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TAX POLICY TO COMBAT GLOBAL WARMING: ON DESIGNING A CARBON TAX

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ABSTRACT

This paper develops several points concerning the design and implementation of a carbon tax. First, if implemented without any offsetting changes in transfer programs, the carbon tax would be regressive. This regressivity could be offset with changes in either the direct tax system or transfers. Second, the production and consumption distortions associated with small carbon taxes, on the order of $5/ton of carbon, are relatively small: less than $1 billion per year for the United States. Stabilizing carbon dioxide emissions at their 1988 levels by the year 2000, however, would require a carbon tax ten to twenty times this size. It would more than triple the producer price of coal and nearly double the producer prices of petroleum and natural gas, would have much more significant private efficiency effects. Third, a central issue of carbon tax design is harmonization with other fiscal instruments designed to reduce greenhouse warming. Ensuring comparability between taxes rates on chlorofluorocarbons and fossil fuels is particularly important to avoid unnecessary distortions in production or consumption decisions.

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Mounting scientific evidence suggests that carbon dioxide emitted in fossil fuel combustion contributes to global warming. This has prompted discussion of carbon taxes, taxes levied in proportion to the carbon dioxide emissions which result from burning different fuels, in virtually all developed nations. Because each individual nation's contribution to global CO_2 emissions is relatively small, most advocates of the carbon tax call for coordinated multinational action. The long-run prospects for coordinated action appear dim, however. A tax large enough to significantly slow carbon dioxide emissions would collect revenues equal to several percent of world GDP, and it seems unlikely that national governments would cede control over such a pool of resources to any international body.

Most countries cannot noticably slow the rate of global greenhouse gas emissions. Nevertheless, Finland, Sweden and the Netherlands have taken unilateral action in adopting carbon taxes. Other nations may follow their lead in adopting national carbon taxes, with revenues accruing to the domestic treasury. Most previous discussions of the carbon tax, however, have been concerned only with plans for multilateral action. This paper addresses a number of tax design issues which are likely to emerge if the current trend toward unilateral carbon tax adoption continues.

The paper is divided into five sections. The first describes the basic structure of the carbon tax, focusing on the policies already in place in Europe as well as proposed taxes for the United States. Section two considers the distributional burden of carbon taxes across income groups. Household data for the United States suggest that the carbon tax falls most heavily on low-income groups. This regressivity could be ameliorated, however, in various ways. The third section examines the production and consumption distortions from a carbon tax, using a simple partial-equilibrium model of the energy market. These estimates do not correspond to the net efficiency cost of carbon taxes because they neglect the reduction in externalities associated with these taxes, but they indicate the cost which must be balanced against potential efficiency gains from the externality channel. Section four discusses the short- and long-run macroeconomic effects of adopting a carbon tax, using previous empirical studies of the relationship between tax rates and real output growth. A central issue in this regard is the disposition of carbon tax revenues. If the tax proceeds are used to reduce other taxes, the adverse output effects of the tax would be significantly smaller than if they are used to finance higher government outlays for climate research or other programs. The macroeconomic effects of a carbon tax are also likely to depend on the way monetary authorities respond to the new levy. Section five considers several design issues relating to carbon taxes, such as harmonization with other greenhouse taxes and the difficulty of taxing fossil fuel use in imported intermediate goods. There is a brief concluding section which discusses broader issues of policy design.

1. The Carbon Tax: Existing Legislation and Proposals

The carbon tax is a tax on carbon emissions generated by the combustion of fossil fuels. Of the three major fossil fuels, coal produces the most carbon per unit of energy, followed by oil and then natural gas. The carbon tax is a specific tax, i.e., a fixed absolute amount per ton of coal or barrel of oil. The tax is designed to internalize the externalities associated with fuel consumption, so it should not vary with shocks to fuel prices as an ad valorem tax would.

To provide a perspective on the potential of a carbon tax to affect greenhouse warming, Table 1 reports current gas emissions by nation. The entries are presented in terms of "equivalent tons of CO_2" using conversion factors developed by the World Resources Institute.[1] The table illustrates the importance of carbon dioxide in contributing to the global greenhouse. CO_2 from fossil fuel combustion currently accounts for 42% of net greenhouse emissions, and for 56% of the non-CFC emissions. This fraction is significant for long-range policy, since current regulations in developed nations promise to sharply reduce emissions of CFCs during the coming decades. Because carbon dioxide emissions are also expected to grow rapidly in the coming half century, CO_2 is even more important than the table suggests.

Table 1 also illustrates, however, that no single nation or group of nations is sufficiently important to significantly affect the rate of global carbon emissions. The United States, the largest carbon emitter, accounts for

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[1]Nordhaus (1990a) uses a different metric for converting different greenhouse gases into equivalent units than the estimates by the World Resources Institute (WRI) in Table 1. The Nordhaus approach suggests that total CO_2 emissions account for 69% of current greenhouse emissions, compared with 63% in the WRI tabulations.

just over twenty percent of world CO_2 emissions from fossil fuel consumption.[2] All of Europe accounts for an emission level comparable to that from the United States. Projected growth in energy utilization during the next century suggests that China will become an increasingly important source of carbon emissions as it uses its large coal deposits to spur industrialization.

Current Carbon Taxes

Despite the limited effect of any single nation's carbon tax on global warming, Sweden, Finland, and the Netherlands have already adopted such taxes. Flavin (1990) discusses a number of other proposals for action in Europe as well as particular states of the U.S. Part of the argument for unilateral action is presumably to provide a role-model for other nations. Table 2 shows the tax rates on coal, petroleum derivatives, and natural gas in each nation. The Swedish tax is levied at a rate of approximately \$62/ton of carbon, compared with approximately \$6.50/ton in Finland and \$1.50/ton in the Netherlands. The taxes in both Sweden and Finland are set at rates which reflect the marginal carbon emissions from each fuel. There are some divergences from this principle in the Dutch scheme, which places a higher relative tax on petroleum derivatives than the carbon criterion alone would suggest.

