverse effects. Part of the preventive policies' appeal is clearly political, however. Enacting an environmental tax increase enables politicians to claim that they have taken immediate action on the global warming "problem."

The possibility of global climate change raises a host of new research questions for economists. Many are more novel, and some might say more interesting, than the analysis of the taxes and subsidies that are aimed at preventing greenhouse gas emissions. Yet in the last few years, a substantial volume of research has considered the design of taxes to slow greenhouse gas emissions and the economic effects of such policies. In this paper, I summarize the insights that have emerged from this work.

The paper begins by explaining that while efficiency considerations create a presumption for using coordinated international policies to alter greenhouse gas emissions, the prospects for such action are bleak. It then focuses on the public finance of carbon taxes at the *national* level, considering the design of such taxes as well as their incidence across and within nations. The next part of the paper focuses on greenhouse gas emission policies that could be enacted in less developed countries, such as the elimination of fossil fuel subsidies and other policies to slow deforestation. A brief conclusion suggests several promising directions for future study.

Prospects for Coordinated International Action

There is a strong theoretical, if not practical, presumption that actions concerned with global climate change should be taken at a supranational level. National emission abatement policies are likely to select inefficient emission targets for several reasons. First, and most important, they neglect the benefits from emission reduction that accrue to other nations, and therefore tend to select too little emission control. Second, no single nation acting alone can stabilize greenhouse gas emissions; this makes it difficult to marshall support

for any action at all. Third, international competition can undermine environmental policy-making. If one nation enacts a policy to reduce a particular class of emissions, polluters with high abatement costs may move to other nations with less stringent emissions standards. As nations compete with each other to retain internationally mobile factors, they may be caught in a "race to the bottom" with respect to environmental policy. Finally, unilateral national policies are unlikely to achieve the least-cost method of reducing emissions, since they do not trade off opportunities for emissions reduction in different countries. Hoel (1993) discusses the gains from multilateral environmental action, and Martin et al. (1992) present empirical evidence on the cost savings from multilateral rather than unilateral policies to reduce greenhouse gas emissions, with a focus on the European case.

In spite of these efficiency arguments, coordinated international action is difficult to achieve. Without a system of international property rights, nor any associated mechanism for enforcing property claims or adjudicating disputes, it is difficult to develop market-based solutions for global environmental problems. International coalitions for environmental action are fundamentally *voluntary* associations which function only when all nations benefit from participation. There is wide disparity in the costs and benefits of different policies across nations on many environmental problems, including global climate change. The central task of designing a successful environmental accord is therefore to find compensation mechanisms, such as aid or other transfers, that will draw the "losers" from environmental policies into the coalition. If wealthy nations with the resources to make transfers that convince other nations to participate in an agreement are not committed to a global environmental accord, or if they choose to free-ride on the actions of other nations, the prospects for success are limited.

Measuring the costs and benefits of global climate change for an individual nation, and even the world, involves substantial uncertainties. In this issue, Nordhaus surveys much of the work to date. One finding is that currently developing nations, which tend to derive higher shares of GDP from agriculture than their developed neighbors, are more sensitive to climate change than currently developed nations. Developing nations are also more likely to be affected by some of the other aspects of global climate change. For example, Cline (1992) lists the 50 nations with the highest predicted costs as a share of GNP of adapting to rising sea levels, one of the consequences of global warming. New Zealand is the only developed nation in his list. For some nations, such as Canada and Russia, global warming might actually prove beneficial and raise agricultural yields. Nordhaus (1991) concludes that the potential costs to the United States of a warming earth will be modest, at least over the next century.

One of the key challenges in forging any cooperative agreement on climate change is the poor alignment between the burdens of reducing current CO_2 emissions, which fall on a small group of nations, and the benefits of such

actions, which are distributed more widely. Since developed nations account for most current greenhouse gas emissions, they would bear a disproportionate share of the costs of policies to lower these emissions. The United States and Canada currently account for 25 percent of world CO_2 emissions. Europe and the former Soviet Union account for 40 percent of the total, and Japan for another 5 percent (World Resources Institute, 1991). The emission shares of currently-developed nations diminish as one looks further into the future. The most rapid growth in CO_2 emissions over the next century is projected to occur in China, the former Soviet Union, and other developing nations. These are the nations that bear the heaviest burdens of long-term slow-growth policies.

