COSTS AND SIDE BENEFITS OF USING ENERGY TAXES TO MITIGATE GLOBAL CLIMATE CHANGE

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THE CLIMATE CHANGE PROBLEM

Atmospheric concentrations of the major greenhouse gases, carbon dioxide, methane, nitrous oxides, and hydroflourocarbons, are increasing substantially due to human activities. Scientific theory suggests that the continued addition of these gases to the atmosphere will alter global climate, increasing temperatures and changing rainfall and other weather patterns. The Intergovernmental Panel on Climate Change (IPCC) estimates that continued growth of greenhouse gas emissions from human activities will increase global mean temperature at the rate of 0.2°C to 0.5°C per decade during the next century [Houghton *et. al.* 1992]. The resulting mean temperatures in the coming century would exceed any experienced during the past 10,000 years.

Global climate change of this magnitude could have significant implications for mankind and the environment. The potential effects are wide ranging and include impacts on agriculture, forestry, water resources, air quality, human health, energy demand, wildlife, biological diversity, and coastal resources.[1] In response to these threats, 154 countries signed the Framework Convention on Climate Change at the United Nations Conference on the Environment and Development in June 1992. Article 2 of the Convention states that the ultimate objective is stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.

In his Earth Day speech of April 1993, President Clinton committed the U.S. to reducing its emissions of greenhouse gases to their 1990 levels by the year 2000 as a first step toward stabilizing greenhouse gas concentrations. However, in the absence of any new measures to abate the emissions of greenhouse gases, emissions are projected to grow by the equivalent of 100 million metric tons of carbon, or 7 percent, from 1990 to 2000 [Executive Office of the President, 1993]. To fulfill the President's commitment, a *Climate Change Action Plan* has been prepared which consists of a set of new actions designed to abate emissions growth and achieve the 2000 target. The action plan relies heavily upon voluntary programs and includes measures to promote energy conservation, development of energy resources and technologies that emit little or no carbon dioxide, forestry practices to increase absorption of carbon dioxide from the atmosphere, and reductions in emissions of methane, nitrous oxides, and hydroflourocarbons.

The actions outlined in the Climate Change Action Plan are intended to hold greenhouse gas emissions to 1990 levels in the year 2000, but beyond 2000 they will not be sufficient to prevent future emissions growth. An important source of emissions growth in the US will be carbon dioxide from the combustion of fossil energy. Even allowing for reductions in energy use per dollar of gross national product in excess of one percent per year due to increases in energy efficiency, income growth will drive energy consumption and carbon dioxide emissions upward at a rate of one percent per year or more for the decade following 2000. In the longer term, the carbon intensity of our energy supply has the potential to grow rapidly due to low cost coal supplies and falling costs of coal based technologies. Carbon dioxide emissions could then grow at rates of up to two percent per year [Leary and Scheraga, 1994a]. Without additional actions beyond those of the Climate Change Action Plan, directed both at energy conservation and reducing the carbon intensity of future energy supply, carbon dioxide emissions will not be stabilized at their 1990 level after the year 2000.[2]

In this paper we examine the potential costs and side benefits of using different energy taxes to achieve stabilization of U.S. emissions of carbon dioxide, the most important anthropogenic greenhouse gas. Energy taxes offer a potentially powerful and low cost mechanism for carbon dioxide control because (i) carbon dioxide emissions

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in the US are generated almost entirely from energy production and use, (ii) the potential damages from carbon dioxide emissions are independent of the spatial distribution of emissions, and (iii) emission sources and abatement options are numerous and highly diverse, making centralized, command-and-control regulation cumbersome.[3] The taxes examined here vary in the chosen tax base and the point of liability for the tax. Three tax bases are considered: the carbon content of fossil energy, the Btu content of fossil energy, and the market value of fossil energy. Liability for these taxes are imposed at two different points: primary producers of energy and final end-users.[4] By taxing fossil energy two incentives are created to reduce carbon dioxide emissions. First, these taxes raise the cost of energy and will induce firms and households to conserve energy. Lower energy consumption will reduce carbon dioxide emissions. Second, these taxes raise the cost of fossil energy relative to other forms of energy that do not generate carbon dioxide emissions. This will induce substitutions away from fossil energy that reduce the carbon intensity of the energy supply and reduce carbon emissions per Btu of energy consumption.

