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Carbon Taxes: Their Macroeconomic Effects and Prospects for Global Adoption—A Survey of the Literature

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Abstract

The carbon tax is a major instrument for curbing greenhouse gas emissions that cause global warming. Yet its adoption has been limited because of concerns over its effects on economic growth, income distribution, and international competitiveness. The paper shows that policymakers can minimize the effects of the tax on economic growth through an efficient recycling of tax revenues and on equity through the adoption of appropriate mitigating or compensating measures. To eliminate the worry about the loss of competitiveness, the paper suggests an international agreement on a coordinated adoption of the tax.

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SUMMARY

Many industrial countries have agreed to binding reductions of greenhouse gases under the Kyoto Protocol. A carbon tax is one of the most efficient instruments available to achieve this objective. While such a tax could generate substantial revenue, it could also reduce the rate of economic growth, worsen the distribution of income, and erode the competitiveness of a country's exports. This paper reviews the literature for empirical evidence on the seriousness of the carbon tax's macroeconomic impacts.

The effect of a carbon tax on economic growth depends on the choice of model, the assumptions underlying the model, and the use to which carbon tax revenues are put. When the model contained "optimistic" assumptions, such as a strong response of economic agents to the tax, ready availability of cheap alternative fuels and technologies, and efficient recycling of available revenues, the tax was shown to have little to no negative effect on growth.

Most studies show the distributional impact of a carbon tax to be generally regressive but its degree varies by country, by type of model used, and by how the tax burden is measured. The studies establish that the regressivity of the tax can be greatly offset by proper mitigation, such as exemption or relief, or by compensatory measures, such as wage subsidies or earned income tax relief.

The effect of carbon taxes on exports could be substantial, but studies show that increased costs of production can be offset by reductions of payroll and income taxes that carbon tax revenues could make possible. An international agreement to adopt carbon taxes in a coordinated fashion would greatly reduce the fears of a loss of export competitiveness.

If the Kyoto Protocol on global warming is ever implemented, carbon taxes could be central to the development of an efficient policy mix.

I. Objectives and Scope of the Paper

In December 1997, representatives of 150 countries of the world met under the auspices of the United Nations in Kyoto, Japan, to discuss the very real threat of global warming and to agree on binding reductions of greenhouse gas (GHG) emissions that cause it. After a lot of acrimonious debate and discussion, it was agreed that, while developing countries for the present would adopt only voluntary reduction targets, most industrialized countries would aim, by the years 2008 to 2012, to significantly reduce their GHG emissions (including the emissions of carbon dioxide (CO_2)) below the levels prevailing in 1990.

Under the agreement (called the Kyoto Protocol), specific targets have been agreed to for each of the 38 industrial countries, and all signatory countries have been called upon to quickly ratify the agreement. Once ratified, each country would be adopting measures, including market-based measures, command and control measures, as well as economic policy measures, which would help it achieve its pre-specified target. The adoption of an appropriate carbon tax clearly would be an option in this policy mix that each country would be considering in the near future. This paper identifies a few worries that policymakers most likely would have concerning the impact of carbon taxes on their economies and attempts to analyze the validity and seriousness of such concerns, based on the arguments and empirical evidence presented in the literature to date.

The main objective of the paper, thus, is to survey the literature relating to the potential effects of carbon taxes as a major instrument of controlling global climate change and reducing domestic and regional air pollution.[1] In doing so, the paper focuses on, and attempts to answer, the following five questions:

1. Is there a rationale for using carbon taxes to mitigate global climate change and is it possible to design a rate and base structure of carbon tax that can be considered appropriate and efficient?

2. What are the potential growth effects of carbon taxes and, if they are negative, how best can they be mitigated?

3. How serious are the likely equity implications of carbon taxes at domestic and international levels and are there ways to mitigate or compensate for them?

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[1] When fossil fuels are burned, carbon dioxide and other toxic gases are released, along with five air-borne particles that pollute the air. Breathing such particles has serious effects on human health (asthma, bronchitis, emphysema and death). The very same activities that are threatening the earth's climate are also seriously threatening human health. See World Resources Institute (1997).

4. How far is the international competitiveness of a country affected by the imposition of carbon taxes?

5. Is a global agreement on the imposition of harmonized carbon taxes really feasible and how far will it help contain the potential negative consequences of such taxes, if any?

The paper is structured as follows: Section II provides the background on the macroeconomic consequences of rapidly growing greenhouse gas emissions and international efforts to contain global warming to date. Section III discusses the theoretical advantages of carbon taxes and compares them to other economic instruments of reducing GHG emissions. It also describes some of the issues relating to the design of carbon taxes. Based on a survey of the literature, Sections IV, V and VI analyze each of the more important "worries" associated with the imposition of carbon taxes that the policymakers most likely will have: the effects of such taxes on productivity and economic growth, on equity and income distribution, and on competitiveness and international trade. Section VII, then, analyzes the factors which are likely to affect whether or not policymakers will proceed with the harmonized adoption of carbon taxes globally. Section VIII summarizes the policy conclusions of the paper.

II. Background: Potential Consequences of Excessive Carbon Emissions

Carbon emissions caused by the widespread and rapidly expanding use of coal, oil and fossil fuel burning for increasing production and consumption have been shown to have undesirable consequences. They contribute to severe air pollution domestically, and the accumulation of carbon dioxide in the atmosphere, a primary source of global warming. Carbon dioxide, methane, nitrous oxide and chlorofluorocarbons (CFCs), identified as greenhouse gases, are believed by scientists to trap outbound sun radiation, warming the atmosphere and inducing climate change.[2] The CO_2 concentration is projected to double around 2065, as compared to the levels of the pre-industrial era, in a business-as-usual scenario (OECD, 1995b). The estimates made by the Intergovernmental Panel on Climate Change (IPCC) are that it would bring about severe air pollution and climate change; whose environmental and economic consequences will obviously vary across countries.[3] It must, however, be mentioned that although there seems to be a growing consensus that global

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[2] The trapping of solar radiation on earth is a physical phenomena that has occurred over centuries. However, since the beginning of the industrialization era, anthropogenic emissions of GHG have accelerated the rate of climate change to levels that are now widely considered as potentially dangerous. The aggregate effects of all GHG are usually expressed in terms of equivalent CO_2 concentration. The GHG are calculated to have increased since pre-industrial times by an amount equivalent to about 50 percent of equivalent CO_2, although CO_2 itself has increased by 26 percent (See Mabey et al, 1997, p. 6).

[3] IPCC details the potential damages that countries would face under various degrees of climate change—damage estimates are shown to be larger for developing than for developed countries. (See IPCC (1996)–Second Assessment Report)

warming is occurring and will pose a genuine danger, there is uncertainty as to its seriousness, its timing and its potential consequences. Many professionals, in fact, believe that the danger is so distant, and probably so small, that technological advances and discovery of alternative renewable fuel sources, in the interim, could easily obviate the need for adopting draconian measures in the near future.

A. Macroeconomic Consequences of Global Warming and Climate Change

Should climate change be as serious as projected, their macroeconomic implications would be as follows:

- *Effects on agricultural production and prices:* Serious global warming would result in the loss of soil moisture and desertification in some areas of the world, while extending the growth seasons in others. Overall, farm yields would most likely fall, causing world prices of agricultural products to rise. This would particularly affect countries which are large importers of such products and cause severe welfare reductions due to price increases.[4] It would also change the terms of trade of individual countries.

- *Rise in sea level*: A large increase in CO_2 concentration is likely to be associated with a sea level rise, ranging between 50 and 100 centimeters, causing at least three types of economic costs to individual countries: costs of protective construction (which would raise public budgets[5]), costs of foregone land services, and costs associated with increased frequency of floods (which would also increase public budgets[6]).

- *Loss of forests*: Global climate change would cause changes in seasonal climate patterns and the loss of extensive forest areas, both of which would have significant consequences for public budgets.[7]

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[4] Without any policy changes, global welfare losses are estimated between US$0.1 - US$1.2 billion. These estimates, and the ones provided in the following paragraphs, are taken from the IPCC (1996) - Second Assessment Report. The scenario is a CO_2 concentration doubled with respect to the preindustrial level.

[5] For the United States alone, these costs are estimated to be US$1.2 billion annually.

[6] Expected annual flood damage in 2100 increases by 36-58 percent (US$150 million) for a one-foot rise for the United States. For the European Union, periodic flooding would increase costs of sea level rise be a factor of 2.7.