Some optimists argue that the problems of achieving coordinated international action can be solved, and they point to the 1987 Montreal Protocol, which established a timetable for phasing out production of chlorofluorocarbons (CFCs), as a model of concerted international environmental action. Ninety-three nations signed the Montreal Protocol, which set targets for the reduction of global CFC production. The lessons of this case therefore warrant some elaboration.[1]

The Montreal Protocol specifies CFC production targets based on a nation's 1986 production of CFCs, with some allowance for production capacity under contract but not yet operational in 1986. Developing nations are permitted to expand their CFC use between 1986 and 1996, and to begin reduction after 1996. The Protocol also provides for transfers to less developed countries to facilitate the adoption of substitute products. This provision helped build global consensus for the agreement by defusing the argument of the less developed countries that their growth would be stunted if they were forced to rely on expensive alternatives to CFCs. The Protocol has no explicit enforcement mechanism, but experience since 1986 has been encouraging: global CFC production has declined faster than the Protocol targets.

There are several reasons why the CFC experience may not generalize to other international environmental problems, such as global climate change. First, there was greater scientific consensus on the nature and the immediacy of the "ozone problem" than on the link between greenhouse gas emissions and global warming. A substantial body of research suggested that CFC emissions were reducing stratospheric ozone levels, and the discovery of a "hole" in the ozone layer above the Antarctic in the early 1980s catalyzed world action to stop ozone depletion.

Second, CFCs are economically much less important than fossil fuels. Chlorofluorocarbon consumption accounted for a trivial share of world GDP prior to the Montreal accord, while fossil fuel consumption is a major economic activity in many nations. Production of CFCs was concentrated among a small

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[1]Benedick (1991) provides a detailed summary of the political negotiations leading up to the Montreal Accord.

set of multinational chemical companies who were also the natural suppliers of CFC substitutes. Some have even suggested that some CFC producers *supported* a ban because they expected to exercise greater market power if current CFC users were forced to switch to substitutes (UNEP, 1991). In contrast, there is wide dispersion in the suppliers of fossil fuels and possible alternatives.

Third, the ozone depletion problem appeared immediate when the Montreal Protocol was signed, in marked contrast to the long horizons involved in the current policy debate regarding greenhouse gases. After the discovery of the ozone hole, CFC emissions were linked with the rising incidence of skin cancer cases. It was therefore possible to identify a near-term gain that could be weighed against the cost of phasing out CFC production. In contrast, policies to reduce greenhouse gases burden current generations for the benefit of future generations.

Even though there were fewer obstacles to reaching international agreement on CFCs than on greenhouse gas emissions, negotiations leading to the Montreal Protocol took several years and frequently threatened to unravel. The Protocol's fund for technology transfer has not been fully funded, a pattern that underscores the difficulty of convincing developed nations to commit resources to international organizations focused on global environmental improvement.

The experience with other attempts to achieve multinational environmental cooperation is less encouraging than the case of CFCs. For example, 13 nations, including the United Kingdom and Poland, have not signed the 1985 Helsinki Protocol on sulfur oxides (acid rain) in Europe. Sulfur oxides are economically more significant than CFCs, and the inter-country differences in the net benefits of Protocol participation are larger than for CFCs. The failure of the Helsinki negotiations may therefore provide a better indication of the prospect for a global warming accord than the success in Montreal. Recent proposals for a carbon tax in the European Community, which are explicitly conditioned on similar actions by other nations, also suggest that CO_2 reduction will be more difficult than CFC reduction.

Although coordinated international action to adopt a carbon tax or similar policy currently seems unlikely, many nations appear committed to unilateral action to reduce greenhouse gases. Finland, Sweden and the Netherlands have already adopted carbon taxes, even though unilateral action by these nations can exert only a trivial effect on the growth rate of global greenhouse gas emissions.[2] I now consider several aspects of unilateral carbon tax design and incidence, as well as the potential difficulties that arise in implementing unilateral taxes in a global economy.