Carbon taxes are not the only excises on fossil fuels in any of the nations which have adopted them. In Finland, for example, the tax rate on gasoline and diesel fuel is higher than that required for "carbon-parity" with the coal tax as a result of the traffic-fuels tax. In Sweden, a pre-existing tax on all energy was cut in half when the carbon tax was enacted, but the

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[2]The other important source of carbon dioxide is deforestation, which is not significant in developed nations.

total tax rates on different energy sources still reflect the sum of the general energy tax and the carbon levy. The net taxes on different fuels are thus not dictated by their carbon contents alone; the analysis below suggests that they should not be.

Although the United States does not have a carbon tax, several proposals for such a tax are before Congress. For example, H.R. 4805, a bill introduced by Representative Pete Stark, calls for a tax of $15.00/ton on coal, $3.25/ barrel on oil, and $.40/MCF on natural gas. These tax rates are well below those which a recent study by the Congressional Budget Office (1990) suggested would stabilize carbon dioxide emissions at their 1988 level by the year 2000.

Table 3 provides descriptive information on the policy analyzed by the Congressional Budget Office, a $100/ton carbon tax, as well as a more modest tax of $5/ton which would be roughly equivalent to the tax per unit of greenhouse gas activity embodies in U.S. taxes on chlorofluorocarbons. The table reports the specific tax rates which each carbon tax would levy on coal, oil, and natural gas, and also shows the percentage change in fossil fuel prices as a share of the well-head or mine-mouth price. The CO_2 stabilization tax would raise coal prices to roughly four times their current level. Natural gas prices would nearly double, and oil prices would increase over 60%. The price changes are proportionately smaller under the more modest carbon tax plan.

The carbon tax applies only to fossil fuels. In this way it differs from an across-the-board energy tax, for example a BTU tax, since it both encourages energy conservation while also encouraging substitution toward energy sources such as hydro-power or nuclear power which do not emit carbon dioxide. It also differs from targetted excises such as a gasoline tax in taxing all combustion of fossil fuels, rather than those in particular industries or applications. Levying higher taxes on only some segments of fossil fuel use requires higher tax rates on the taxed sectors to achieve a given reduction i emissions, and also introduces distortions across uses. There is little reason to introduce these distortions if the ultimate aim of policy is reducing the level of greenhouse emissions at least cost.

The Revenue Potential of Carbon Taxes

Carbon taxes have the potential to generate substantial revenues for most developed countries. Table 4 illustrates this, showing total consumption of each of the three fossil fuels as well as carbon tax revenues from a $100/ton carbon tax. The ratio of revenues to GNP is highest in the U.S., the most fossil-fuel-intensive nation. A $100/ton carbon tax would raise revenues of more than three percent of GNP. By comparison, the same tax would raise only 1.2% of GNP if instituted in Japan. This reflects the greater energy efficiency of the Japanese economy.

A central issue in carbon tax design involves who receives the revenue. As Schelling (1990) aptly observes, no industrialized nation is likely to surrender control over revenues equal one thirtieth (or even one hundredth) c GNP to an international organization. Proposals for a global carbon tax are therefore face a dilemma. If the tax rate is high enough to significantly reduce emissions, few if any countries will allow an international agency to collect the taxes. If the tax rate is low enough to make an international agency operational, however, it is unlikely to discourage significant amounts of fossil fuel combustion. The next several sections therefore concentrate c unilateral domestic carbon taxes.

2. Distributional Incidence of Carbon Taxes

One of the central objections to adopting carbon taxes in developed nations is the perceived regressivity of excise taxes, of which carbon taxes are an example. Claims of excise tax regressivity typically rely on annual surveys of consumer income and expenditures which show that energy expenditures are a larger fraction of income for very low income households than for middle or high-income households. A household's annual income may be an unreliable indicator of its actual well-being, however. The essence of the life-cycle and and permanent-income theories of consumption is that household income may vary from year to year, for both predictable and stochastic reasons, but that consumption is set on the basis of long-run income. These theories imply that a household's total expenditures may be a more reliable indicator of economic well-being than the same household's annual income.[3]

This section uses data from the United States' Consumer Expenditure Survey to assess the claim that carbon taxes are regressive, measuring household well-being on the basis of both annual income and consumption outlays. The results support the view that a carbon tax is regressive, but the findings based on the expenditure measure of incidence are less dramatic than those based on income rankings. They nevertheless suggest that if a carbon tax were adopted without any offsetting changes in other tax or transfer programs, the burden would fall more heavily on low-income than well-off households.

Energy Expenditure Patterns

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[3]This point is developed in more detail by Davies, St.-Hilaire, and Whalley (1984), Kasten and Sammartino (1988), and Poterba (1989).

The 1985 Consumer Expenditure Survey is a stratified national sample of approximately two thousand households.[4] To illustrate patterns of energy expenditures across the distribution of household well-being, households are grouped into deciles based either on their income in the previous quarter, or their total expenditures in the current quarter. Table 5 shows the average expenditure patterns for households in each of these categories, focusing on outlays for heating oil, gasoline, electricity, and natural gas. There are some omitted energy outlays, such as direct household outlays for coal and wood, but these are a small fraction of the outlays shown in the table.

Since energy is a necessity, it is not surprising that the share of incom which low-income households devote to heating fuel, electricity, and gasoline is significantly higher than that of better-off households. The upper panel in Table 5 classifies households by income, and reports energy expenditures a: a share of income. For the lowest income decile, which spends substantially more than its income, both gasoline and electricity outlays exceed ten percen of income. Because many households in the bottom income strata may be experiencing transitory income reductions, however, a more reliable picture o the distribution of energy outlays emerges from focusing on the second and third income deciles versus the top deciles. These data suggest a clear pattern of larger outlays as a share of income at lower rather than higher income levels. Total energy outlays for households at the 25th percentile of the income distribution are approximately 16% of income, compared with only 7 for households at the 75th percentile of the distribution.