[7] Annual losses to the U.S. Forestry Service for a 2.6 warming are estimated to be US$2.5 billion.

- *Water shortages:* With a warmer global climate, in most countries the demand for water would rise, putting pressure on existing water supply systems and requiring larger public budgets.[8]

- *Cooling and heating needs*: Climate change would increase cooling needs and will impose higher air conditioning costs; at the same time, it would reduce heating costs as winter would not be that harsh, making the "net" effect ambiguous and highly variable across countries and regions.

- *Air and water pollution:* A warmer climate aggravates problems of air and water pollution, requiring larger government outlays on pollution control systems.[9]

- *Health:* Air pollution will increase the occurrence of respiratory diseases and will necessitate larger public expenditures on health and result in lower labor productivity.

In addition to the aforementioned effects, there will be other potential beneficial and adverse effects. Warming is likely to reduce the severity of winters but would raise death rates as a consequence of heat waves. There would also be other, though unquantifiable, effects such as migration, human comfort, and ecosystem and biodiversity loss.

It is obvious, thus, that a major climate change, if it occurs as projected, will have direct effects on the size of public budgets (flooding, forest land preservation, pollution control), terms of trade (agricultural yields, labor productivity), rates of economic growth (agricultural yields, labor productivity, natural resources depletion) and welfare of population (price increases, flooding, pollution, health impacts).

The available studies, quoted in IPCC (1996), estimate that damages from doubling of CO_2 concentrations in the global atmosphere could be as high as 1.5-2 percent of world GDP, for world impact, and 1-1.5 percent of GDP of developed countries, and 2-9 percent of the GDP of developing countries[10]. (See Table 1 for the desegregated information on the potential impacts of climate change by region.).

Because of this, as well as other reasons, there is a worldwide interest in finding ways to mitigate global climate change.

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[8] Estimated costs for the United States range between US$7 billion and US$11.4 billion. OECD losses are estimated to be around US$34.8 billion annually and US$46.7 billion worldwide.

[9] Titus (1992) concludes that doubling the CO_2 concentration would impose water pollution control costs in the range of US$15 billion to US$67 billion annually.

[10] Given that the damages of global warming rise with the levels of GHG, delaying actions to curb emissions will obviously result in potentially larger damages in the future.

Table 1. Estimates of Annual GDP Losses in Different Countries/Regions of the World Resulting from Doubling of CO_2 Emissions

Country/Region	Fankhouser (1995)		Tol (1995)	
	In billions of U.S. dollars	Percent of GDP [1]	In billions of U.S. dollars	Percent of GDP [1]
European Union	63.6	1.4		
United States	61.0	1.3		
Other OECD	55.9	1.4		
OECD America			74.2	1.5
OECD Europe			56.5	1.3
OECD Pacific			59.0	2.8
Total OECD	180.5	1.3	189.5	1.6
E. Europe/former USSR	18.2 [2]	0.7 [2]	-7.9	-0.3
Centrally planned Asia	16.7 [3]	4.7 [3]	18.0	5.2
South and Southeast Asia			53.5	8.6
Africa			30.3	8.7
Latin America			31.0	4.3
Total non-OECD	89.1	1.6	126.2	2.7
World [4]	269.6	1.4 [4]	315.7	1.9 [4]

Source: IPCC (1996), page 205.
[1] Note that the GDP base may differ between the studies.
[2] Former Soviet Union only.
[3] China only.
[4] Percentage of GDP when GDP is calculated on the basis of market exchange rates. The "order of magnitude" of these estimates does not change if corrected damage categories are purchasing-power-parity adjusted and expressed as a fraction of PPP-corrected GDP.

B. INTERNATIONAL EFFORTS TO CONTROL GLOBAL WARMING TO DATE

The first official action to address the climate change problem was the establishment in 1988 of the Intergovernmental Panel on Climate Change by the United Nations Environment Program and World Meteorological Organization. The IPCC released its First Assessment Report in 1990 providing evidence on the climate change. This report was used as a basis for negotiating an international agreement to control GHG emissions at the 1992 Rio Earth Summit when 155 countries signed the Framework Convention on Climate Change (FCCC). The agreement called for voluntary actions by countries to curb emissions to the levels prevailing in 1990 and no binding provisions were made.

In 1995, the Conference of the Parties (COP) was established as the FCCC's ultimate authority. The first meeting of this Conference (COP-1) took place in 1995 where the central issue of the adequacy of the commitments made at Rio to contain global warming was discussed. It was found that very few countries had reduced emissions or even stabilized them at the 1990 levels. It became clear at the meeting that a different type of commitment was called for. Also, in 1995, the IPCC released its Second Assessment Report (SAR) which concluded that if emissions continued growing unabated, the world's average surface temperature could rise between 1 and 3.5 degrees centigrade by the year 2100 (which will be higher than during any century over the last 10,000 years), with consequences ranging from increased drought to increased flooding.

Adopted by the COP in its second meeting (COP-2) in 1996, the SAR report concluded that "the balance of evidence suggests that there is a discernible human influence on global climate".[11] The COP-2 also endorsed the SAR as "currently the most comprehensive and authoritative assessment of the science of climate change, its impacts and response options now available", and concluded that legally binding targets for the reductions in GHG were urgently called for. The COP, in its third meeting held in Kyoto in December 1997, reached precisely such targets.[12]

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[11] The SAR suggested a portfolio of possible actions to reduce emissions of GHG. Two such actions were, first, a phasing out of distortionary policies that increased GHG emissions and, second, international cooperation to limit GHG emissions through the implementation of coordinated carbon/energy taxes, activities that can be implemented jointly, and tradeable quotas. (IPCC, 1996).

[12] The recently concluded Kyoto Protocol requires industrial countries to reduce their emissions of GHG below 1990 levels between 2008 and 2012 by about 5 percent overall. The European Union is to reduce emissions by 8 percent, the United States by 7 percent and Japan by 6 percent. Some countries would need to achieve smaller reductions while a few, mostly developing countries, would not have any mandatory targets, at least for now. Countries that do not meet their own emission targets can strike deals with other countries that do better than required and buy the excess "quota". A later meeting of COP will decide on "appropriate and effective" ways to deal with noncompliance. The Kyoto Protocol is to take effect once it is ratified by at least 55 nations that represent at least 55 percent of 1990 CO_2 emissions and the targets will be binding on an individual country only after its

(continued...)

Although the Kyoto Protocol recognizes six different GHG—carbon dioxide, methane, nitrous oxide and three halocarbons used as substitutes for ozone-damaging CFCs—causing global warming, carbon dioxide is considered to be the largest single contributor to the greenhouse effect with a longer lifetime in the atmosphere.[13] The analysis of alternative policy actions in the literature has, therefore, focussed on reducing CO_2 emissions as the most important single step to mitigate global warming.

C. Adoption of Carbon Taxes To Date

In theory, the reduction of CO_2 emissions can be accomplished through different mechanisms, broadly divided into command and control regulations and economic instruments. Between these two types, economic instruments, including carbon taxes, are shown to have the advantage of reaching the environmental goals at the least cost. Not only are carbon taxes shown to be a sound policy to reduce CO_2 emissions, but they also raise substantial revenues (OECD, 1995b). The adoption of carbon taxes, nevertheless, will impose certain economic costs on the society and such costs must be weighted against benefits that may be realized.[14]

Despite the fiscal and environmental advantages of carbon taxes, international cooperation desired by the SAR has not taken place and the international adoption of carbon

[12](...continued)
government ratifies the agreement.

[13] CO_2 represents approximately 60 percent of the volume of GHG. To measure how much each gas contributes to climate change, scientists have developed each one's Global Warming Potential (GWP): carbon dioxide (1), methane (11), nitrous oxide (270), CFCs (3400-7100). The lower the GWP, the more significant the gas in terms of greenhouse effect. It basically means that 11 kilograms of methane has the same effect as 1 kilogram of carbon dioxide.