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[2]Haugland, Lunde, and Roland (1992) describe the structure of carbon tax policies that have been adopted in Scandinavian countries. Many of the institutional details have important effects on the effects of these taxes. In Sweden, for example, there is a cap on the share of a firm's sales that can be collected; this effectively results in a zero marginal tax rate for many firms.

Table 1
Alternative Taxes on Fossil Fuels

	Coal	*Oil*	*Natural Gas*
Unit of Measure	Ton	Barrel	10^3 cu. ft.
Tons of Carbon/ Unit of Fuel	.605	.130	.016
Carbon Emissions/ Billion BTUs	.025	.020	.015
BTU Content	24.2	6.5	1.07
Average Mine-Mouth or Wellhead Price, 1989	$23.02	$17.70	$1.78
$5/ton Carbon Tax:			
Absolute Tax	3.17	0.65	0.08
Percentage of Price	13%	4%	5%
BTU Tax:			
Percentage of Price	13%	5%	7%

Notes: Poterba (1991) with new calculations relating to fuel BTU content.

The Anatomy of a Carbon Tax

The carbon tax on each fossil fuel is proportional to the amount of carbon dioxide emitted when it is burned.[3] Coal produces more carbon dioxide per unit of energy than either oil or natural gas, so it faces the highest carbon tax rate. If the combustion of each fuel is assumed to affect the environment only through its effect on carbon emissions, then the optimal Pigouvian tax on each fuel will be proportional to its CO_2 emissions.[4]

Table 1 describes the carbon tax in more detail. The first few rows offer information on carbon emissions, energy content measured in BTUs (British Thermal Units), and recent prices of the various fuels.[5] The next two rows show the impact of a $5/ton carbon tax. It would raise coal prices by 13 percent, and increase the consumer prices of oil and natural gas by 4 percent and 5 percent respectively. The table also compares the tax rates on different fuels from a carbon tax with those from a BTU tax, a tax on the energy content

[3]Greenhouse gas tax policy should not be limited simply to taxing CO_2. Emissions of all gases that contribute to global warming, such as methane and nitrous oxides, should be taxed at the same rate per unit of "global warming potential." Nordhaus (1990) and Schmalensee (1993) discuss how to measure global warming potential.

[4]When the government can raise revenue through lump-sum taxes, then the optimal tax on each good equals the externality imposed by its consumption. Diamond (1973), Sandmo (1975), and Poterba (1993) develop this point and consider the effect of restricting the government's set of tax instruments.

[5]Tax rates are sometimes specified per ton of carbon, and other times per ton of carbon dioxide emitted. Since the atomic weights of carbon and oxygen are 12 and 16 respectively, a ton of carbon corresponds to 3.67 tons of CO_2. Tax rates can be translated accordingly.

Table 2
Implicit Carbon Taxes, Dollars / Ton of Carbon, G-7 Nations, 1988

	Coal	*Oil & Oil Products*	*Natural Gas*
United States	0	$65	0
Japan	−17	130	2
Germany	−77	212	23
France	0	351	38
Italy	0	317	80
United Kingdom	−46	297	0
Canada	0	108	0

Source: Hoeller and Coppel (1992).

of each fuel, set for coal at the same level as the $5/ton carbon tax. The BTU tax places a higher relative burden on natural gas than on the other fuels. Because externalities are associated with end-products of combustion, not with energy use *per se*, there is a strong rationale for basing Pigouvian taxes on emissions rather than other fuel characteristics such as BTU content.

It is difficult to translate Table 1 into practice for two reasons. First, fossil fuel combustion creates many potential externalities other than global climate change. In this case, the optimal taxes on various fossil fuels can differ from those prescribed by a simple analysis of relative CO_2 output. Various studies, described in Viscusi (1992), have evaluated the local air pollution and other externalities associated with fossil fuel use. These studies generally suggest that the negative externalities associated with coal combustion exceed those from other fossil fuels, implying that the extra tax burden on coal should exceed that on other fuels.