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[4]Poterba (1990) describes the data sample in more detail, and uses a similar approach to study the distributional burden of higher gasoline taxes in the United States.

The lower panel in Table 5 presents comparable data with households grouped into deciles according to total expenditures. The results are significantly different from those based on the income ranking, and indicate the potential importance of choosing among the alternative approaches to measuring distributional incidence. The disparity between the shares of income devoted to various energy sources at low and high incomes is much larger than the variation in expenditure shares between low- and high-expenditure households. For example, a household in the second expenditure decile devotes approximately twelve percent of total outlays to energy items, compared with just under ten percent for a household in the ninth expenditure decile. The ratio of income shares devoted to energy for households in the second and ninth income deciles, by comparison, is more than two-to-one.

The expenditure ranking is likely to provide a better perspective on the distributional burden of energy outlays and associated taxes for two reasons. First, some households experience transitory shocks to income — unemployment or illness, for example — and their expenditures will reflect long-run economic circumstances rather than transitory conditions. Second, lifecycle variation in the outlay-income ratio, for example periods of low income relative to expenditure during retirement, can make current income a misleading guide to economic well-being. The data in Table 5 thus suggest that energy outlays are higher among less well-off households, but not by as much as typical incidence measures might suggest.

Carbon Tax Burdens

The data in Table 5 on energy expenditure patterns are a critical input in analyzing the distributional burden of the carbon tax. The analysis which follows considers a specific proposal: a $100/ton carbon tax instituted in 1990.[5] This avoids the problem of forecasting energy producer prices in future years, and also corresponds better to the available data on expenditure patterns. The analysis also assumes that the United States imposes a unilateral carbon tax, so that producer prices of each fossil fuel are unaffected; there is complete forward-shifting of the carbon tax.

These assumptions translate into substantial increases in the retail prices of fossil fuels. Based on projected retail energy prices in 2000, as reported in the Annual Energy Outlook, the retail prices of fuel oil and gasoline would rise by 27% and 25% respectively, the retail price of natural gas by 23%, and the retail price of coal by 114%. The other important component of the incidence calculation is the change in electricity prices. Although coal accounts for 57% of the electrical generating capacity in the United States, compared with 5.5% for oil and 9.4% for natural gas, coal costs are only 17.1% of the total for U.S. electrical generation.[6] Petroleum accounts for 4.4% of total costs, and natural gas for another 8.7%. These fractions have shifted significantly during the last fifteen years as U.S.

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[5]Given concerns about the macroeconomic effects of instituting a carbon tax, it is unlikely that such a plan would be instituted without a significant phase-in period. The distributional results presented here, however, are likely to provide some evidence on the long-run effects of such plans.

[6]These estimates of fuel shares of total kilowatt-hours generated are drawn from the Energy Information Administration, Annual Energy Review 1988. The data on the various fuels' shares of costs are based on data in the Edison Electric Institute 1984 Statistical Yearbook.

electric utilities have converted from oil to coal to reduce the nation's oil imports. Following the Annual Energy Outlook (1990) assumptions regarding the difference between the retail prices of fossil fuels and those faced by utilities, the retail price of electricity is estimated to rise by 36% as a result of a $100/ton carbon tax.

Estimated changes in retail prices can be combined with the data on energy expenditure patterns in Table 5 to estimate the distributional burden of the carbon tax. Results of this exercise are shown in Table 6, which reports both the absolute dollar cost and the extra outlays as a share of income and total expenditures for various income and outlay deciles. The tabulations suggest that carbon taxes are regressive, regardless of whether income or expenditures are used as the basis for ranking households. For households in the bottom three income deciles, for example, a $100/ton carbon tax would pose an average burden of more than five percent of annual income. For households in the top two income deciles, the estimated burden is less than two percent. The disparities in the estimated burdens are smaller when expenditure rather than income is used to rank households, but these differences are still substantial. Households in the bottom three expenditure deciles would face burdens which averaged 3.7% of their total expenditures, while the burdens for those in the top three deciles would average 2.6% of total outlays. The relative burden declines smoothly as one moves up the expenditure distribution.[7] Although these calculations relate to the $100/ton carbon tax, the general distributional pattern would apply to any carbon tax. A

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[7]Johnson, McKay, and Smith (1990) present similar calculations for the United Kingdom, showing somewhat greater regressivity of energy taxes even using the expenditure incidence basis.

$5/ton tax, for example, would impose costs of roughly 1/20th those reported in Table 6.

These findings do not completely describe the distributional incidence of carbon taxes, for many reasons. First, they ignore the general equilibrium effects of higher fossil fuel prices. The prices of steel, aluminum, autos, and other energy-intensive commodities would rise in response to a carbon tax. While the magnitude of these price changes will be smaller than the first-order effects analyzed here, they should be addressed in future work. Second, the analysis ignores asset market effects. Even if the world price of fossil fuels stays fixed, the returns to intermediaries, such as oil refiners and distributors, would fall. If this reduced the value of equities in oil companies, it would appear as an additional burden falling primarily on those in the higher income and expenditure categories. Finally, the analysis neglects the macroeconomic effects which might follow from enactment of a carbon tax. If households at different points in the income or expenditure distribution face different exposures to unemployment, then slower growth would burden households differentially.

Policies to Offset Regressivity

The carbon tax would be regressive if it were instituted as a stand-alone policy. However, this is not an especially plausible scenario. The recent history of tax policy in most industrial nations suggests strong political resistance to imposing higher taxes which particuarly burden the poor. A central issue is therefore likely to involve designing schemes to neutralize the distributional effects of the carbon tax.