[14]Given the uncertainty of the time frame over which global warming becomes a serious threat to humanity, certain authors recommend a gradual approach which will lower CO_2 emissions without causing serious economic dislocations. A carbon tax that limits costs to US$10-15 per metric tonne of carbon emitted is considered quite adequate (see *Business Week*, December 8, 1997, p. 64). Other authors recommend the use of revenues from carbon taxes to significantly mitigate the economic costs to society. For example, the revenues may be used to reduce distortionary taxes, such as social security taxes, income taxes and inflation taxes (caused by growing fiscal deficits) in the economy. Other options for the use of carbon tax receipts include the financing of additional environmental programs or encouraging the development of alternatives to fossil fuels or energy efficient technologies through tax incentives; reduction of public deficits, if any; or increasing public spending, in general, and for education and health, in particular. However, there seems to be a consensus in the literature that the best available option is to reduce existing distortionary taxes (Golombek et al (1995); Bohringer and Rutherford (1997); Welsch (1996); Repetto and Austin (1997); Goulder (1995)).

taxes has been limited to date.[15] In fact, as pointed out at the United Nations meeting (known as Earth Summit +5), held in New York in June 1997, and the COP-3 meeting held in Kyoto in December 1997, global warming continues to be a serious threat to the ecosystem and human welfare unless serious policy measures are put in place to curb CO_2 emissions globally.

The reluctance on the part of policymakers to adopt carbon taxes is partly due to the interest in some countries in adopting market-based rather than government policy instruments—the United States, for example, has defended the establishment internationally of a system of tradable emission permits, instead of a carbon tax, as a means of achieving a global reduction in GHG emissions—a position which has found a prominent place in the recently-agreed Kyoto Protocol as well. Three additional major reasons for the lack of progress towards the global adoption of a system of carbon taxes include: first, worries about their impact on productivity and economic growth; second, worries about their equity implications; and third, worries about their implications for competitiveness and international trade,[16] and the remainder of the paper addresses these economic concerns. Based on a review of the literature, it attempts to provide insights into the validity of the three worries that have prevented a wider adoption of a system of carbon taxes to date. It is hoped that the analysis of the paper will contribute to a better understanding of the issues and will allow a fuller discussion of the system of carbon taxes as one of the viable instruments of curbing CO_2 emissions and reducing the rate of global warming.

III. Carbon Taxes as Compared to Other Economic Instruments

A. Alternative Economic Instruments

Four basic types of economic instruments are identified in the literature regarding environmental policy (OECD, 1997b). They are labeled as "economic" because the objective is to induce, through economic policy changes, changes in the behavior of economic agents, compelling them to take into account the estimated costs and benefits of alternative actions open to them. Such instruments are distinct from "noneconomic" measures, such as command and control regulations. The four basic economic instruments are: charges and taxes, tradable emission permits, subsidies, and deposit-refund systems.

Charges and taxes can be of three types: emissions charges, user charges, and product taxes. Emission charges are based on pollutants emitted, user charges are charges for the use of public effluents or deposits, and product taxes cover taxes on products whose production or consumption creates pollution.

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[15] So far Denmark, Sweden, Norway, Finland, and the Netherlands have moved in that direction.

[16] For example, the European Union has conditioned the adoption of a common carbon tax to the adoption of similar policies by other countries.

Tradable emission permits involve an allocation of permits to economic agents to emit given amounts of GHG which, when spare, can be traded in the market. All polluting agents must have the necessary number of permits to cover their emissions.

Subsidies include grants, soft loans or tax reliefs that promote clean technologies or help polluters bear the private costs of pollution control in the short run.

Deposit refund systems require surcharges to be levied on potentially polluting substances which are, then, refunded if pollution is avoided by recycling those substances.

With respect to climate change, carbon taxes and tradable emission permits have received the greatest attention in the literature because of their relative advantages.

B. Major Advantages of Economic Instruments

Two major advantages of carbon taxes and tradable emission permits are their relative efficiency and potential revenue.

The first advantage of these economic instruments is that they achieve environmental goals at least cost (Baumol and Oates, 1988). Their potential efficiency gains have static and dynamic dimensions.

The static efficiency results from the fact that a market mechanism induces emitters to choose an efficient, cost minimizing, pattern of abatement. Economic agents with low abatement costs will make larger reductions in emissions than those with high costs. Rationally, each economic agent will abate up to the point where the marginal cost of abatement equals the marginal cost of polluting (given by the tax rate or the market price of the permit). Because of such a behavior, marginal cost of abatement gets equated among various economic agents, which is the necessary condition for achieving cost effectiveness.

The dynamic efficiency results from the incentives that the price mechanism provides for research in, and development of, pollution abatement and energy efficient technologies. That is because economic agents (e.g., carbon emitters) have an incentive to find cost-effective ways of achieving emission reductions. With a carbon tax, economic agents pay a tax on remaining emissions from the use of fossil fuels. Finding ways to use less fossil fuels, therefore, bestows cost savings for the firms, which then pay less in taxes due to reduced emissions. Similarly, with a system of tradable emission permits, such technology improvements allow the agents to have "spare" permits to sell in the market and receive pecuniary reward.

The second advantage of economic instruments is their potential for raising government revenue. The argument is self explanatory in the case of carbon taxes. The same potential exists with respect to tradable permits if the emission permits are initially "auctioned" by the government to the economic agents for a "price". However, it may be the case that the net present value of the revenues collected through the tax might be different from the revenues realized from the auction.

C. Carbon Taxes Versus Tradable Permits

Before attempting to compare carbon taxes with tradeable permits, certain basic difficulties of designing each one of these instruments need to be highlighted .

The "optimal" level of an environmental tax, theoretically, is determined by the marginal social damage caused by emissions (this is also the level of the Pigouvian tax[17]). However, to determine its level, one needs to know the marginal social damage, a task that is complicated and costly, not to mention uncertain. An alternative to the determination of an appropriate level of the tax could be to decide on a level of environmental quality acceptable to the society and set the tax rate at a level that would be high enough to help achieve it. Even this alternative does not eliminate the need for the empirically validated information about the relation between taxes and the response of economic agents to reduce emissions. Because of the difficulties of determining the appropriate level of the tax, many writers believe that a pre-specified desired "target" level of environmental quality may or may not be achieved through the imposition of carbon taxes.

In a system of tradable emission permits, on the other hand, the community (national or international) agrees on a targeted level (national or global) of environmental quality (optimally it should be where marginal social damage equals the marginal cost of abatement), and, therefore, the number of CO_2 tons allowed to be emitted (nationally or globally). Consistent with that target, then, permits are allocated (within countries and amongst countries) and trading is permitted among the economic agents (within or across the borders of individual countries). Obviously, the allocation of permits which everyone would consider a "fair" basis represents one of the major difficulties of implementing a (national or international) system of tradable emission permits. The methods of allocation could include (1) a grandfathered system, where the permits are allocated based on existing levels of emissions, (2) a permits allocation system which allows equal per capita emissions, based on the country's population as a share of world population, and (3) a system of emission permits which allows equal emissions per dollar of GDP, which is based on the share of world GDP. The choice between these three options of allocation of permits is clearly complicated, since individual countries would benefit differently under each of these options. Once the permits are allocated, however, and an efficient market for permits develops, a market clearing price would emerge. This will present to the economic agents the "true" opportunity cost of emitting and, since all economic agents will face the same price for a permit, the marginal cost

[17] However, in the presence of distortionary taxes, the level of optimal tax may well be below the Pigouvian tax (Bovenberg and de Mooij (1994)).

of abatement will be equalized between all potential agents and the condition of cost minimization will be achieved. There is yet another issue relating to tradeable permits. The initial permits may be sold through auctions or freely distributed. The former method has the advantage of providing revenue but, in an international context, it is unclear who will be auctioning the permits or receiving and spending the revenues.

How does one choose between the global adoption of carbon taxes and internationally tradeable pollution permits as instruments of controlling global climate change?[18]

In a world with certainty, as was pointed out above, both of them can achieve environmental goals at least cost.[19] However, climate change has important uncertainties associated, both with the "benefits" of controlling climate change and with the "costs" of reducing emissions. Under uncertainty, therefore, both environmental policies are likely to be sub-optimal. If the marginal benefits are uncertain, but the abatement costs are not, the consequences in terms of social costs will be the same under the two policy instruments. Uncertainties associated with the potential consequences of global warming should not affect the choice of the economic instrument. However, this result does not hold when one considers the uncertainties of the marginal abatement costs.

Baumol and Oates developed two propositions that help one understand the role of each instrument. First, the steeper the marginal control cost curves are, the greater the distortion that is caused by a system of tradable permits and the smaller the distortion that is caused by the carbon tax. Second, a carbon tax seems to be a better policy if the marginal control curve is steeper than the marginal benefits curve; a system of permits is preferable, if the reverse is the case. Therefore, the choice among the two economic instruments must depend on one's estimates of the costs and the benefits of reducing emissions.