The second problem in implementing the tax rates in Table 1 is that most developed nations already tax fossil fuels. Many of the existing taxes are justified by revenue needs rather than externality correction. In the United States, for example, the current tax rate on gasoline is just over 30 percent of the producer price, while in Britain, Sweden, and other European nations the tax rate often exceeds 60 percent of the producer price. Table 2 shows the existing implicit taxes on each of the three major fossil fuels in the G-7 nations; negative signs imply that a fuel is subsidized. The table confirms the widely known pattern that energy tax burdens in the United States are low relative to those in other nations, but also shows the disparity of the net tax treatment of coal across industrial countries. Germany, Britain, and Japan all provide subsidies to their coal industries. How should the carbon tax be combined with pre-existing taxes? In the unlikely case where existing fossil fuel taxes have been set optimally for Ramsey and Pigouvian reasons, and if the potential effect of fossil fuels on global climate can be viewed as a previously-ignored external-ity, then the carbon tax should be added to the existing tax. Failing this case, it

is difficult to make strong statements about the combination of the carbon tax and other levies.

The International Incidence of a Carbon Tax

If enacted in the United States today, a tax of $5/ton on carbon such as that considered in Table 1 would slow, but not stabilize, the growth of CO_2 emissions. It would raise between $10 and $15 billion annually. A carbon tax of $100/ton, which could result in U.S. emissions of CO_2 in the early part of the next century *below* levels in the late 1980s (Congressional Budget Office, 1990), would raise approximately $200 billion, or more than 3 percent of GNP. Even in Japan, where energy consumption per dollar of GNP is lower than in the United States, revenues from such a tax would be more than 1 percent of GNP. Schelling (1992) observes that the sheer magnitude of these revenue flows represent an important obstacle to any coordinated international action that involves revenue collection by a supranational organization. Few developed countries are likely to cede control over revenues of this magnitude to an international organization.

Practical analyses of carbon taxes must therefore focus on unilateral tax policies without revenue transfers across countries. Whalley and Wigle (1991) use a computable general equilibrium model to evaluate the effect of enacting similar carbon taxes in all countries, with each country keeping the revenue it collects. Their findings underscore the difference in incidence between a carbon tax levied on consumption of fossil fuels, and a similar tax levied on production. When nations are permitted to keep the revenue they collect, a consumption-based tax places a much higher burden on oil-producing countries than a production-based tax. A consumption-based carbon tax that would reduce CO_2 emissions by 50 percent would reduce GDP by 4 percent in North America, 1 percent in Europe, and by 19 percent in oil exporting countries. This contrasts with an equal-value tax on production, which *raises* GDP by 5 percent in oil-producing countries, and reduces GDP by 4 percent in both Europe and North America. The key difference between these policies is that with the production tax, fossil fuel exporters receive the revenue from the tax.

Whalley and Wigle's (1991) estimates, and those from other computable general equilibrium models, reflect the loss in output that results from higher fossil fuel prices.[6] Further analysis with these models suggests that these output losses are sensitive to the structure of pre-existing taxes, on both fossil fuels and other goods. Goulder (1992) and Bovenberg and de Mooij (1992), for example, show that carbon fuel taxes interact in important ways with labor income taxes.

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[6]Dean and Hoeller (1992) survey long-run results from six general equilibrium models, and emphasize the substantial difference in their results. Joskow's (1992) discussion of the results from the Jorgenson-Slesnick-Wilcoxen (1992) model illustrates some of the difficulties associated with the use of computable general equilibrium models for assessing greenhouse gas policy.