Several policies would reduce the burdens on low-income and low-expenditure households. First, many transfer programs are already indexed for price changes. Since the carbon tax will be paid by consumers in the form of higher retail prices, indexed components of income will partly adjust to offset the tax burdens. In the United States, for example, two thirds of the income received by households in the lowest expenditure decile is indexed, reflecting the importance of elderly families who receive Social Security as well as other transfer recipients in this group.[8]

Indexed income is not a complete antidote to carbon tax regressivity. Not all low income households are transfer recipients, and even for those who are, the data in Table 5 show that their expenditure patterns place more weight than average on energy outlays. Thus transfer adjustments based on average budgets will under-compensate low-income or low-expenditure households for their higher energy prices.

A second approach to ameliorating the distributional burdens of the carbon tax is increased use of redistributive income taxes. In the United States, for example, the EITC (Earned Income Tax Credit) provides a natural device for reducing the tax burdens on those low-income households who receive labor income rather than transfers. Changing the level of personal allowances in the tax code would provide another way to redistribute toward low-income and low-expenditure households, although with different incentive effects.

Still a third approach to reducing regressivity would be an explicit policy of tax credits for energy expenditures. Allowing each household a tax

[8]Such indexed transfers are also important for households in the second expenditure decile, where they constitute 46% of income, but decline at higher expenditure levels.

credit equal to the first one or two percent of income devoted to purchasing energy would enable the tax authorities to alter the average price of energy, hence blunting the carbon tax' redistributive effects, while preserving the marginal price effects of the tax.

None of the redistributive schemes described above will completely offset the distributional impact of a carbon tax. If transfers are increased, households who do not receive transfers will still be worse off. If tax credits are used, households with incomes below the tax-filing threshold will not be compensated. Yet the distributional effects of the carbon tax do not appear insuperable. A combination of income tax and transfer policies could be used to neutralize the tax reform for most households.

3. Production and Consumption Distortions from a Carbon Tax

A carbon tax would affect the behavior of firms and consumers. By raising the price of fossil fuels relative to other energy sources, and by changing the relative prices of different fossil fuels, the tax would induce both inter-fuel substitution and lower energy consumption. Although these changes may on balance be beneficial because of their long-run effects on global climate, they nevertheless represent production and consumption distortions relative to the no-tax scenario. The costs associated with these distortions must be balanced against the benefits from lower risk of global warming. This section presents simple estimates of these costs.

Partial Equilibrium Tax Analysis

The standard approximation for the deadweight loss from a commodity tax when there are no external effects associated with consumption of the good is

DWL = dQ*dq/2, where Q is the quantity and q is the consumer price of the good. The derivatives represent the effects of a small tax imposed with no pre-existing taxes, anad the analysis takes prices in all other markets as given and fixes producer prices in the market being analyzed. When only one price is affected by a specific tax, a convenient expression for this efficiency cost is

(1) $$DWL = \eta_D*(\tau/p)^2*(pQ)/2.$$

In this expression, η_D is the compensated elasticity of product demand, τ is the specific tax rate, and p is the (fixed) producer price.

When several prices change, however, as they do in the case of a carbon tax which alters the prices of coal, oil, and natural gas, the analysis must recognize both own- and cross-price effects. This is particularly important in the current context, where changes in the prices of all three fossil fuels will lead to smaller changes in the demand for each fuel than would changes in each market in isolation. In this case, the cost of production and consumption distortions is given by

(2) $$DWL'_i = [\Sigma\epsilon_{ij}(\tau_j/p_j)]*Q_i p_i*(\tau_i/p_i)/2.$$

The bracketed expression represents the proportional change in the quantity of good i demanded as a result of tax changes in each of the j markets.[9]

These results involve a first-order approximation which applies to small taxes introduced around the no-tax equilibrium. Coordinated international action with respect to carbon taxes would inevitably alter producer prices for fossil fuels. For unilateral policies, however, it is more natural to treat

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[9]The analysis assumes no pre-existing taxes in any markets, which is not quite accurate for the fossil fuel markets in many developed nations. The problem of pre-existing taxes will be addressed in the next draft.

the world fossil fuel price as fixed. The partial equilibrium framework may be suitable for this problem, even though for larger taxes it is necessary to use computable general-equilibrium models.[10]

Demand elasticities are the central parameters needed to estimate the deadweight burden of carbon taxes. There is a voluminous previous literature devoted on the estimation of energy demand; Bohi (1981) surveys this field. Energy demand elasticities are very sensitive to the horizon being analyzed; short run elasticities are far smaller than long-run values. With respect to gasoline, for example, Pindyck (1979) reports a first-year demand elasticity of -.11, rising to -.49 at a five year horizon and -.82 at ten years. The dramatic differences are due to the variety of margins on which consumers can optimize. In the first year after a price shock, most of the response takes the form of reduced driving, while over longer runs, there is a change in fuel efficiency of the auto fleet which exerts much more important effects on gasoline demand. Similarly, in industry, the short-run response to energy price changes will involve changes in the scale of operations; in the longer run, capital equipment may be modified or replaced to optimally adapt to the new price regime.

Table 7 presents benchmark own-price demand elasticities for coal, oil, and natural gas for use in deadweight loss calculations. These reflect concensus estimates as reported by Anderson, Hofmann, and Rusin (1990). They are within the range of long-run elasticities reported by Bohi (1981), although they are lower than some of the final-demand energy elasticities he

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[10]A general equilibrium analysis of a world carbon tax, recognizing the effects on producing countries and also the changes in world fossil fuel prices, is presented in Whalley and Wigle (1990).

reports. For evaluating the carbon tax, however, the elasticities of interest are those for coal, crude oil, or natural gas demand with respect to the mine-mouth or well-head price. The comparison of these values with retail gasoline price elasticities, for example, is therefore inappropriate. Nevertheless, it is important to understand that low elasticity estimates imply small dead-weight losses; the efficiency cost is proportional to the elasticity. Thus, it is straightforward to evaluate the sensitivity of the results to, for example, a doubling of each own-price elasticity.[11] The table also shows significant cross-price elasticities for the various fossil fuels.

