ASSESSING CARBON EMISSIONS CONTROL STRATEGIES: A CARBON TAX OR A GASOLINE TAX?

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Produced for:
American Council for an Energy-Efficient Economy
1001 Connecticut Avenue NW, Suite #801
Washington, DC 20036

ACEEE Policy Paper No.3

February 1990

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SUMMARY

This paper assesses the effectiveness, fairness, and economic implications of two measures currently being advocated to reduce U.S. emissions of carbon dioxide from the combustion of fossil fuels: a gasoline tax and a carbon fuels tax. We compare a $1 per gallon gasoline tax with a carbon tax of $85 per ton of carbon, either of which would initially generate $112 billion in tax revenues.

We conclude that either a gasoline or a carbon tax would significantly reduce U.S. carbon emissions by stimulating energy conservation. However, we estimate that a carbon tax would reduce carbon emissions by two to three times as much as a gasoline tax. The carbon tax could reduce current U.S. carbon emissions by about 14 percent and as much as 20 percent (~189 to 272 million tons of carbon). The gasoline tax could reduce current emissions by about 7 percent (~87 million tons).

These estimates do not include growth in emissions due to future economic growth or the effect of lower energy prices resulting from depressed energy demand. Incorporating these factors in the analysis suggests that a $112 billion carbon tax would essentially hold U.S. carbon emissions constant through the end of the century. Cutting U.S. emissions 20 percent by the year 2000 would require an initial tax level of about $300 billion, though after demand adjustment the amount of revenues actually collected would total only about $200 billion. For comparison, $200 billion is about 60 percent of annual U.S. expenditures on energy, or about half of total federal and state income tax revenues. A carbon tax would thus require a "tax shift" to substitute for other taxes such as income or sales taxes.

A gasoline tax could provide greater national security and trade deficit-reduction benefits than a carbon tax. It would permit the United States to cut oil consumption, and possibly oil imports, by about 2 million barrels per day, one-eighth more than a carbon tax. The direct oil import savings would total $10-20 billion per year, depending on the price of crude oil.

The overall energy demand reduction due to a carbon tax, however, would reduce non-tax energy expenditures at least $45 billion per year compared to $32 billion in savings due to a gasoline tax, at today's energy prices.

The gasoline tax would approximately double the price of automobile fuel and cost the average car owner about $430 per year. The carbon tax would increase the prices of natural gas, oil products, electricity, and coal by roughly 30, 30, 20 percent, and 150 percent, respectively, and cost consumers about $200 directly and $230 in costs passed-through by businesses.

However, either tax could be reduced to a zero tax increase by using the revenues to offset other taxes. This "tax shift" could be accomplished by substituting either energy tax for current income or state sales tax revenues. A gasoline tax would--in the absence of rebates--be more burdensome on low-income families than a carbon tax. Either tax could be made income-neutral through rebates or targeted social benefits.

The overall economic impact of a gasoline or carbon tax could be near zero or even positive--assuming revenues were returned to the economy through a tax shift or were used for deficit reduction, and cost-effective energy-efficiency options were substituted for energy use. Inflationary impacts from either tax would be negligible if the tax merely replaced other taxes.

A large gasoline tax would have to be extended to diesel fuel for use in light vehicles. It would otherwise lose effectiveness as new car buyers switched to diesel-powered cars to avoid the tax.

In summary, policy makers placing priority on reducing carbon emissions would find a carbon tax a useful tool. Policy makers placing priority on reducing oil imports and associated national security and economic costs might find the gasoline tax the tool of choice.

ACKNOWLEDGMENT

The authors are grateful to the following energy experts and economists for their detailed reviews and insightful comments: Douglas R. Bohi; Roger S. Carlsmith; James A. Edmonds; Nicholas Fedoruk; Howard S. Geller; Edward Kahn; Marc R. Ledbetter; Hillard G. Huntington; Edward Kahn; Marc H. Ross; Michael Scott; Tom Secrest; and Barry D. Solomon. We are also appreciative of David Barns' revisions in and assistance with the Edmonds-Reilly model.