Labor supply depends on the real after-tax wage measured in terms of consumer prices. Since carbon taxes are indirect taxes, they reduce the real after-tax wage.[7]

Enacting a carbon tax affects the government's budget as well as relative prices. Because substantial tax increases are likely to have contractionary macroeconomic effects, some proposals call for coupling a carbon tax increase with other tax cuts to generate a revenue-neutral policy. In European countries that rely on indirect taxes for significant revenues, a natural policy would involve reducing the value-added tax or other excise tax rates. For the United States, it would be possible to reduce income taxes to offset carbon tax revenues. The possibility of using carbon tax revenues to cut other tax rates has spawned a recent debate on "revenue recycling," with several studies claiming that adopting a carbon tax could yield efficiency gains rather than deadweight losses. Goulder (1993) shows that the efficiency cost of a carbon tax is much attenuated if the tax proceeds finance other tax cuts, such as reductions in the personal income tax. Shackleton et al. (1992) claim still more, arguing that if carbon tax revenues are used to reduce capital tax burdens, for example by instituting an investment tax credit, then the carbon tax can actually *raise* national output.

Initially, the revenue-recycling argument seems fallacious. If the status quo includes some extremely inefficient taxes, then almost *any* new tax can generate an efficiency improvement. Simply demonstrating that raising the carbon tax and reducing other onerous taxes would lead to an efficiency gain does not imply that carbon taxes should be adopted. Rather, one must compare the carbon tax policy with the set of all feasible policies that could reduce the onerous taxes and achieve a balanced budget. On reflection, however, the revenue-recycling argument may make more sense. If there is a causal link between enacting a carbon tax and cutting particular other taxes, perhaps because of political constraints on raising existing taxes, and if there are no other ways to enact changes in these other taxes, then it *is* appropriate to consider how the funds are used in evaluating the net benefit from a carbon tax. Absent a strong basis for linking enactment of a carbon tax to other particular tax changes, a plausible assumption is that carbon taxes would be paired with a proportionate reduction in all existing revenue sources.

In addition to the uncertainty about how carbon tax revenue would be used, which has an important effect on how the carbon tax affects output, there is some disagreement about whether higher fossil fuel prices affect the rate of economic growth. Because growth rate effects compound from year to year, they have the potential to dwarf many of the other effects of changing fossil fuel taxes. However, the available empirical evidence about these effects is not

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[7]The after-tax wage is $(1 - t)w/p(1 + s)$, where w denotes the nominal wage, p the producer price level, t the marginal income tax rate, and s the average indirect tax rate. Carbon taxes raise s. This distorts labor supply. The cost of this distortion depends on the pre-existing level of $(1 - t)/(1 + s)$, the initial tax wedge.

conclusive (Jorgenson and Wilcoxen, forthcoming 1993; Weyant, in this journal). The rate of productivity growth in many developed countries declined at roughly the same time as the 1973 oil price shock. Whether these two developments are causally related, however, is an open question, and warrants further analysis.

The computational models described above yield results on the long-run output reduction that might accompany higher taxes on fossil fuels. These output reductions can not be viewed in the same light, however, as output reductions from traditional distortionary taxes that are enacted to raise revenue. Since carbon taxes are *Pigouvian* taxes, at the optimal tax rate the present value of the marginal output losses associated with the tax would precisely equal the present value of the marginal gains from reducing greenhouse gas emissions. Even if the taxes are not set optimally, if there is some social value to reducing greenhouse gas emissions, the foregone output associated with a carbon tax overstates the net social cost of these policies.

Are Carbon Taxes Regressive?

One of the most frequent objections to raising fossil fuel taxes in most developed countries is that such taxes fall most heavily on low-income households. This regressivity argument has been a central component of opposition to higher gasoline taxes in the United States. The underlying basis for the argument is simply that the ratio of consumption to income declines as one moves up the income distribution (Poterba, 1989).

There are now several studies of the distributional burdens of carbon taxes in the United States and other nations: Smith (1992) provides evidence for Europe, and Jorgenson, Slesnick, and Wilcoxen (1992) and Poterba (1991) for the United States. These studies suggest that simple analyses of the ratio of expenditures on fossil fuels relative to income substantially overstate the regressivity of such taxes. If tax burdens are analyzed relative to lifetime income, the fossil fuel taxes appear less regressive than when compared with current income. In addition, most developed nations have a variety of auxiliary fiscal policies that reduce, or could be used to reduce, any adverse distributional effects of carbon taxes. For example, many transfer programs are already indexed for price changes. Transfer recipients are therefore partly insured against tax-induced changes in consumer prices. Carbon tax proposals could also be coupled with modifications in income tax schedules to redistribute purchasing power to low-income households.