Estimating Production and Consumption Distortions

The local approximation approach described above is unsuitable for analyzing the effects of large tax changes such as the \$100/ton CO_2 stabilization tax for the United States discussed above. This tax would raise coal prices by 263%, and oil and gas prices by between 70 and 100%. This approach can, however, be used to analyze smaller tax changes, such as the \$5/ton carbon tax which has been suggested by Nordhaus (1990b).[12]

The results of this calculation, which are presented in Table 7, suggest that distortionary costs are not a critical consideration in evaluating low-

[11]The sensitivity of the estimated deadweight losses to changes in the demand elasticites may be more complex than this suggests. If the policy being analyzed is simply a given specific tax on carbon content, then lower elasticities will translate into lower deadweight burdens. If the policy is a requirement for a given percentage reduction in carbon emissions, however, lower elasticities will in turn require higher tax rates; this effect will raise the deadweight burden.

[12]The preliminary results in Table 7 assume away any pre-existing taxes on fossil fuel use. For petroleum, the presence of gasoline taxes in most developed nations makes this assumption suspect. Recognizing these pre-existing taxes would raise the estimated deadweight burdens on oil.

rate carbon taxes. The total production and consumption distortion in the three markets is less than $300 billion, measured in 1989 dollars, or less than one one-hundredth of one percent of GNP. At least for policies like the "precautionary" carbon tax, the efficiency loss from the tax would be small.[13] This analysis awaits further confirmation using general equilibrium modelling tools.

4. Macroeconomic Effects of Carbon Taxes

The efficiency costs isolated above correspond to the distortions in firm and household behavior in an economy with otherwise perfect markets. In such a setting, these would be the only effects of enacting a carbon tax. Prices of many goods would adjust to the tax, but this would not generate any macroeconomic effects. In practice, both nominal wages and nominal prices are costly to adjust, and excise tax shocks can have real effects. A number of recent studies[14] indicate that adopting the sort of carbon tax considered above would reduce U.S. real GNP by between one and three percent.

There are two channels through which a carbon tax could have such effects. First, a $100/ton carbon tax adopted without any offsetting policies would substantially reduce the federal deficit. Estimates for the United States suggest that such a tax would collect revenues of more than 3% of GNP. This would represent a radical shift toward contractionary fiscal policy. While

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[13]These estimated deadweight burdens compare favorably with those from other revenue sources; see for example Ballard, Fullerton, Shoven, and Whalley (1985).

[14]Studies which simulate the long-run effects of a carbon tax on economic activity include Manne and Richels (1989), Hogan and Jorgenson (1989), and the Congressional Budget Office (1990).

deficit reduction might convey long-run benefits, in the short run there might be adverse macroeconomic effects. These might result from the higher overall tax rates, direct and indirect, associated with such a policy; this could discourage labor supply, for example.

A carbon tax need not raise revenue, however. It could be combined with other fiscal reforms to ensure revenue neutrality. In European countries which rely on indirect taxes for significant revenue shares, a natural policy would involve reducing the VAT or other excise tax rates when the carbon tax is introduced. For the United States, it would be possible to reduce income taxes to offset carbon tax revenues. The critical simulation is thus a revenue neutral increase in carbon taxes, and this is not usually reported in the prior literature.

The second channel through which a carbon tax could affect real output involves the sluggish adjustment of wages and prices in response to higher taxes. The importance of these effects depends critically on how monetary policy responds to the tax policy shock. To illustrate this effect, consider enactment of a carbon tax with an offsetting reduction in labor income taxes.[15] The household's after-tax real wage is given by $w(1-\beta)/p(1+\theta)$, where β is the labor income tax rate and θ is the total indirect tax rate. The real wage facing firms is w/p, where w is the nominal wage paid by the firm and p is the producer price level. The revenue neutrality of the tax policy should keep $(1-\beta)/(1+\theta)$ approximately constant, so the producer real wage which was an equilibrium before the tax shock will also be an equilibrium after it.

[15] This analysis draws heavily on the more general discussion in Poterba, Rotemberg, and Summers (1986).

In the money market, the real supply of money $M/[p(1+\theta)]$ equals the demand which in turn depends on real output. If output were unaffected by the tax change <u>and the money supply were also fixed</u>, then an increase in θ would require a reduction in producer prices (p). If prices were fully flexible, higher indirect taxes would lead to an immediate and equiproportionate fall in producer prices and wages, and there would be no effects on real activity. If nominal wages are slow to adjust, however, then the fall in producer prices following the tax change will raise the real wage facing firms. This will reduce labor demand and lower real output.

This scenario need not occur, however. If the monetary authority increases the supply of money to accomodate the tax increase, then the initial level of w and p will continue to be an equilibrium; the only difference is that the price <u>level</u> will be higher after the indirect tax increase than before. The extent to which a revenue-neutral shift to indirect taxes such as the carbon tax raises prices, and the extent to which it reduces output, therefore depends on the monetary response to the fiscal change.

The importance of price rigidities, and hence the magnitude of the foregone output associated with adoption of a carbon tax, is controversial. The empirical evidence presented in Poterba, Rotemberg, and Summers (1986) suggested that a three percent of GNP shift from direct to indirect taxation would reduce real GNP by .6 percent in the quarter when the tax change took effect. The lost output in the first three years after the tax policy takes effect is nearly three percent of one year's GNP.

One important feature of this analysis, which relies on price rigidities, is that in the long run a revenue-neutral shift to higher energy taxes would not affect real activity. This view is inconsistent with the finding of some recent studies which suggest that higher energy prices would adversely affect long-run productivity growth rates and therefore have progressively larger adverse effects on economic performance. If the growth slowdown coincident with, and following, the 1973 oil price shock is attributed to higher energy prices, taxes which raised energy prices would be predicted to have similar effects in the future. Whether the productivity slowdown of the 1970s was caused by the oil price shock, or actually began well before the price increase, is an open issue with obvious implications for policy analysts concerned with global warming.

5. Implementing Carbon Taxes

This section addresses four issues which arise in implementing carbon taxes: the choice of carbon taxes in the presence of other externalities, the control of cross-border energy flows, the subsidization of processes which withdraw carbon from the atmosphere, and the harmonization of the carbon tax and other taxes which affect greenhouse emissions. Each of these issues is considered in turn.