We compare the performance of the different taxes based upon two criteria: the costs and side or *ancillary benefits* of the taxes. The costs of the taxes are approximated by calculations of changes in consumer and producer surpluses in energy markets. The direct benefits of the taxes are reduced damages from slowing the rate of climate change. Each tax is set at a level to achieve equivalent carbon dioxide emission abatement and therefore yield equivalent direct benefits. However, the taxes also generate side or ancillary benefits which vary across the different tax instruments. The ancillary benefits we examine are changes in criteria air pollutant emissions other than carbon dioxide that result from imposition of the taxes. The effects of energy taxes on these air pollutant emissions represent a potentially important side benefit of abating carbon dioxide emissions to mitigate climate change.

A Comparison of the Costs of Different Tax Instruments

A tax on the carbon content of fossil energy imposed upon primary producers is *a priori* the least-cost instrument for abatement of carbon dioxide emissions. This is because emissions of carbon dioxide are proportional to the carbon content of primary fossil fuels and a tax on carbon content is very nearly equivalent to a tax on carbon dioxide emissions. A carbon tax at the point of primary production therefore imposes a uniform price per unit of carbon dioxide emission regardless of fuel, source, or end-use. Optimizing responses by energy producers and users to the common price signal will result in equal marginal abatement costs across all emission sources and least-cost abatement. Least-cost abatement will include a mix of energy conservation and reductions in carbon intensity from substitutions of natural gas and oil for coal and substitutions of non-fossil energy for fossil energy. A carbon tax creates an incentive for all three types of abatement measures.

Other tax schemes do not produce a uniform price per unit of carbon dioxide emission and therefore fail to satisfy the conditions for least-cost abatement. If a carbon tax is imposed on end-users rather than primary producers, there will be fugitive emissions upstream from the end-user for which the price is zero.[5] Because the Btu content of fossil energy is not proportional to carbon content or carbon dioxide emissions across fuels, a Btu tax imposes a different price per unit of emission depending upon the fuel used. An ad valorem tax on fossil energy imposes a price per unit of emission that varies not just by fuel type but also by sector of end-use. These non-uniform price signals will fail to induce the cost-minimizing mix of carbon dioxide abatement measures. In particular, the Btu and ad valorem taxes provide no incentive to substitute natural gas or oil for coal, relatively low cost measures for reducing carbon dioxide emissions.

Table 1 presents estimates of the costs of the different types of taxes when set at levels that achieve stabilization of US emissions of carbon dioxide from 1990 through 2030 at the 1990 emission level. The analysis is conducted using the U.S. EPA's GEMINI model. GEMINI is an intertemporal, partial equilibrium model of the U.S. energy system. GEMINI combines a technologically detailed modeling approach with intertemporal optimizing behavior by forward looking consumers, primary energy producers, and energy processors. The model generates projections of primary and secondary energy production by type and technology, energy consumption by type, technology, and end-use, and emissions of carbon dioxide and other greenhouse gases. The model projections are conditional upon exogenously specified assumptions regarding fossil energy stocks, income and population growth, oil prices in the world market, non-energy costs of competing primary production, processing, and end-use technologies, and other variables.[6]