The possibility of coupling carbon taxes with other policy changes, whether to achieve distributional ends or for other reasons, highlights an important limitation of most existing models of these taxes. Modellers usually evaluate "pure" policies, such as carbon taxes levied on all fossil fuels. In practice, policies will inevitably be enacted with exemptions and other special provisions that both reduce their power to limit greenhouse gas emissions, and magnify

their adverse effect on the amount of output lost per unit of emissions abatement. The revealed preference of policy-makers in many countries for command-and-control, rather than efficient, market-based pollution control policies, underscores the potential divergence between actual and theoretical policies.

While most discussions of the economic effects of carbon taxes focus on long-term output effects, a word should be added about the possible short-term macroeconomic effects. Even a balanced-budget carbon tax can have adverse short-run effects on output if nominal wages and prices respond slowly to higher taxes. To illustrate this possibility, consider a carbon tax that is coupled with a reduction in labor income tax rates. The carbon tax represents an increase in the overall indirect tax rate, and for a fixed set of producer prices, it will raise the consumer price level. If the nominal money supply is constant—that is, if the monetary authority does not accommodate the carbon tax—then higher consumer prices will translate into a smaller *real* money stock. This amounts to a monetary contraction, a "self inflicted wound" in macroeconomic terms, and to lower aggregate output.[8] Slow phase-in of a carbon tax would blunt these effects.

Implementation Issues in an Open Economy

One additional theoretical argument for supranational rather than unilateral actions to curb greenhouse gas emissions involves the difficulties of implementing policies such as carbon taxes in open economies. Most national-level carbon tax proposals call for taxing imports of fossil fuels in the same way as domestic production. This does not completely solve the problem of equal treatment of foreign and domestic production of fossil-fuel intensive goods, however. If imports of such goods are not taxed, there will be production inefficiencies as production of these intermediate goods will be diverted from domestic locations. Poterba (1991) argues that border taxes on a few classes of imports—for example, steel, autos, and chemicals—could avoid most of these problems. In practice, however, it might be difficult to adopt such "environmental tariffs" under current GATT rules.

Nations with unilateral carbon taxes might also choose to provide tax rebates to exporters of goods with high fossil fuel content, to avoid adverse competitive effects in international trade. Such export rebates and related provisions have been enacted in some of the Nordic countries' carbon taxes,

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[8]Poterba, Rotemberg, and Summers (1986) suggest that a 3 percent of GNP shift from direct to indirect taxation, for example, from an income tax to a carbon tax, would reduce real GNP by .6 percent in the quarter when the tax change took effect and cumulatively by 3 percent of annual GNP over the policy's first three years. The Congressional Budget Office (1990) presents more specific results on the macroeconomic effects of carbon taxes with various assumptions about other policy responses.

with the result that these taxes provide no marginal disincentive for CO_2 emissions for large firms engaged in export trade (Haugland, Lunde, and Roland, 1992).

Reducing Greenhouse Gas Emissions in Less Developed Nations

The discussion so far has concentrated on unilateral policies to reduce greenhouse gas emissions in developed countries. Efficient policies to slow greenhouse gas emissions, however, are likely to involve some reductions in emissions from less developed countries (LDCs) as well. Mors (1991) estimates that the costs of reducing CO_2 emissions in less developed countries may be only one-fourth of the cost in developed nations, mainly because many LDCs have relatively inefficient energy utilization systems. There are important differences between analyzing policies for controlling greenhouse gas emissions from LDCs and developed countries. These differences arise because the same policies that could be used in developed nations, such as carbon taxes, might have different effects in LDCs, and because there are new policy options, such as programs to slow deforestation, that must be considered.