The Greenhouse and Other Externalities

While excise tax rates on fossil fules which are proportional to their CO_2 output may be appropriate to correct greenhouse externalities, they are not necessarily the optimal tax rates on the different fossil fuels. Standard results on optimal taxation in the presence of externalities, for example Sandmo (1975), recognize that optimal tax rates in the presence of externalities depend on three factors: (i) the net externalities associated with a good's consumption; (ii) the distribution of a good's consumption across households with different marginal social welfare weights; and (if there is a positive revenue requirement) (iii) the compensated elasticities of demand for the taxed good, and other goods, with respect to the price of the taxed commodity.

A detailed calculation of "the" optimal tax rates on various fossil fuels is beyond this paper, but it is possible to sketch how other considerations might affect optimal taxes. First, with respect to other externalities, coal is a more substantial contributor to other types of air pollution (sulfur dioxides and particulates, for example) than either oil or natural gas. Estimates of the externality costs of these emissions vary. In the case of sulfur emissions, however, Bernow and Marron (1990) suggest a value of \$1500/ton of SO_x. For the United States, average SO_x emissions per ton of coal burned by electric utilities are approximately 42.2 pounds[16], suggesting an externality cost of \$32. Similar calculations could be performed for other pollutants and other fuel sources to find the total externality-correcting taxes which are needed.

Second, distributional considerations do not yield particularly strong guidance in setting the relative tax rates on the different fossil fuels. Table 5 suggested that electricity outlays are skewed more toward low-income households than are expenditures for other types of fossil fuels. Since coal is important for electricity generation but not for direct energy purchases, this would suggest <u>ceteris paribus</u> that tax rates on coal should be lower. One issue which might warrant attention concerns the burden of reduced coal output. Coal miners bear the brunt of such changes, and previous policy

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[16]This is based on data in Joint Committee on Taxation (1987).

debates have explicitly considered compensation plans to avoid these effects (see Congressional Budget Office (1987)).

Carbon Taxes and Border Controls

One of the major administrative concerns with a unilateral carbon tax concerns imports. The appropriate taxes on domestic fossil fuel production are relatively straightforward to enforce, as are the taxes on imports of coal, natural gas, and petroleum derivates. More difficult assessment problems arise with respect to imports of intermediate or final goods which have been produced using fossil fuels. Unilateral carbon tax policies which do not effectively tax such commodities could be unattractive both because they create production inefficiencies, distorting production of these intermediate goods away from domestic locations, and because the opportunities for offshore production reduce the revenue potential of the tax.

Table 8 presents evidence directed at the potential importance of this problem. The table synthesizes information from the 1985 input-output table of the U.S. economy developed by the Office of Technology Assessment (1990). The first column shows direct U.S. consumption of oil, coal, and natural gas.[17] This is the total of fossil fuel use in either production or household activities for the year in question. Column two shows energy imports. This component of imported fossil fuel would be relatively easy to tax. The third column shows the amount of fossil fuel embodied in non-fossil-fuel U.S. imports. These estimates were made using the 1985 input output table, which

[17] The table shows refined petroleum only, since the input-output table treats crude as an input to refined petroleum and the refined petroleum as the input to all other activities.

shows the total inputs of coal, oil, and natural gas to each of 85 categories of goods. Combining these data with information on the value of imports in each category, and assuming that the energy use coefficients for foreign production are the same as those in the United States, yields estimates of the amount of each fossil fuel which was used in producing imported goods.

Two conclusions emerge from this table. First, the embodied energy imports are not trivial. The estimate in the third column equals approximately one eighth of total coal consumption, one tenth of natural gas use, and one twentieth of refined petroleum use. Closer inspection of the goods which account for embodied energy imports, however, shows that relatively few imports — steel, autos, and chemicals are the three most important — account for a very large share of the embodied fossil fuels. It would not seem particularly difficult to levy import duties on these goods in proportion to their estimated carbon emissions.[18]

Taxing Emissions vs. Subsidizing Carbon Sequestering

The carbon tax raises the cost of adding carbon dioxide to the atmosphere. It does not, however, provide similar incentives for all methods of altering the global carbon balance. A notable omission is that a carbon tax does not reward activities which remove carbon from the atmosphere; tree-planting is an obvious example of such a carbon sequestering policy. Just as advocates of tradable permits in more standard pollution contexts have long argued for equating the marginal costs of each alternative method of changing the ambient

[18]This is the approach adopted under current U.S. law with the excise tax on CFCs. The Treasury is empowered to estimate the CFC content of imported goods, and, in cases where this estimate is impossible, can levy of tax of up to five percent on imports. See Joint Committee on Taxation (1990).

level of various pollutants, there is an argument for subsidizing projects which reduce the level of global carbon.

A number of administrative issues make the implentation of carbon sequestering subsidies difficult, however. The net private cost of some sequestering activities, for example tree-planting, is small relative to the potential public subsidy. If the subsidy assumes that trees live for many years and draw CO_2 from the atmosphere over their lifetime, tax cheats could plant trees, collect their subsidy, destroy the trees, and collect another subsidy. There are of course ways to minimize these problems: subsidies could be tied to the land on which the trees are planted, limiting each property to no more than one subsidy each fifteen or twenty years. Alternatively, the subsidy could be provided incrementally in each year the trees are alive.

A workable system of subsidies for carbon sequestering might be devised, but it would require a higher degree of administrative organization than a carbon tax. Rather than burdening a relatively simple carbon tax plan with the complexities associated with policing carbon sequestering, policy in this area might begin with a relatively small carbon tax and then address issues of carobn sequestering at a later date.