From the perspective of the regulator, or an international institution overseeing the global warming agreement, significant differences exist, however. Marketable permits reduce the uncertainty of achieving a desired level of environmental quality as the regulator directly sets the target and issues the necessary number of permits corresponding to the desired target. With carbon taxes, on the other hand, the regulator must rely on unquantifiable expectations about the response of economic agents.

Another difference between the two instruments arises when there is high inflation. Continuing high inflation erodes the real value of a tax, specially if it has a specific rate of tax based on carbon content. This shortcoming, however, can be overcome with periodical

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[18] The discussion that follows is largely based on Baumol and Oates (1988).

[19] See Baumol and Oates (1988), and Hanley, Shogren and White (1997).

revisions of the tax. Tradable emission permits, on the other hand, automatically accommodate to inflation.

Carbon taxes and tradable permits also impose different financial burdens on the economic agents. A carbon tax imposes significant burdens particularly on those who are intensive users of fossil fuels. A system of tradable permits does not if the permits are allocated for free, and does so only if they are initially auctioned to raise revenue or if the firms must obtain more permits than those initially allocated to them.

Still another difference between the two instruments arises when geographical considerations relating to the environmental problem are considered. In some cases it may be important to distinguish between pollution sources based on their location (a polluting firm located next to a city, for example, does not cause the same damage as one located in an isolated place). In such cases, the rate of the carbon tax may need to vary between localities and regions. Such a custom-tailored tax rate can be cumbersome to design and may be unacceptable politically. A system of tradable permits that takes into account these spatial differences, on the other hand, would be easier to implement. In the case of global warming, however, as all GHG emissions contribute to global warming equally and in a similar way, such spatial differences may not be that relevant.

While both carbon taxes and tradable permits compensate for a negative externality and, therefore, increase economic efficiency, carbon taxes provide a more steady source of public revenue which can be used to reduce or even eliminate distortionary taxes. Tradable permits, will generate revenue only one time when and if auctioned initially. One can also think of periodic auctions but that would be extremely costly administratively both for the regulator and the polluting firms.

Carbon taxes are also considered a "fair" policy if it is believed that society has the right to a clean atmosphere and all emitters should be "punished" for polluting it. Carbon taxes follow the polluter-pays-principle, under which emitters are required to compensate society through taxes. These revenues are then used to protect the environment or benefit the society in other ways. In a tradeable permits market, such a compensation would exist only if permits are allocated initially to the entire public and polluters are called upon to pay for them, through an auction[20]. But once the firms have the permits, they can acquire the right to pollute more by buying permits from each other, without compensating society in general.

As can be seen, the choice of an appropriate economic instrument to reduce carbon emissions is a complicated one and depends on many circumstances. Policymakers must balance the pros and cons of each type of economic instrument, without disregarding the

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[20] Of course, the public will not give away the permits free of cost and the social cost of polluting will have to be recognized.

possibility that the "optimal" choice may well be a combination of both. Without giving an iron-clad answer to the question of the appropriate choice of the economic instrument in any given situation, the remaining part of the paper focuses on carbon taxes which, while providing a steady source of government revenue and permitting the governments to use those revenues for the broader social good, is certainly one of the important tools for curtailing global warming.

D. Design of Carbon Tax

The case for the levy of a carbon tax as a means to reducing CO_2 emissions is straightforward. A carbon tax forces fossil-fuel users to "internalize" the economic externalities caused by the emission of GHG—in this case the global warming effect. As noted earlier, the design of the carbon tax would depend on the objectives being pursued and the "optimal" tax would be set such that marginal social damage resulting from pollution is equal to the marginal cost of abatement.

However, two problems that arise in this connection are worth mentioning here:

- First, what is the scope and size of the social damage? As this can mean either domestic damage or global damage, this ambiguity results in difficulties for the setting of an "optimal" tax rate as well as the decision about the tax base.

- Second, how should one estimate the social damage—should it cover only domestic damage or cover global damage as well? The estimates of damage caused by global warming at present are highly uncertain and call for a large amount of information, not readily available.

In the case of GHG emissions globally, obviously, the "optimal" tax would be one that is based on the amount of emissions. However, international monitoring of CO_2 emissions into the global atmosphere will be cumbersome and costly. Taxing carbon content through a product tax on fossil fuels, on the other hand, is more attractive [21]. The choice between taxing emissions and taxing emission-causing products will depend on the cost and feasibility of monitoring emissions and the possibility of establishing a direct one-to-one link between the consumption of the product (fossil fuel) and the extent of the damage (CO_2 emissions). Since such a link is relatively easy to determine, while monitoring emissions is very difficult and expensive, a product tax, based on the carbon content of a fuel source, is an appropriate choice to reduce CO_2 emissions.

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[21] Another option that has been considered is a product tax based on the energy (BTU) content of the fuel. See Bovenberg (1993). However, energy content is not directly related with CO_2 emissions and it would tax energy sources that do not contribute to the global warming effect. The incentive to switch from high-carbon fuels to less-carbon fuels would not exist.

Since, as noted earlier, an optimal tax is not easy to determine, a 'second best' option would consist of choosing a target of a socially acceptable environmental quality and determining a tax rate that will achieve that target.[22] The necessary carbon tax to reach a specific level of reduction is shown to be higher (i) the lower the emissions are per unit of GDP, and (ii) the smaller the elasticity of substitution is between fossil fuels and other factors (Hoel, 1993).

Other considerations that might enter into the determination of the rate of the carbon tax include the objective of the tax as a revenue raiser and the relative long- and short-term effects of the tax. Theoretically, there is a potential conflict between the environmental goal and the revenue raising property of the tax. If a carbon tax is truly effective and reduces emissions, by shifting fuel consumption to less carbon intensive fuels, the revenue raised could be relatively small. On the other hand, if significant revenues continue to flow from the tax, this may indicate that longer term environmental goals are not being achieved and stricter, more effective, measures are called for in order to change fuel consumption patterns.

The distinction between long- and short-term objectives that the regulator wishes to pursue is also important. If the aim is to achieve a long-term response, that is, to affect changes in the capital stock and bring about technological innovations (dynamic efficiency effects), the appropriate tax rate may be lower than if the objective is short-term, that is, to bring about quick and immediate improvements. A related issue here also is how the carbon tax should be phased in. Phasing-in the tax over time allows the economic agents to smoothly adjust to the negative effects of the tax on the economic activities. There does not seem to be a unique answer to how the carbon tax should be phased in. Farzin and Tahoneen (1996) showed that the optimal carbon tax, in fact, may well be constant through time, or increase monotonically or even have an U-shape. If phased in, periodic revisions of the tax rate, when it is specific and not ad valorem, may be necessary to avoid possible erosion of its real burden due to inflation.

The design of a carbon tax also cannot be isolated from considerations about how the revenues raised by the tax will be utilized—in fact, this plays a crucial role in determining the 'net' economic impact of the tax and its political acceptability. To be more precise, the potential use of the revenues is important for the following reasons:

- First, although, the size of the revenues will depend on a large number of factors (level of the tax, phase in, etc.), they are likely to be significant particularly in countries with a large energy sector that is dominated by carbon-high fuels.

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[22] The choice of the standard is somehow arbitrary. For example different proposals were at the table for the third meeting of the COP. Among them were a 15 percent reduction below 1990 levels by year 2010 and a 20 percent reduction below 1990 levels by year 2005.

- Second, how the revenues are used may help allay some of the worries caused by the imposition of the tax, for example, its impact on economic growth, or its distributional effects, or its effect on a country's international competitiveness.

- Third, revenues may be allocated to public activities that can help mobilize public opinion in favor of the adoption of the tax.

E. Alternative Uses of Carbon Tax Revenues

There are, at least, three options to utilizing or recycling carbon tax revenues: they can be used to (1) increase expenditures on environmental and other public programs; (2) reduce budget deficits and lower inflation; or (3) reduce existing distortionary taxes (referred to as "revenue switching" in the literature).

The **first option** allows the possibility of compensating those sectors of the economy that would be more adversely affected by the tax. Examples here could include sectoral assistance in the form of tax reliefs for workers and firms in the energy area, which may be particularly hard hit by carbon tax. However, by doing that, policymakers risk not being able to achieve their environmental goal and, as a negative effect, even induce an undesirable allocation of resources to the sector that receives the help, continuing to increase emissions. Providing such reliefs and exemptions also reduces overall welfare for society (Bohringer and Rutherford, 1997).