The cost estimates are the changes in consumer and producer surpluses over the period 1990 to 2030 annualized using a 3 percent discount rate. Estimates of welfare changes over such a long time horizon are clearly very speculative. However, the estimates can be useful for ranking the different taxes and approximating their relative costs. The model simulations confirm our expectation that a carbon tax on primary production is the least-cost tax instrument for abating carbon dioxide emissions from energy use. Imposing the carbon tax at end-use results in 25 percent higher costs, but is still lower than any of the Btu or ad valorem taxes. In contrast, the cost of the Btu tax is lowest when it is imposed at end-use rather than on primary production. The Btu tax on fossil energy is projected to be 40 percent more costly than the least-cost tax when imposed on end-use and 70 percent more costly when imposed on primary production. In the case of the ad valorem tax on primary fossil energy, no tax rate up to 200 percent was found which succeeded in stabilizing carbon dioxide emissions. This is because coal, the most carbon intensive of the fossil fuels, has such a low value at the mine that the ad valorem tax decreases the relative price of coal in comparison to natural gas and oil. This creates an incentive to substitute coal for natural gas and oil, increasing carbon intensity. An ad valorem tax of 125 percent on end-use did succeed in stabilizing emissions, but only at very high cost.

We have also made projections for a modified end-use Btu tax. The end-use tax is modified so that electric utilities have no tax liability for their use of fossil fuels in the generation of electricity. Instead, electricity end-users are liable for the Btu tax. The Btu content of consumed electricity is calculated as the average Btu input of fuels per kwh of electricity consumption for the entire nation. As can be seen in Table 1, this modification raises the cost of stabilizing carbon dioxide emissions tremendously. The reason is that electric utilities, the largest consumer of coal and the largest source of carbon dioxide emissions in the US, have no incentive under the modified end-user tax to substitute other fuels for coal in electric power generation. This forces reliance on much more costly emission abatement measures. There is an important lesson to be drawn here. A tax on electricity consumption that does not take into account differences in emission rates for different fuel inputs is an extremely high cost instrument for implementing climate change mitigation policy.

Ancillary Benefits of Energy Taxes

In the above comparison of energy taxes, we are interested in their cost-effectiveness for achieving a single policy objective: the stabilization of carbon dioxide emissions. The direct benefits of the tax policies are the damages avoided by slowing climate change. However, the taxes will have other effects that will be of interest to policy makers and which are relevant for selecting a tax instrument for the primary purpose of mitigating climate change. One important set of side or ancillary benefits include the benefits of reducing emissions of air pollutants other than carbon dioxide. Air emissions potentially affected by energy taxes include criteria air pollutants and toxic air pollutants. Reductions of these emissions can bring benefits in the form of improved air quality, environmental quality, and human health.

We report here on work done in collaboration with Professor Larry Goulder of Stanford University to study the potential changes in criteria air pollutant emissions that may result from the imposition of energy taxes.[7] The emissions included in the analysis are sulfur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (VOCs), particulates (TSP and PM_{10}), carbon monoxide (CO), and lead (Pb). Because the sources of these emissions are ubiquitous and not limited to energy production and use, a more comprehensive model than the GEMINI model is needed for the analysis. The analysis is conducted using an intertemporal, general equilibrium model of the US economy [Goulder, 1993]. The model is unique among disaggregated general equilibrium models in its treatment of the dynamics of production, incorporating both energy resource stock effects and capital adjustment costs. The US tax system and connections between tax incentives, production methods, and consumer behavior are given detailed treatment, making the model well suited to the analysis of the effects of energy taxes on economic activity. The model provides complete coverage of all production sectors of the US economy and an accounting of emissions from production activities. The model captures both direct and indirect effects of energy taxes on air emissions. The direct

Table 1
A Comparison of the Costs of Stabilizing Carbon Dioxide Emissions Using Different Energy Taxes

Tax Base	Primary Production	Tax Liability End-Use	Modified End-Use
Carbon Content			
Annualized Cost[a]	125	155	—
Tax Rate	$120/metric ton	$180/metric ton	—
Btu Content			
Annualized Cost[a]	210	175	1100
Tax Rate	$3.30/million Btus	$4.00/million Btus	$35.00/million Btus
Market Value			
Annualized Cost[a]	—	450	—
Tax Rate	—	125%	—

[a] Annualized costs are reported in billions of 1990 $.

effects are changes in emissions from the combustion of energy that result from changes in aggregate energy consumption and changes in the fuel mix. The indirect effects are changes in emissions from non-energy combustion sources that result from changes in the output of different sectors of the economy in response to higher energy prices.