Carbon Taxes vs. CFC Taxes

The carbon tax is not the only fiscal instrument which affects the emission of greenhouse gases. A number of nations have already adopted limits or taxes on CFC emissions; they are currently taxed in the United States according to a sliding rate scale which is shown in Table 9. One policy design issue which can readily be addressed involves setting appropriate relative tax rates on CFCs and fossil fuels. This requires data the relative contribution of the various gases (per unit emitted) to greenhouse warming; in turn, this requires information on the time profile of greenhouse effects for the various gases, as well as the social time preference rate. Nordhaus (1990a) explores the links between the relative greenhouse effects of different emissions, and finds that with a social discount rate of one percent per year, one pound of CFC-11/12 has the same ultimate greenhouse effect as 1.184 tons of carbon emitted as CO_2 (4.34 tons of CO_2).[19]

If the only justification for taxing both carbon emissions and CFCs is to avoid long-run global warming, then the tax rates on the two gases should be set in proportion to their greenhouse effects. The second column of Table 9 shows the carbon taxes associated with current U.S. CFC tax levels. If a carbon tax were adopted, some attempt to bring the rates of CFC and carbon taxation into rough agreement would clearly be useful.

Other Issues

There are many questions concerning carbon tax design and implementation, such as the phase-in rules which would be adopted, the treatment of exports (can firms claim rebates for fossil fuels used in exported products?), and the procedures for handling claims that some firms or households use fossil fuels in ways which reduce CO_2 emissions relative to standard estimates. These and other issues would need to be addressed if a carbon tax were enacted. Relative to many other fiscal instruments, however, the carbon tax seems straightforward to specify and enforce.

[19]If the discount rate were zero, then one pound of CFC-11/12 is the equivalent of .79 tons of carbon from CO_2; with a discount rate of four percent per year, the equivalence factor is 1.42.

6. Conclusions: General Principles to Guide Policy

This paper has analyzed a variety of issues associated with the design and implementation of a carbon tax. Several findings emerge. First, if implemented without any offsetting changes in transfer programs, the carbon tax would be regressive. There are many ways to reduce this regressivity, for example with offsetting changes in either the direct tax system or transfers. Second, the efficiency costs of small carbon taxes, for example a tax of $5/ton of carbon, are relatively small. For the United States, immediate implementation of such a tax would impose annual efficiency costs of less than $1 billion. Although some analyses have called for taxes at this level until further information on global warming becomes available, other proposals suggest far higher taxes. Stabilizing U.S. carbon dioxide emissions at their 1988 levels by the year 2000, for example, would require a carbon tax of close to $100 per ton. This tax, which would more than triple the producer price of coal and nearly double the producer prices of petroleum and natural gas, would have much more significant efficiency effects. Implementing such a policy might also affect the level of real output unless the monetary authority fully compensated for the tax by raising the money supply. Third, a central issue of carbon tax design is harmonization with other fiscal instruments designed to reduce greenhouse warming. Ensuring comparability between taxes rates on chlorofluorocarbons and fossil fuels is particularly important to avoid unnecessary distortions in production and consumption decisions.

Although the paper concentrates on rather narrow issues involving carbon taxes, several broader issues of policy design should also be recognized. First, concerted international action in adopting carbon taxes would avoid some of the administrative difficulties, and distortionary effects, of unilateral carbon tax adoption. If all nations participate in a carbon tax treaty, the tax can be implemented by taxing all fossil fuel production at mine-mouth or well-head. If a single country adopts the tax, however, it becomes necessary to tax both imported fossil fuels as well as other products which may embody fossil fuels. The multilateral approach, while solving this problem, raises additional questions concerning compensation and the appropriate distribution of revenues across nations.

Second, the current uncertainties regarding the future course of the global environment suggest the need for policy flexibility. It is important to avoid substantial efficiency costs or output losses today in pursuit of uncertain future benefits.[20] Because much new information is likely to accumulate in the next decades both on the scientific basis of the greenhouse effect and on the economic costs of countermeasures, current policy should avoid irreversible decisions. Losses in real output from high current taxes are irreversible. There is relatively little doubt that sharp increases in energy prices from a carbon tax large enough to stabilize CO_2 emissions near current levels would have significant adverse effects on real GNP. A strong case for the benefits of such a tax burden is therefore needed to outweigh these costs.

Third, it is important to recognize that economic policy toward reducing greenhouse emissions is part of a broader fabric of fiscal policy to encourage economic growth, promote equitable distribution, and internalize external effects. Some of these concerns operate directly with respect to the appropriate levies on fossil fuels, and optimal tax rates on these fuels should

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[20]This point has been made in many previous analyses of policy response to global warming; examples are Lave (1988) and Nordhaus (1990b).

not be determined solely by reference to carbon emission levels. The current concern with greenhouse emissions may, however, provide a long-needed stimulus for attempting to calibrate and implement these tax policies.

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Table 1: Regional and National Contributions to Greenhouse Warming

Country	CO_2 Emissions Fossil Fuel	Land Use	Total	Methane Emissions	CFC Emissions	Tot
Europe	.520	—	.520	.085	.480	1.1
United States	.530	.026	.533	.130	.350	1.0
USSR	.450	—	.450	.060	.180	0.6
Brazil	.023	.540	.563	.028	.016	0.6
China	.260	—	.260	.090	.032	0.3
World	2.500	1.200	3.700	.800	1.400	5.9

Source: World Resources Institute, World Resources: 1990-91, Table 24.2. Each entry reports CO_2 equivalent emissions from different sources. Note th fossil fuel column includes CO_2 emissions from cement production.

Table 2: Carbon Taxes Rates ($US), Sweden and the Netherlands, 1990

	Sweden	Netherlands	Finland
Gasoline & Diesel Fuel	$16.03/bbl.	$2.73/bbl.	$11.51/bbl.
Coal	97.69/ton	1.49/ton	3.89/ton
LPG	118.17/ton	1.94/ton	?
Natural Gas	$2.63/10^3$ cu.ft.	$0.029/10^3$ cu.ft.	$.08/10^3$ cu.ft.
Effective Date	1/1991	2/1990	1/1990

Notes: Calculations for Sweden assume an exchange rate of 5.75 SEK/dollar, while those for the Netherlands assume 1.75 guilders/dollar.