The effects of raising fossil fuel prices in LDCs has received less research attention than the comparable problem for developed countries. The work that has been done suggests important heterogeneity in the likely effects of such policies on different LDCs. Blitzer et al. (1992), for example, contrast the effect of a carbon tax on India and Egypt, and recognize that differences in the relative use of coal and other fossil fuels, as well as differences in economic structure, play an important role in determining the effects of such taxes on individual nations.

Less developed countries also differ from developed countries in their current tax treatment of fossil fuels. While most industrial nations tax these fuels, many LDCs currently subsidize the direct consumption of fossil fuels, and the indirect consumption through electricity. Table 3 presents suggestive information on these subsidies, drawn from Shah and Larsen (1991). The World Bank (1992) estimates that eliminating fossil fuel subsidies could reduce carbon dioxide emissions by 29 percent in the former Soviet Union and Eastern Europe, and by 11 percent in currently developing nations. Combined, these reductions would yield an 11 percent reduction in current global emissions of carbon dioxide. Eliminating these subsidies would also confront consumers in the subsidizing nations with world market prices for their fuels, thereby improving the efficiency of global energy consumption.[9]

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[9] Just as introducing new carbon taxes would have adjustment costs, removing current subsidies would result in economic dislocation. Again, these could be minimized by gradual phase-out.

Table 3
Subsidies to Fossil Fuel Consumption
(*measured by ratio of domestic to border price*)

Country	Coal	Oil	Natural Gas
China	.84	.48	.40
Former USSR (1991)	.50	.49	.35
Poland	.31	.77	.50
India	.86	.90	—
United Kingdom	.90	—	—
South Africa	.50	—	—
Czechoslovakia	.40	.85	—
Mexico	—	.48	—

Source: Shah and Larsen (1991), Table B1.

While existing energy subsidies may be difficult to justify on efficiency grounds, they may serve distributional objectives within countries. This makes the claim that subsidy removal provides a "free lunch" overly optimistic. Viewed from the perspective of a social planner with distributional as well as efficiency objectives, eliminating the subsidies may have real costs. This is supported by a cursory analysis of fossil fuel subsidies in the developed world, where these subsidies are invariably the result of domestic political pressures. In the United Kingdom, for example, subsidies to coal use sustain mine employment in particularly depressed regions. In the United States, despite overwhelming evidence that scrubbing high-sulfur coal is not a cost-effective way to reduce sulfur oxide emissions, clean air policy for more than a decade required scrubbers on some power plants. This was largely due to the political influence of high-sulfur coal miners.

The political economy of fossil fuel subsidies in LDCs poses an important impediment to efficient global action to reduce greenhouse gas emissions. A cost-effective way to surmount these internal political problems could involve resource transfers from some developed nations to some LDCs, explicitly targetted at compensation for the "losers" from policy reforms. Finding an institutional structure for such transfers, however, confronts the problems of coordinated international action that were described earlier.

The importance of deforestation in contributing to greenhouse gas emissions from less developed countries raises a second set of differences between global climate policies in developed and developing nations. Forest-burning currently accounts for approximately one-fifth of anthropogenic emissions of carbon dioxide (World Resources Institute, 1991). In Brazil, deforestation is three times as important as fossil fuel consumption as a source of CO_2 emissions (Shunker, Salles, and Rios-Velilla, 1992). Some forecasts call for rapid increases in the rate of deforestation, particularly in Amazonia, in the early part

of the next century. Most rain forest burning occurs as the forest is converted to agricultural use by new settlers, so policies to slow this settlement are candidates for reducing the level of greenhouse gas emissions.

Before examining the role of taxes and other government policies that affect the rate of deforestation, it is essential to recognize that not all deforestation creates greenhouse gases. Living forests are an important carbon *sink*: photosynthesis draws CO_2 out of the atmosphere. Cutting tropical hardwoods for furniture construction, and replacing the felled trees with new growth, therefore has the potential to absorb greenhouse gases. *Burning* tropical forests either to clear land or for firewood, or failing to replace forest that is cut for lumber, *does* contribute to the ambient level of greenhouse gases.