In the context of the first option, another proposal, that is particularly popular among environmentalists, is to earmark such revenues to finance tax incentives in order to promote energy efficiency or expand environmental protection expenditures. Although it sounds laudable, this proposal has some drawbacks: Firstly, to "earmark" revenues prevents governments from optimizing the allocation of available governmental revenues amongst competing alternative uses. The argument here is that government expenditure on a given program should be based on the need for, and priority of, a category of spending rather than on the ready availability of an "earmarked" source of finance. It makes little economic sense to incur larger public spending on an activity simply because enough revenues are available. Secondly, the revenues generated by carbon tax would depend on the response of the economic agents to the tax. If fuel consumers significantly shift their consumption, in order to avoid the tax, the revenues from the tax would decline significantly and specific programs dependent upon them would be unduly jeopardized.

The **second option** would allow governments to lower inflation by curtailing budget deficits and reducing interest payments on public debt by present and future generations. Linking the revenues collected from environmental taxes with macroeconomic management is obviously desirable but one should not lose the perspective that the main purpose of the tax is to discourage economic activities that generate carbon emissions. If a high rate tax achieves that objective, and in the process generates little to no revenue, it is welcome nevertheless.

The **third option** of the reduction of other distortionary taxes (or revenue switching) is considered by economists as the best possible use for the revenue collected through carbon taxes. The attractiveness of this option, however, depends on current tax burden (how high it is) and the characteristics of the tax structure (how distortionary the taxes are) in each country. Reduction of general consumption taxes is one possibility and has the economic benefit of partially, if not fully, offsetting the potential increase in energy prices caused by the carbon tax. Two other alternatives that have received wide attention in the literature include: reductions in labor taxes and/or social security taxes and taxes on capital gains. Studies, such as Welsch (1996) and European Economy (1994), have concluded that using the revenues to reduce employers' social security taxes improves employment and significantly mitigates economic costs of the tax in terms of GDP. Mabey et al (1997) reach the same conclusion when revenues are used to reduce labor taxes or income taxes, although the positive effects are found to be greater in the case of labor taxes, confirming the findings of Welsch and European Economy. Some other studies, such as Jorgenson and Wilcoxen (1994), however, found that the best positive effects, including an increase in GDP, occur when carbon tax revenues are used to lower taxes on capital incomes.

To summarize this section, there is a consensus amongst economists, that potential gains to the economy from the imposition of carbon taxes will depend on specific conditions, such as their design, the responsiveness of the polluters, and the uses to which their revenues are put, all of which are likely to differ from country to country. No generalization is, therefore, possible on how best to design the carbon tax or utilize the revenues resulting from it.

IV. Effects of a Carbon Tax on Economic Growth

There are three dimensions to calculating the costs and benefits to the economy of mitigating carbon emissions—direct welfare costs, macroeconomic costs, and revenue benefits (Mabey et al, 1997). The literature has, however, focussed primarily on the macroeconomic cost in terms of its effects on the reduction in GDP growth. The causation is as follows: A carbon tax curtails the use of fossil fuels as a source of energy for production purposes and, with a decline in the use of one of the factors of production, there is a reduction in national output compared to the case where there are no restrictions.[23] Economic costs of a carbon tax are, therefore, usually measured as the percentage change of future GDP with respect to a "base scenario" where no carbon tax existed (the latter is called the business-as-usual scenario).

[23]This is an example of Le Chatalier Principle: Economic agents cannot do better in a constrained framework.

A. Pre-1995 Studies

The most complete assessment of the studies done about the effects on GDP growth rate of mitigating CO_2 emissions is contained in the Second Assessment Report of the IPCC (1996[24]). In that report, the economic models are divided into the so called "top-down" and "bottom-up" categories. Top-down models use aggregate data of the whole economy and analyze environmental policies, including carbon tax, distinguishing the energy sector from other sectors and focusing on the interaction between sectors. Bottom-up models emphasize the technological options for energy savings and fuel switching possibilities available to economic agents. Bottom-up models tend to be more optimistic about the negative impacts of a carbon tax on the growth rate of GDP.

A summary of top-down models relating to the U.S. economy reveals the economic costs (loss of GDP) of a scenario where emissions are stabilized at the 1990 levels that could range between 0.2 and 0.7 percent of GDP in 2010. If, instead, a 20 percent reduction in emissions below 1990 levels is postulated for 2010, the estimated costs increase and range between 0.9 to 1.7 percent of GDP (IPCC, 1996). However, most of these studies assumed lump sum redistribution of carbon tax revenues. When carbon tax revenues are recycled more efficiently, the economic costs of carbon taxes, in terms of GDP losses, decrease.

The IPCC Report also reports on the costs estimated by various bottom-up models. In their case, the estimates range between -1.2 percent (net benefit) to 0.5 percent.

B. More Recent Studies

Mabey et al (1997) have conducted a review of the studies about the economic impact of a carbon tax and have shown how different studies end up with different estimates, depending upon the assumptions made (see Table 2).

Most recently, Repetto and Austin (1997) have identified the key assumptions that largely determine the effect of carbon tax on economic growth in the United States (see Table 3). The key assumptions include the extent to which (1) substitution exists among energy sources, alternative energy technologies, products and production methods are available, there is a responsiveness to technological innovations and price signals, and markets create opportunities for improvements in energy efficiency; (2) non-fossil backstop fuels are available at reasonable costs; (3) there is a potential for "joint implementation" programs for emission reductions; (4) the carbon tax revenues are recycled through a reduction in distortionary and economically burdensome taxes; (5) air pollution damages are averted; and (6) climate changes are averted.

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[24] Papers published after 1995 are noted and summarized in the Appendix.

Table 2. Estimates of Reductions in Projected GDP in Different Regions of the World Resulting from Assumed Reductions in CO_2 Emissions

Study **(Period covered by the study)**	Country/Region	Assumed Reductions (-)/ Increases (+) in CO_2 Emissions (in percent)	Estimated Reduction(-) in Projected GDP (Percent of baseline[1])
Manne and Richels (1992) **(1990-2100)**		**From the levels prevailing in 1990**	
	• USA	-20	-3.0 [2030]
	• OECD	-20	-2.0 [2010]
	• Soviet Union - Eastern Europe	-20	-4.0 [2020]
	• China	+100	-10.0 [2050]
	• Rest of World	+100	-5.0
	• World	+16[2]	-5.0
Edmonds and Reilly (1983) **(1975-2050)**		**From the levels prevailing in 1990**	
	• USA	+70	-0.4
	• World	+162	-1.0
Nordhaus (1991) **(1990-2100)**	• World	[3]	-1.0
Burniaux et al (1991) **(1990-2020)**		**From the levels prevailing in 1990**	
	• N. America	-20	-0.8
	• Europe	-20	-7.0
	• Pacific	-20	-3.7
	• Energy - Exporting Developing Countries	+50	-3.6
	• China	+50	-1.5
	• USSR	-20	-2.2
	• World	+17[4]	-1.8
Whalley and Wigle (1991) **(1990-2030)**	• World	[5]	-4.2

Source: Based on information given in Mabey et al (1997), page 74.

[1]As compared to the levels that would have otherwise prevailed (without any policy change) in the baseline year. The baseline year is the year indicated in square brackets.
[2]This is equivalent to a 75 percent reduction from the levels of emissions that would have otherwise prevailed in 2100.
[3]This is equivalent to a 50 percent reduction from the levels of emissions that would have otherwise prevailed in 2100.
[4]This is equivalent to a 37 percent reduction from the levels of emissions that would have otherwise prevailed in 2020.
[5]This is equivalent to a 50 percent reduction from the levels of emissions that would have otherwise prevailed in 2030. The study considers the imposition of a global tax to achieve the assumed reduction.

Table 3. United States: Estimated Effect on GDP of Stabilizing Emissions at 1990 Levels When Alternative Sets of Assumptions are Valid

Validity of Assumptions[1]	Estimated Effect on GDP (percent reduction (-)/ increase (+))
If none of the assumptions is valid	< -2
If only assumption A1 is valid	-1
If only assumptions A1-A2 are valid	~ -0.5
If only assumptions A1-A3 are valid	~ -0.1
If only assumptions A1-A4 are valid	~ +1.1
If only assumptions A1-A5 are valid	~ +2.1
If all the assumptions are valid	~ +2.3

Source: Based on estimates made in Repetto and Austin (1997), page 16.

[1] Possible assumptions recognized by the authors in their analysis are as follows:
Assumption 1 (A1): Efficient economic responses take place.
Assumption 2 (A2): Non-carbon backstop fuel are available.
Assumption 3 (A3): Joint implementation exists.
Assumption 4 (A4): Revenues are recycled.
Assumption 5 (A5): Air-pollution damages are averted.
Assumption 6 (A6): Climate changes are averted.