Table 3: Proposed CO_2 Stablization and Reduction Taxes, United States

	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
Average Mine-Mouth or Wellhead Price, 1989	$23.02	$17.70	$1.78
<u>CO_2 Stabilization Tax ($100/ton):</u>			
Absolute Tax	60.50	12.99	1.63
Percentage of Price	263%	73%	92%
<u>Slower CO_2 Growth Tax ($5/ton):</u>			
Absolute Tax	3.17	0.65	0.08
Percentage of Price	13%	4%	5%

Notes: Data for row three are drawn from Manne and Richels (1989), for row four from the Department of Energy, <u>Annual Energy Outlook</u> 1990, and for rows two and five from the Congressional Budget Office (1990). Rows six and seven are based on author's calculations.

Table 4: Fossil Fuel Consumption and Revenues from $100/Ton Carbon Tax

	Fossil Fuel Consumption			Carbon Tax Revenues	
Country	Coal (M tons)	Petroleum (M bbls)	Natural Gas (B cu.ft.)	Level ($88 B)	Percent of GNP
OECD Europe	609	4511	8812	$109.8	1.99%
France	32	656	1007	12.1	1.28
W. Germany	211	884	2075	27.7	2.30
Italy	25	660	1283	12.1	1.47
U.K.	124	613	1990	18.8	2.31
Canada	60	584	2353	15.1	3.12
United States	883	6308	17933	164.6	3.42
Japan	125	1727	1586	32.6	1.15
OECD Total	1776	13482	31332	333.7	2.40

Source: U.S. Department of Energy, International Energy Annual 1988.

Table 5: Distribution of Energy Expenditures, United States, 1986

Income Decile	Natural Gas	Fuel Oil	Gasoline	Electricity
	Expenditures as a Percentage of Income:			
1 (Lowest)	4.6	2.0	14.7	12.6
2	3.9	0.6	6.1	6.3
3	3.1	0.6	6.7	5.2
4	2.7	0.6	6.3	4.6
5	2.1	0.5	5.6	4.0
6	1.5	0.5	5.2	3.1
7	1.3	0.4	4.5	2.8
8	1.0	0.3	4.2	2.4
9	0.9	0.3	3.8	2.1
10	0.7	0.1	2.5	1.6

Expenditure Decile	Natural Gas	Fuel Oil	Gasoline	Electricity
	Expenditures as a Percentage of Total Outlays:			
1 (Lowest)	2.4	0.4	5.2	4.8
2	2.8	0.3	4.1	4.5
3	2.3	0.5	5.6	4.3
4	2.3	0.5	5.3	3.8
5	2.1	0.4	5.5	3.6
6	1.7	0.4	5.8	3.5
7	1.6	0.4	5.6	3.6
8	1.3	0.4	5.6	3.1
9	1.2	0.4	5.2	2.9
10	1.1	0.2	4.2	2.7

Source: Author's tabulations based on 1985–6 Consumer Expenditure Survey.

Table 6: Distributional Incidence of $100/Ton Carbon Tax, United States, 1986

Distribution Across Income Classes

Income Decile	Total Burden	% of Income
1 (Lowest)	$451.9	10.1%
2	374.6	5.0
3	484.6	4.6
4	521.0	4.1
5	563.7	3.6
6	608.6	3.0
7	689.6	2.7
8	762.6	2.3
9	875.3	2.1
10	889.7	1.5

Distribution Across Total Expenditure Classes

Expenditure Decile	Total Burden	% of Outlays
1 (Lowest)	$252.5	3.7%
2	349.8	3.7
3	465.6	3.8
4	527.5	3.7
5	588.6	3.4
6	681.3	3.4
7	772.3	3.2
8	804.2	2.8
9	944.2	2.7
10	871.4	2.3

Source: Author's tabulations based on 1985-6 Consumer Expenditure Survey.

Table 7: Production & Consumption Distortions for Carbon Taxes, United States

	Coal	Oil	Natural Gas
Domestic Use ($1989B)	20	304	33
Demand Elasticities			
Coal	−0.56	0.22	0.16
Oil	0.10	−0.70	0.10
Natural Gas	0.12	0.13	−0.52
Slower CO_2 Growth Tax ($5/ton):			
Percentage of Price	13%	4%	5%
Deadweight Loss ($1989B)	0.09	0.17	0.02

Source: Row one is drawn from Table 4, row two from the Annual Energy Outlook 1990, row two–four from Anderson, Hoffman, and Rusin(1990), and rows five and six are the author's calculations.

Table 8: Fossil Fuel Embodied in U.S. Imports, 1985

	Direct U.S. Consumption	Energy Imports	Energy Embodied in Non-Energy Imports
Coal (M tons)	773.6	2.9	106.3
Refined Petroleum (M bbls)	5632.2	689.2	340.8
Natural Gas (B cu ft)	16372.3	920.9	1910.9

Source: Author's calculations based on the Office of Technology Assessment (1990). The entries in row two refer to refined petroleum. If the calculations focused on crude oil instead, total U.S. consumption would be 4603, imports 1189, and embodied imports 278.2.

Table 9: Chlorofluorocarbon (CFC-11 & CFC-12) Tax Rates, United States

Year	Tax Rate (Dollars/Pound)	Implied Carbon Tax (Dollars/Ton)
1990	$1.37	$1.16
1991	1.37	1.16
1992	1.67	1.41
1993	2.65	2.24
1994	2.65	2.24
1995	3.10	2.62
1996	3.55	3.00
....	....	....
2000	5.35	4.52

Source: Column 1: U.S. Congress, Joint Committee on Taxation (1990). Column Author's estimate using Nordhaus' (1990b) calculations of the equivalent CO_2 emissions per ton of CFC-11/12 gas. I use the Nordhaus estimate of this rat assuming a discount rate of one percent per year.