Governments in LDCs can employ several different policy instruments to affect forest utilization. The first and probably most important set of policies concern incentives for settlement and agricultural expansion in currently-forested areas. In Brazil, for example, the national government has historically encouraged settlement in rain forest regions. Binswanger (1989) and Reis and Margulis (1991) explain that credit policies, infrastructure development, and other government subsidies played a key role in the rise of cattle-ranching in Amazonia. They further argue that given Amazonia's soil, such ranching would not be economically attractive *without* the government subsidies.

Removing existing subsidies that encourage deforestation parallels removing fossil fuel subsidies in promising an efficiency-enhancing means to slow greenhouse gas emissions. They are likely to be particularly cost-effective policies. Cline (1992) concludes that the cost of reducing global carbon emissions by removing government incentives to deforest are only several dollars per ton. This is substantially less than most estimates of emission-reduction costs in developed nations.

A second set of policy instruments that affect forest clearing are taxes on logging and other related activities. Panayotou and Sungsuwan (1989) study deforestation in Thailand, and conclude that taxes on resource rents would have significant effects in discouraging logging in environmentally sensitive areas. Empirical analysis of such policy proposals depends on a set of elasticities, such as that for logging activity with respect to net log prices, that in many cases are known with very little precision. The prospective importance of carbon dioxide emissions from the Third World suggests that estimating these parameters is an important research priority.

Finally, land tenure rules have important effects on the utilization of tropical forests. One of the central problems in Amazonia, for example, where land claims are difficult to enforce, is that land users do not take a long-term perspective in making land use decisions. Imperfect property rights reduce the cost of obtaining land, and lead tenants to maximize short-run returns, often by burning the forest and exploiting the resulting land for only brief periods. Weak property rights discourage replanting of forest. The reform of land tenure rules in LDCs is a complex problem, and one that has many potential

effects other than those concerned with global climate change. Nevertheless, this is a type of policy that could significantly affect greenhouse gas emissions.

Conclusion

This paper has sidestepped the single most important question in designing a carbon tax: what is the optimal tax rate? In principle, this question is simple to answer: the optimal carbon tax equates the present discounted value of the net externalities from a ton of carbon emitted today with the marginal cost of emission reduction, making appropriate correction for distributional differences in the incidence of benefits and costs. Even after several years of intense research activity on carbon taxes and global warming, however, there is great uncertainty concerning the optimal carbon tax rate. While such uncertainty is not unprecedented in tax policy discussions (what is the optimal tax rate on capital gains?), the *sources* of this uncertainty suggest promising directions for future research. Two aspects of this uncertainty deserve comment.

One source of uncertainty about optimal carbon taxes concerns the appropriate discounting for time and risk in considering the policy's costs and benefits. In this journal, Chichilnisky and Heal survey many of the issues related to this question. Cline (1992) has emphasized that policies to reduce greenhouse gas emissions are more attractive at low discount rates and when the policy analysis involves a longer time horizon. Yet there is little agreement on what discount rate is appropriate for such calculations.

A second source of uncertainty concerns the economic consequences of a given level of greenhouse gas accumulation. The efforts by Nordhaus (1991) and Cline (1992) to estimate how the U.S. would be affected by global warming suggest the immensity of the calibration exercise. The task is complicated further by the sensitivity of the loss estimates to events that occur with low probability. Even if the mean and median outcomes are not particularly costly, outcomes with one chance in ten may be very costly to the United States and other nations. It is difficult enough to estimate the *mean* effects of various levels of greenhouse gas emissions; trying to specify the entire distribution of such outcomes, as well as the probability of remote outcomes such as shifts in the Gulf Stream, is an extraordinary research challenge for physical scientists. Economics must be ready, however, to help evaluate such forecasts as they become available, and to focus attention on areas where uncertainty reduction is most valuable.

Given the significant cost uncertainties associated with policies to slow greenhouse gas emissions, *caution* is likely to be a key characteristic of optimal policies. Low carbon taxes, enacted on a nation-by-nation basis, can establish the mechanism for revenue collection and provide some evidence on how these taxes affect economic activity. Immediate enactment of a high-rate carbon tax

would entail substantial policy risk, and is best done (if ever) after experience with more modest tax levels.

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