The authors show that in studies whose models contain "pessimistic" assumptions, such as (a) limited substitution; (b) slow technological response to price signals; (c) non availability of non fossil fuels; and (d) absence of international cooperation, the economic costs tend to be high for the achievement of any given level of an environmental goal (CO_2 abatement). In fact, the higher the target, the higher the cost. On the other hand, in studies where the models use assumptions which are "optimistic", the predicted costs tend to be lower.

In relation to the United States, Repetto and Austin show that if (a) non carbon backstop fuels are available; (b) responses of economic agents are rational; and (c) energy and product substitution as well as joint implementation possibilities exist, the adoption of a carbon tax leads to positive impacts on GDP, for relatively low targets of environmental quality; and a small negative impact on GDP, for relatively high targets. If one adds the assumption that carbon tax revenues are recycled efficiently, then the authors show that a positive impact on GDP is guaranteed, independently of the environmental target chosen.

Thus, to the question of the likely effects of a carbon tax on economic growth, a clear-cut answer does not exist. The adoption of a carbon tax does not necessarily have to result in a loss of GDP growth rate—it depends on the validity of assumptions made and the circumstances prevailing in an economy. Additionally, it is important to mention here that GDP is not a welfare measure; GDP growth rate may well decline and yet the welfare may improve because of environmental improvements.

Even though there is a lack of a consensus on the effects of a carbon tax on economic growth (due to different assumptions made in individual models), there seems to be a general agreement that the manner in which carbon tax revenues are used and the efficiency with which economic agents respond play an important role in the final outcome. If carbon tax revenues are recycled appropriately, one can expect the effect of a carbon tax on economic growth not to be that negative.

V. Effects of a Carbon Tax on Equity and Income Distribution

As with any policy action, the imposition of a carbon tax is likely to result in gains for some sections of the population (the winners) and losses for other sections of the population (the losers). A carbon tax will, thus, entail different burdens for different groups of population and, unless these distributional aspects are adequately dealt with, potential losers would most likely block the implementation of the tax.

A. Potential Winners and Losers

Two important questions, therefore, are: (1) Which groups would most likely gain and which groups would most likely lose from the imposition of a carbon tax? and (2) What can be done to reduce the adverse effects of the tax on the losers?

In answering these questions, it is necessary to distinguish between domestic consequences of a carbon tax (if only one country imposes the tax), and international distributional consequences (if the carbon tax is adopted globally).

Domestically

Domestically, there are at least two sets of impacts: the sectoral impacts, that is, the consequences of the tax for the energy industry as opposed to other industries; and the wider distributional impacts, that is, the consequences of the tax for the low-income groups as compared to the high-income groups, given the potential regressivity of the tax.

With respect to sectoral impacts, clearly the sector that most likely will be affected by the carbon tax is the energy sector.[25] Energy firms would face a higher cost for their main input. How much of the cost increase they would ultimately bear themselves would obviously depend on market conditions. The impact of a carbon tax on prices, and the resulting use of alternative fuels, would also depend on whether markets are local or international. For example, with prices set internationally and a relatively inelastic demand curve, final consumers would bear all the added costs. But if demand was not completely inelastic, the burden of the carbon tax is likely to be shared between the energy sector and the final consumers of energy intensive products[26].

With respect to distributional impacts, the issue that has been discussed widely in the literature is the regressivity of the tax. It is argued that because low income families spend a larger proportion of their income on energy-related products, a carbon tax would unfairly impose a higher burden on them. The IPCC (1996) report summarizes the distributional results contained in different studies (see Table 4).

In general, a carbon tax is found to be regressive. However, it is less regressive than is generally portrayed, at least when it is related to the levels of current expenditures and not current incomes of various economic groups. Poterba (1991) estimates the impact of a $100 per tonne carbon tax on the income distribution in the United States. He uses two variables—per capita income and per capita expenditure (intended to represent permanent income). In both cases, the carbon tax is found to be regressive; however, significatively less regressive when expenditure data are used.

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[25] Fuel combustion in the energy sector is responsible for more than 95 percent of anthropogenic emissions of CO_2.

[26] In countries which who are both large energy producers and large energy consumers, the incidence of the carbon tax will be somewhat difficult to assess.

Table 4. Results of Empirical Studies on the Redistributive Impact of a Carbon Tax

Study	Country	Model	Results
Bull, Hassett & Metcalf (1993)	United States	Computable dynamic general equilibrium	Tax burden is nearly proportional with respect to lifetime income
DeWitt, Dowlatadabi & Kopp (1991)	United States	Partial equilibrium model	Regressive and varies across regions
Jorgenson, Slesnick &Wilcoxen (1992)	United States	Computable general equilibrium model	Mildly progressive or regressive, depending on the welfare function
Poterba (1991)	United States	Partial equilibrium model	Regressive but impact is smaller if expenditure data are used
Schillo, Giannarelli, Kelly, Swanson & Wilcoxen (1992)	United States	Aggregate macroeconomic model	Regressive to neutral
Schillo, Giannarelli, Kelly, Swanson & Wilcoxen (1992)	United States	Microsimulation model	Regressive to neutral
Pearson (1992)	Europe	Partial equilibrium model	Regressive
Pearson & Smith (1991)	Europe	Consumer expenditure (partial equilibrium)	Regressive for some countries, mildly regressive for others
Shah and Larsen (1992)	Pakistan	Partial equilibrium model	Proportional to progressive
Hamilton & Cameron (1994)	Canada	Computable general equilibrium model	Moderately regressive

Source: IPCC (1996), page 37.

Pearson and Smith (1991) studied the distributional effects in European countries of a carbon/energy tax equivalent to US$10 per barrel of oil. For Ireland and the United Kingdom, a regressive impact was found, but for Germany, the Netherlands, Italy, France and Spain, the percentage burden of the carbon/energy tax was found to be only weakly related to income.

Hamilton and Cameroon (1994) found, in a study on Canada, that a tax of Can$27.70 per tonne of carbon emitted would be only moderately regressive. Jorgenson et al (1992) report a carbon tax in the United States to be mildly regressive or even progressive, depending on the welfare function used.

Very few studies have been done for developing countries. In an analysis for Pakistan, however, Shah and Larson (1992) found that a carbon tax may well be proportional to income or even progressive as energy-intensive manufactured goods are 'superior' goods and are largely consumed by the relatively well-off.

Globally

With respect to the distributional impacts of a global carbon tax, the answer depends on the distribution of damages that would otherwise be caused by global warming. As was pointed out earlier, these damages are estimated to vary greatly across countries and regions. Therefore, the benefits of stabilizing or reducing CO_2 emissions will also vary.

As against this, the distribution of costs between countries of a carbon tax is likely to depend on the type of agreement reached, that is, whether each individual country adopts an independent stance and sets its own target or adopts a common stance and accepts a global target. Hoel (1993) shows that the percentage of GDP loss from a given carbon tax, aimed at achieving individual stabilization, is higher, the smaller is the elasticity of substitution between fossil fuels and other factors. On the other hand, the percentage of GDP loss following a common carbon tax is higher (i) the higher are emissions per unit of GDP and (ii) the larger is the elasticity of substitution between fossil fuels and other factors. Based on these factors, his study concludes that, in the European Community, a program of "individual stabilization" would imply higher costs for Greece, Portugal and Norway, and lower costs for Denmark, France and Germany. If instead, a common carbon tax is adopted, costs would be high for Greece, Ireland and Portugal and low for France, Italy and Norway.

OECD (1995a) summarizes different studies on the estimate of the distributional costs of national carbon taxes intended to achieve the same percentage reduction in each region. Results vary per region and model, although the general tendency is towards higher costs for developing countries (or the "rest of the world") (see Table 5).

Table 5. Estimates of Costs of a Carbon Tax
by Region and by Model

Cost in 2020 (In percent of GDP)

Country/Region	Barnes et al (1992)	Oliveria (1992)	Manne (1992)	Rutherford (1992)
United States	2.0	1.1	2.2	1.3
Other OECD	1.9	1.2	1.1	0.4
China	2.8	0.7	2.7	2.0
Ex-USSR	0.9	1.7	3.1	1.5
Rest of the World	2.0	3.8	4.9	2.3

Source: Dean (1994), as quoted in OECD (1995a).