This research was sponsored by the American Council for an Energy-Efficient Economy, with support from John A. Harris IV, the Educational Foundation of America, the James C. Penny Foundation, Inc., and the Alida Rockefeller Charitable Lead Trust. Additional support was provided by Battelle Memorial Institute, Pacific Northwest Laboratories.

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INTRODUCTION

This paper is intended to help policy makers understand the relative merits of imposing a gasoline tax or a carbon-content tax on the consumption of fossil fuels. The purpose of either tax measure would be to control the emissions of carbon dioxide in order to reduce the risk of climatic change, though a gasoline or motor fuels tax could also be intended to reduce economic and national security costs associated with crude oil imports.

We compare hypothetical gasoline and carbon taxes for effectiveness by estimating the annual tons of carbon emissions reduced for taxes that are initially equivalent in terms of revenue. We also estimate the carbon emissions and tax revenues for both measures after consumers have responded to the higher prices the taxes would impose. The latter comparison is necessary because consumers respond differently to price changes in different fuels, and the taxes would not increase uniformly the prices of all fossil fuels or fuel products.

We weigh the potential equity problems of the two environmental taxes by estimating the total tax burden of both taxes by income level and by state or region. Tax burden is estimated by total annual dollar amount as well as by percent of family income. We specifically consider income redistribution effects among income groups and states or regions.

We do not attempt to quantify the benefits of reduced risk of climatic change because we consider them to be incalculable at the present, though we estimate complementary economic and security benefits.

EFFECTIVENESS: A COMPARATIVE ANALYSIS

Determining Equivalent Tax Levels

Conclusions about the effectiveness of energy-environmental taxes depend heavily on the methods and assumptions used to evaluate them. We have applied and evaluated three separate models reflecting different methodological approaches to assess the effectiveness and costs of a gasoline versus a carbon tax. These approaches include a straightforward set of hand calculations using price elasticities of demand, the U.S. Department of Energy PC-AEO econometric model, and the Edmonds-Reilly Energy-Economic parametric model.

The price elasticities of energy demand assumed in these models are obviously important. More subtly, the decision to compare effectiveness on the basis of expected revenue or expected emissions reduction after consumers have adjusted to higher prices can give different results from comparisons based on initial--that is, first year--expectations. We begin our analysis on the basis of initial revenues. This choice was made in order to provide guidance to policy makers in the context in which the debate has evolved. However, we demonstrate how the distortion from this approach can be avoided and how policy makers could anticipate consumer price responses in order to make the tax instruments approximately equal.

We take as our point of departure a proposal which has received popular support: a $1 per gallon gasoline tax advocated by environmental organizations.[1] This tax, for purposes of our analysis, would be phased in over three to five years. For comparison, we structure an alternative which would be applied to fossil fuels in proportion to carbon content. This tax measure has also received prominent support.[2] We thus estimate tax rates which would be applied to coal, oil products, and natural gas in order to raise the same initial revenue as a gasoline tax of $1 per gallon.

We estimate that a $1 per gallon gasoline tax would initially produce $112 billion per year in revenues--if consumers were for some unexpected reason unable or unwilling to reduce consumption. (A $1 per gallon gasoline tax is equivalent to an $8 per million BTU tax, and would not be unusual by international standards. See Figure 1.) To formulate an equivalent carbon tax, we simply scale tax rates for coal, oil products, and natural gas based on their average carbon content. (See Table 1.) Because coal contains 73 percent more carbon per unit of energy than natural gas, the tax on coal is set 73 percent higher than for natural gas. Similarly, the tax on oil products is set 43 percent higher than on natural gas. Expressed differently, the tax on natural gas, oil products, and passed through from coal to coal-fired electricity would be approximately $1.17, $1.67, and $2.08 per million BTU (primary basis), respectively. These rates would initially yield annual tax revenues of about $112 billion.