The scenarios used for the analysis of ancillary benefits of energy taxes differ from the scenarios that were used in the cost analyses presented in the previous section. Two taxes are examined: a carbon tax and a Btu tax, both imposed on primary production of fossil energy. The tax rates are set at levels that will result in carbon dioxide emissions in the year 2000 that are equal to 1990 emissions. Unlike the scenarios of the previous section, however, carbon dioxide emissions are not stabilized by the tax after 2000 but are permitted to grow. Projected changes in emissions of carbon dioxide and other air pollutants relative to a reference case for the year 2000 are reported in Table 2. The reference case is designed to incorporate the effects of the Clean Air Act Amendments of 1990 and projected changes are over and above reductions already mandated by law.

Stabilization of carbon dioxide emissions at their 1990 level in the year 2000 requires almost a 9 percent reduction relative to the base case projection of the Goulder model. Depending upon the pollutant and the tax instrument used, ancillary reductions in other air pollutants range from 1 percent to almost 7 percent of base case emissions. Both taxes have their greatest impacts as a percentage of baseline emissions on nitrogen oxides. This is not surprising as fuel combustion is the source of over half of US emissions of nitrogen oxides. PM-10, a subcategory of particulates, is the least changed by the energy taxes. Other than these two similarities, the pattern of effects of carbon taxes and Btu taxes on air emissions are quite different. After nitrogen oxides, the emissions most impacted are carbon monoxide and volatile organic compounds under a Btu tax and sulfur oxides and total suspended particulates under a carbon tax. Overall, the Btu tax generates greater emission reductions of the pollutants analyzed.

The projected ancillary emission reductions of criteria air pollutants will generate a variety of benefits. The benefits include reduced human mortality and morbidity related to air quality, reduced damages to agricultural and forestry crops, reduced damages to man-made materials, improved visibility, and reduced damages to wildlife and ecosystems. To illustrate the potential magnitude of benefits in monetary terms, we apply a range of estimates of the dollar value of benefits per ton of emission reduction for four of the pollutants to the projected emission changes. In the case of the carbon tax, the estimated benefits of reductions in VOCs, SO_x, particulates, and NO_x in the year 2000 range from \$300 million to \$3 billion. The estimated benefits of the Btu tax range from \$500 million to over \$4 billion. These estimates are very crude and do not include all potential benefits.[8]

Conclusion

Energy taxes are not created equal when viewed as instruments for implementing climate policy. A carbon tax imposed on primary production of fossil energy comes closest to the ideal of placing a uniform price on carbon dioxide emissions. This is the condition necessary for least-cost abatement of carbon dioxide and model simulations confirm that this tax is the most cost-effective of the taxes examined. Energy taxes, however, may serve other objectives in addition to carbon dioxide abatement. For this reason, it is useful to know how large is the cost difference if a different tax base or tax liability is chosen. Our simulations suggest that the cost differences are substantial, ranging from a 25 percent increase to a several fold increase relative to the least-cost carbon tax.

Taxing energy to reduce carbon dioxide emissions and slow global climate change can also generate side or ancillary benefits in the form of reduced emissions of criteria air pollutants. These emission reductions represent potentially important benefits that should be weighed in evaluating the benefits and costs of climate change policy.