B. Alternatives for Mitigating Negative Distributional Impacts

There are two ways to reduce negative distributional impacts: mitigation and compensation measures. The former refers to reducing impacts **ex-ante**, while the latter refers to assistance **ex-post**.

Mitigation Measures

The typical mitigation measure is to create a system of exemptions and reliefs. For example, in a situation of globally agreed carbon taxes, national programs could exempt exports to other countries, provided each country under the agreement itself will be taxing the consumption of fossil fuels. In the absence of such an international agreement, a unilateral increase in the prices, due to the levy of a carbon tax, could lead to an increase of emissions in countries which do not levy the tax, as there will be a shift in the origin of the supply of fossil-fuels-based products. In the literature, this is known as "leakage". A significant "leakage" would, therefore, hurt domestic economies without reducing overall emissions. Therefore, where the possibility for significant "leakages" exists, international agreements are an important prerequisite for successfully reducing emissions globally.

One possible solution to the "leakage" problem is to exempt from carbon tax those export-oriented industries that face substantial competition internationally. However, doing so, would have strong drawbacks. It would require a higher tax on other domestic sectors, so as to achieve a given environmental goal, which would distort the economy towards the exempt industries and maybe even increase emissions. Besides, exemptions would most likely become permanent, reducing the overall efficiency of the carbon tax (Pearson and Smith, 1991). Bohringer and Rutherford (1997) conducted a case study of sectoral exemptions in Germany and found that such policy implied significant welfare losses.

Compensatory Measures

Compensatory measures can be financed through carbon tax revenues and can be adopted to "offset" the regressive impacts of the tax. They may, for example, include enhancing the earned income tax credits for the working poor or compensating the industry by reducing its labor or income taxes. The study by Bohringer and Rutherford (1997) proposed a uniform carbon tax-cum-wage subsidy. Mabey et al (1997) showed that recycling through labor taxes in Europe generated output gains that were progressively distributed.

Without doubt, a carbon tax implemented widely across countries will have important distributional impacts. To mitigate its negative effects at the domestic level in each country, tax revenues would need to be used efficiently. To ensure that a carbon tax adopted globally, or by a large number of countries, is efficient to control climate change, it would be essential that there not be an increase in emissions by non-participating countries.

VI. Effects of a Carbon Tax on a Country's International Competitiveness

The adoption of a carbon tax is likely to affect firms producing energy-intensive outputs seriously. First, it would increase their production costs which would lead to a loss of competitiveness, specially for those firms which compete in an international market, and which cannot promptly adopt technological changes. Second, because of the loss of competitiveness, many firms would most likely relocate in countries that face less restrictive environmental regulations and/or weaker monitoring of such regulations. This is the so-called "pollution haven" hypothesis.

However, there will be some tendencies countering such effects. According to Porter (1990), reducing pollution and maximizing profits go hand in hand and environmental regulations often induce firms to be more competitive and efficient. Similar arguments are presented by Bommer (1996) who concluded that relocation of polluting firms is explained more by business strategic reasons and trade liberalization rather than by weaker environmental standards.

What is the true relationship between carbon taxes and international competitiveness? To answer this question one must first clarify what is meant by international competitiveness. Competitiveness has different meanings for different levels of economy—it is different for a firm or an industry than for the country as a whole (OECD, 1997a).

A. Competitiveness at the Firm Level

At the firm or the industry level, a carbon tax would hit the energy intensive firms and industries particularly hard and is likely to lead to loss of sales, loss of market share and ultimately plant closures, but such a result might not come about if all firms face similar cost increases. Besides, firms or industries do not operate in a static environment and generally adapt their operations to new regulations. Furthermore, environmental regulations are only a part of a vast array of factors that determine the overall competitiveness of a firm or an industry. Finally, firms or industries may find that there is an increasing demand for environmentally-friendly goods and it is in their interest to capture those emerging markets.

OECD (1997a) reports the findings of two studies that concluded only a weak relation between environmental regulations and firms' profitability. One of these studies, in fact, reported that firms can achieve high levels of competitiveness even with high carbon tax and/or other regulatory costs as older production capacity, which was less efficient, is retired and the establishment of newer, cleaner plants is accelerated as a part of the dynamic response of the firm or the industry to the tax.

B. Competitiveness at the Country Level

At the country level, the effect of a carbon tax may be different since countries do not "compete" in the same way as firms do. Some economists have argued that the best measure of a country's international competitiveness in the long run is its productivity growth and, as Repetto et al (1996) have shown, it is not clear if the U.S. environmental regulations have reduced her productivity growth or have discouraged new investments, including those from abroad. Panayotou (1997) too, reporting on a survey of senior executives and CEOs, has found that while environmental regulations do affect investment decisions, they do not do so in any major way.

The effect of a carbon tax on the international competitiveness of a country would also depend on how the revenues raised from the carbon tax are utilized. If distortionary taxes, such as payroll taxes, social security taxes or corporate income taxes, are lowered, the "loss" of international competitiveness, if any, might be significantly offset.

Despite the lack of much empirical evidence to support the claim that a carbon tax must curtail international competitiveness, policymakers everywhere continue to face stiff opposition to the tax simply on the basis of "perceived" worry. The European Community's proposal of introducing a carbon/energy tax equivalent of US$10 per barrel of oil, for example, was conditioned on other industrial countries adopting similar measures. Developing countries are also unwilling to commit themselves to adopting significant measures to reduce CO_2 emissions unless industrialized countries take the lead. It is clear, therefore, that any unilateral action on carbon tax would be unlikely unless additional research establishes convincingly that such a worry is totally irrational.

VII. Prospects for the Global Adoption of Carbon Taxes

A natural policy response to the aforementioned concerns would be the imposition of an **international carbon tax**—levied and collected internationally—but such a tax is unlikely to be accepted as countries will be most reluctant to give up their sovereignty in respect of taxing powers to some international organization. Alternatively, an international agreement could be reached which would result in the **harmonized adoption of the carbon taxes** across countries. (The adoption of the value-added taxes in the member countries of the European Community offers the best example of how this may be done.)

Such an agreement would certainly mitigate the fear of loss of international competitiveness. The harmonized adoption of carbon taxes across countries, at agreed common rates, would have the advantage of imposing the same burden on similar industries in different countries. All firms would choose emission levels such that the marginal cost of abatement equates the tax rate. With a uniform tax rate, those marginal costs will be equalized among firms across countries and the global warming will be controlled at the least possible cost.

However, there are two difficulties that can be foreseen in reaching an international agreement on the adoption of harmonized carbon taxes across countries. The first relates to the distribution of costs of such a tax among countries. Even with equal marginal costs of abatement, total costs of reducing emissions would differ from country to country. Countries that would face higher costs in terms of their economic growth will then oppose the agreement unless they are compensated through some kind of side payments by other countries. The second relates to whether the new tax would be in addition to, or in place of, existing taxes and duties on fossil fuel products. Since existing taxes may have been established in the past to raise budgetary revenues or to correct domestic environmental externality, the carbon tax may well become an additional tax, aimed at solving the global warming problem. But, then, the rates of this tax would need to differ between countries, depending upon the country's "contribution" to the global warming problem (Hoel, 1993).

The best that can perhaps be expected is an international agreement under which countries of the world would agree to institute a more or less uniform carbon tax, perhaps at a relatively low rate to begin with, directed at solving the global warming problem. Whether or not the new tax would be added to or replace taxes that may already exist to achieve domestic revenue and other goals would be left up to countries concerned as would be the uses to which the revenues of the tax should be put.

VIII. Summary and Policy Conclusions

With the recent Kyoto meeting, a global agreement to reduce GHG emissions and to contain global warming has been already achieved. The adoption of carbon taxes is one, albeit an important, element of the package of measures that will help countries reach their agreed emission targets. It, therefore, warrants careful consideration by policymakers everywhere. Carbon taxes will not only contain global warming (even though one cannot, with certainty, estimate its exact magnitude or impact), but they will also serve as revenue raising instruments.

The main reason why carbon taxes should be seriously considered is that, as economic instruments, they reach environmental goals at least costs compared with command and control regulations. Furthermore, they have been shown to be both statically and dynamically efficient—they induce emitters to choose an efficient, cost minimizing, pattern of fossil fuel consumption, in the short run, while providing incentives for research and development in pollution abatement and energy efficient technologies, over the longer run.