We would expect consumers to respond differently to the two types of tax, however. The rate of conservation would depend on price elasticities of demand, which vary by fuel type, and by the percentage price increases by fuel.[a] Elasticities estimated in the literature vary widely. Under the carbon tax, a $2.08 per million BTU increase in the price of coal would more than double the price of that fuel, whereas a $1.67 per million BTU oil products price increase would amount to only a 27 percent hike. Even if the price elasticities were identical, the varying percentage price increases would lead to varying price responses overall.

CONSUMER RESPONSE TO INCREASING ENERGY PRICES

We have reviewed estimates of consumer response to energy price changes in order to evaluate the economic effects of the two energy-environmental tax strategies. A tax on energy would reduce climatic risks (or enhance national security) only if the higher price reduces consumer demand for carbon fuels (or imported petroleum). The economic measure of consumer price response is called the price elasticity of demand, and it is defined as the percentage change in quantity of consumption for a one percent change in price.

(a) Energy conservation is used here in the broadest sense, including fuel substitution and non-energy substitution for energy-efficiency improvements.

The key price elasticities we consider are those for oil products used in transportation and heating, all end-uses of electricity (since a tax on coal, natural gas, and oil products will increase the price of electricity), natural gas for space heating and industrial processes, and coal used by utilities or industry.[3]

The best summary analyses of energy price elasticities of demand available to us were conducted in the early eighties.[4] Douglas Bohi, in a ten-year old Resources for the Future report, reviewed the economics literature for estimates of short-run and long-run elasticities by demand sector and fuel type. For transportation sector demand for gasoline, for example, he found a consensus around -0.2 and -0.7 over the short and long run, respectively.[5] Estimates for other sectors and fuel types were approximately the same.[6] (Estimates of the price elasticity of demand for gasoline given in other sources are shown in Table 2; most are similar to Bohi's.) Bohi cautions, however, that the studies he examined all predate the increases in the real price of gasoline in 1979-1980, with resulting demand and supply shifts. Instead, most of the studies were conducted over observation periods when the real price of gasoline was actually declining and consumer options for efficient automobiles were limited. The combination of these two factors probably underestimates energy price elasticity of demand.

Jae Edmonds of Pacific Northwest Laboratories conducted a major review of price elasticities across all sectors and fuel types in a study contemporaneous with Bohi's.[7] He observed a similar consensus regarding elasticities, which he incorporated in the IEA/ORAU Long-Term Energy-Economic Carbon Dioxide Model.

More recently, and more narrowly, Louisiana State University economist Carol Dahl conducted an extensive literature review of estimates of the price elasticity of demand for gasoline.[8] She found a consensus for the short-run price elasticity of gasoline around -0.29, and intermediate- and long-term averages around -0.60 and -1.05.

Gately and Rappoport, however, concluded on the basis of their empirical work that the long-run price elasticity of total oil demand is somewhat less than -0.4. They acknowledged that this elasticity is lower than some others in the literature, but noted that if the demand specification included a longer-lag length, the estimate would increase.[9] In general, there appears to be a degree of consensus about energy price elasticities. A defensible estimate of the long-run elasticity for general energy services in each of the major consuming sectors is around -0.7.[10] We conservatively chose, however, to use a lower elasticity, -0.5. We did this in part because our analysis does not consider the effects of fuel substitution, which tends to increase the magnitude of elasticity estimates.

Some caveats should be kept in mind in applying elasticity estimates to assess the effect of taxes on consumption. First, firm definitions of "short-run" and "long-run" are frequently lacking. Since the long- and short-run elasticities discussed here are quite different, the choice of which elasticity to select to assess the impact of a price increase in a given year is not a trivial point, and must be made with care. Second, none of the above analyses appears to address explicitly the fact that Corporate Average Fuel Economy (CAFE) standards have forced automakers to increase the efficiency of new automobiles. This regulatory impact, which allowed consumers to purchase more efficient automobiles than would have otherwise been the case, was likely a crucial determinant in the responsiveness of demand to price. Demand specifications which do not account for CAFE explicitly may be overstating the demand responsiveness to price when it is CAFE that is doing the work.[11] Indeed, it appears that CAFE was the decisive factor in fuel economy improvements over the last decade, since average automobile efficiency has increased even as gasoline prices have fallen. (See Figure 2.) It is logical to assume, however, that price increases through tax policy or otherwise would be a necessary complement to regulatory policy over the long run to maintain momentum in automobile fuel economy.