Table 2
Projected Changes in Air Emissions: 2000

	CO_2	NO_x	SO_x	TSP	PM-10	CO	VOC	Pb
Carbon Tax								
Change[a]	-145	-1480	-490	-160	-110	-1000	-300	-0.07
(%)	(8.6)	(6.6)	(1.9)	(1.8)	(1.0)	(1.5)	(1.4)	(1.0)
Btu Tax								
Change[a]	-145	-1480	-510	-200	-170	-2330	-590	-0.17
(%)	(8.6)	(6.6)	(2.2)	(2.2)	(1.6)	(3.4)	(2.7)	(2.2)

[a] Emission changes for carbon dioxide are reported in millions of metric tons. All other emission changes are reported in thousands of metric tons.

Although we find taxes on the Btu content of fossil fuels to be 40 to 70 percent more costly than a carbon tax, a Btu tax yields greater reductions in criteria air pollutant emissions. A crude and partial illustration of the monetary value of the ancillary benefits suggest that stabilizing carbon dioxide emissions in 2000 at the 1990 level might add a few hundred million to a few billion dollars to the annual benefits of the policy. In comparison to the cost differential of the two taxes, our results suggest that the additional ancillary benefits of the Btu tax are not sufficient to make it an attractive alternative to the carbon tax as an instrument of climate policy. The ancillary benefits however may play an important role in establishing the efficient tax rate for an energy tax that is intended primarily as a tool to abate carbon dioxide emissions.

ENDNOTES

1. See, for example, Smith and Tirpak (1989).

2. Note that stabilization of global emissions of carbon dioxide and other greenhouse gases will not achieve stabilization of greenhouse gas concentrations, which is the goal of the Framework Convention on Climate Change. Continued emissions at current levels would yield rising concentrations of greenhouse gases in the atmosphere. Stabilization of greenhouse gas concentrations will require substantial reductions in global emissions below current levels. See Lashof and Tirpak (1989).

3. In Leary and Scheraga (1994b) we discuss the advantages of market instruments such as taxes and tradeable permits for the control of carbon dioxide relative to centralized, command-and-control regulation. The potential cost advantages of market instruments are substantial. In addition, we discuss the potential performance of tradeable carbon permits relative to a carbon tax and find that there are reasons to favor the carbon tax.

4. The primary producer taxes impose the tax liability at the well head and mine mouth, and also on imports of fossil energy. The end-user taxes impose the tax liability on the end-user of the fossil fuel. For example, liability is placed with the electric utility for its use of coal, oil, and natural gas to generate electricity. The end-user of electricity is not liable for the tax in this scheme. In a modified end-user tax that we analyze for the Btu tax, liability is placed with the electricity end-user. This will be discussed below.

5. Gasification and liquefaction of coal reduce the carbon content of the fuel delivered to end-users and produce significant emissions of carbon dioxide. If the carbon tax is paid at the point of distribution to end-users, a zero price is paid for the upstream emissions, violating the conditions for cost minimizing abatement. At the present time these technologies are relatively unimportant, but they are projected to play a potentially important role in future energy supplies.

6. For more complete descriptions of the GEMINI model see Scheraga et. al. (1991) and Leary and Scheraga (1994a).

7. See Goulder (1993). The analysis reported here is part of a larger study done by EPA that examines the potential ancillary benefits that would be achieved as part of different greenhouse gas control programs and is summarized in Scheraga and Herrod (1993).

8. The dollar per ton benefit estimates were culled from a variety of sources at EPA. The estimates range from \$360 to \$2400 per metric ton of VOCs, \$300 to \$1800 per metric ton of SO_x, \$430 to \$10900 for particulates, and \$10 to \$100 for NO_x. These estimates reflect estimated effects on mortality, acute morbidity, damages to crops and materials, and visibility. The reader should recognize that the benefits of emission reductions are highly variable with local circumstances such as baseline air quality, local factors that influence the effect of emission changes on air quality, the exposed population, and other factors. Marginal benefits of the emission reductions projected for energy taxes may very plausibly fall outside the range of estimates we use in our illustration. Nonetheless, we believe our illustration provides a useful first order approximation of the magnitude of the ancillary benefits.

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