While adopting carbon taxes, policymakers everywhere could well be concerned about their potential negative macroeconomic effects—productivity and economic growth, equity and income distribution, and international competitiveness. These fears, while legitimate, do not seem to be so overwhelming as to dissuade policymakers from reaching an international agreement. Each one of the potential negative consequences, as the paper has shown, can be mitigated through a carefully designed set of measures and an efficient recycling of the revenues. Measures can be adopted that can help ensure that the negative impact of the carbon tax on economic growth will be minimal, and even be positive. Carbon tax revenues can also help finance measures that can adequately compensate the poorer segments of the population and thereby reduce the regressivity of the tax.

The worry about the loss of international competitiveness is probably the one that is currently stopping a more widespread adoption of carbon taxes. However, as the studies reported in the paper show, it is not completely clear if environmental policies and the loss of international competitiveness are that closely linked. And, even if that were the case, an international agreement towards the simultaneous adoption of the tax can be designed in a way that can help alleviate this worry.

The road the world must travel to reduce global warming—by significantly curtailing and not further expanding the production of GHG emissions—is obviously a difficult one and policymakers everywhere will need to make serious concerted efforts, and undertake coordinated measures whenever necessary, to achieve the desired global goals and targets. The literature contains some helpful pointers to dealing with the perceived worries that carbon taxes seem to present for the policymakers and make them shirk from taking the first steps on the road to reducing global warming.

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Annotated Summary of More Recent Literature

The subject of climate change is generating an active interest amongst the policy makers around the globe and many analytical studies have been published on the potential effects of carbon taxes and other economic instruments. The best compilation of studies done before 1995 can be found in IPCC's Second Assessment Report. The following list provides brief summaries of a few of the more recent papers—it does not pretend to be an exhaustive survey by any means.

1. Fankhouser, S. and S. Kverndokk, 1996,. Resource and Energy Economics, Vol. 18, pp. 83-102.

Title: "The Global Warming Game – Simulations of a CO_2-reduction Agreement"
Objective: To analyze incentives for, and the benefit of, a possible cooperation to reduce CO_2 emissions.
Model: Simulation model where global warming is treated as an open access resource problem. The problem is analyzed through a static reciprocal externality game. CO_2 is emitted as a by-product of GNP—producing activities. Accumulation of CO_2 has negative global effects.
Results: The non-cooperative outcome differs from the social optimum. There are gains from cooperation. However, a socially optimal treaty can be achieved only with compensatory payments.

2. Hakonsen, L. and L. Mathiesen, 1997, *Environmental and Resource Economics*, Vol. 9, pp. 171-198.

Title: "CO_2-Stabilization May be a 'No-Regrets' Policy"
Objective: To analyze the cost of stabilizing CO_2 emissions at the 1990 level by year 2000, in the case of the Norwegian economy.
Model: Static CGE model. Labor supply is endogenized, CO_2 tax revenues are used to reduce a distortionary tax (employer's social security contributions). The negative externalities included are health problems, damage to buildings and reduction in transportation that reduces road maintenance and losses caused by congestion.
Results: A 20 percent CO_2 reduction yields a 1 percent gain in GDP.

3. Golombek, R., C. Hagem, and M. Hoel, 1995, *Resource and Energy Economics,* Vol. 17, pp. 25-46.

Title: "Efficient Incomplete International Climate Agreements"
Objective: To study the design of a carbon tax.
Model: Two group of countries. The first group acts cooperatively to maximize the sum of welfare for the group. Remaining countries (second group) act

independently and in pure self-interest. The scenario analyzed is one in which global emissions are to be reduced by a 15 percent.

Results: There is an 'optimal' combination of taxes concerning taxes on production and consumption of internationally traded fossil fuels. In such optimal tax structure, the sum of the consumer and producer taxes should be equal across fossil fuels. Also, the 'net' welfare effect is positive when carbon tax revenues finance reductions in existing taxes.

4. Williams, M., 1995, *Energy Economics,* Vol. 17, No. 4, pp. 319-327.

Title: "Global Warming and Carbon Taxation"

Objective: To determine the proper level of a global carbon tax.

Model: A physics-based model where CO_2 emissions are related to atmospheric concentrations, concentrations to temperature and temperature to economic damage. It is not an economic model.

Results: The optimal carbon tax is zero.

5. Smith, C., S. Hall, and N. Mabey, 1995, *Energy Economics,* Vol. 17, No. 2, pp. 133-146.

Title: "Econometrics Modelling of International Carbon Tax Regimes"

Objective: To compare the impacts of carbon and energy taxes on CO_2 emissions in eight OECD countries.

Model: An econometrics model of energy demand, integrated in an international macroeconomic model. The model uses sector equations and fuel consumption is a function of energy prices, GDP, a time trend and other determinants.

Results: A carbon tax would be more efficient in reducing emissions than an energy tax. There are wide differences in the levels of abatements. The United States and Canada would have the highest, Japan and Germany the lowest.

6. Bohringer, C. and T. Rutherford, 1997, *Journal on Environmental Economics and Management,* Vol. 32, pp. 189-203.

Title: "Carbon Taxes with Exemptions in an Open Economy: A General Equilibrium Analysis of the German Tax Initiative"

Objective: To analyze the welfare costs of exemptions in environmental policy, particularly carbon tax schemes that exempt energy and export-intensive industries.

Model: Static open general equilibrium model that includes labor taxes, capital taxes, value added taxes, and other indirect taxes. Analysis applied to the German economy.

Results: Exemptions are costly to society. A better alternative, as means to save jobs in specific industries, is a uniform carbon tax whose finance revenues sector-specific wage costs.

7. Welsch, H., 1995, *Resource and Energy Economics,* Vol. 17, pp. 213-237.

Title: "Incentives for Forty-Five Countries to Join Various Forms of Carbon Reduction Agreements"

Objective: To discuss different agreements to implement a 50 percent cut in overall emissions by 2050 compared to 1987 levels.

Model: Three agreements are considered. (1) An agreement with optimal quotas, (2) an agreement with fixed quotas, based on per-capita emissions rights, and (3) an agreement with flexible (tradable) quotas, also based on per-capita emissions rights. The framework used is static and the growth of carbon emissions is taken to be uniform for all countries. The data used is for the forty-five major carbon emitting countries.

Results: A flexible quota agreement is almost identical to the optimal quota agreement.

8. Fisher-Vanden, K.A., P.R. Shukla, J.A. Edmonds, S.H. Kim, and H.M. Pitcher, 1997, *Energy Economics, Vol.* 19, pp. 289-325.

Title: "Carbon Taxes and India"

Objective: To compare the costs of stabilizing emissions in India at different levels and under two alternative policy instruments: carbon taxes and tradable permits.

Model: Equilibrium model with explicit assumptions about demographics, energy resources, productivity change, international trade, and fiscal policy. Estimation of the tax impact on GDP and consumption, primary energy consumption, and energy resources. With respect to tradable permits, two allocations schemes are considered: grandfathering, and equal per-capita emissions allocation.

Results: Tradable permits represent a lower-cost method to stabilize Indian emissions than carbon taxes do.

9. Farzin, Y.H. and O. Tahvonen, 1996, *Oxford Economic Papers,* Vol. 48, pp. 515-536.

Title: "Global Carbon Cycle and the Optimal Time Path of a Carbon Tax"

Objective: To design an optimal carbon tax.

Model: Dynamic model that includes climatological behavior of carbon concentration in a economic model. Marginal extraction costs of fossil fuels rise when the resource stock is depleted.

Results: The optimal carbon tax may well be constant through time, increase monotonically or have a U-shape. It depends on the underlying assumption of how CO_2 is accumulated in the atmosphere.

10. Welsch, H., 1996, *Environmental and Resource Economics,* Vol. 8, pp. 141-155.

Title:	"Recycling of Carbon/Energy Taxes and the Labor Market"
Objective:	To provide a quantitative assessment of a cost shift from labor to energy by means of a carbon/energy tax.
Model:	General equilibrium model for the European Community. Goods of the same kind but different origin are incomplete substitutes, and within each region, the overall amount of each good is allocated to imports and domestic production.
Results:	The goals of CO_2-reduction and improved employment are complementary, provided the reduction in labor costs financed by the carbon/energy tax is not offset by increased wage claims.

11. Merethe Larsen, B. and R. Nesbakken, 1997, *Environmental and Resource Economics,* Vol. 9, pp. 275-290.

Title:	"Norwegian Emissions of CO_2 1987-1994"
Objective:	To evaluate the effects of the CO_2 tax Norway has had for five years.
Model:	Partial economic model for various sectors of the economy.
Results:	Compared to a no-tax scenario, emissions have reduced significatively with the tax.