PREVIOUS STUDIES OF ENERGY TAX EFFECTIVENESS

Harry Broadman and William Hogan at the Harvard Kennedy School in 1987 estimated the amount of an oil import fee which could be justified to account for national security and economic losses associated with high levels of crude oil imports.[12] The problem they tackled is analogous to that of greenhouse gas emissions, except that the external costs they addressed were military and economic rather than environmental.

Broadman and Hogan concluded that a fee of $10-11 per barrel of imported crude oil would be necessary to minimize total economic and security costs associated with energy imports. Such a tariff would--if "passed through" to consumers--be the equivalent of a gasoline tax $0.24-0.26. It would thus amount to only one-quarter of the gasoline tax we consider, though it would be roughly comparable to the tax on gasoline that would result from a carbon tax.[13]

Broadman and Hogan argue that for two major reasons the social cost of importing crude oil is higher than the market price actually paid, and therefore an oil import tariff is justified. First, the United States represents so large a share of the world crude oil market that it can affect the world oil price. In economic terms, the nation is an oligopsonist. Reducing U.S. crude oil imports should effectively reduce the world oil price.[14] There would also be a benefit to the U.S. government because the tariff collected by the Department of the Treasury would otherwise have been paid to foreign suppliers. That is, the tariff would reduce U.S. demand for imported crude oil, which in turn would reduce the foreign (but not domestic) price, and the United States would pay foreign suppliers less for what it would still import. Domestic suppliers would also earn more per unit of energy sold than before the tariff.

Second, a large, unanticipated increase in crude oil prices resulting from a supply disruption would impose large national security costs, including significant transfers of wealth abroad. These transfers could cause major macroeconomic and trade balance problems and costs. Because gasoline demand is very inelastic in the short term, the risk of macroeconomic disruption would be high.

A major flaw--or benefit, depending on one's perspective--of a crude oil tariff is that it would drive domestic oil prices higher and create a windfall for domestic oil producers. Broadman and Hogan acknowledge that consumers would experience some difficulty adjusting to a tariff, but argue that, overall, economic output would expand because the tariff would narrow the trade deficit and benefit consumers with lower and domestic producers with higher prices.[15] But their observation that producers and consumers are "in aggregate" the same does not mitigate the distributional problems with a tariff.

In 1987, the U.S. Department of Energy (DOE) published an overview of the nation's energy situation, Energy Security, which among other things contained two significant and much-discussed cost-benefit analyses.[16] The first was an assessment of crude oil import fees per barrel of $5 and $10, as well as a $22 "floor" tariff. The second assessment examined the costs and benefits of a 10-cent and 25-cent per gallon tax on gasoline.[17] Energy Security concluded that for all three oil import tariffs and both gasoline taxes the costs to the nation in aggregate would greatly outweigh the benefits. If the DOE analysis were correct, it would be difficult to justify any environmental tax in the absence of a quantifiable environmental benefits. The methods by which DOE reached their conclusion, however, have been heavily criticized.

Consider DOE's analysis of the gasoline taxes. DOE assumed that gasoline taxes were applied in 1988, that they applied to highway diesel fuel as well as gasoline, and that the time period till 1995 was of prime concern.[18]

Four effects of the taxes were explicitly examined by the study: reductions in crude oil import costs; consumer welfare losses; the overall impact on the economy caused by inflation and reduced income levels; and national security benefits of reduced crude oil imports, especially in the event of an oil supply disruption.

One key set of assumptions determined the study's results concerning the effectiveness of a gasoline tax in reducing consumer demand: price elasticities. In fact, the study's authors assumed that the price elasticity of demand for gasoline is exceedingly low--a $0.25 gasoline tax reduced 1995 total crude oil consumption by only about one percent compared to a Base Case. And this is in response to a real price increase of 31 percent for gasoline and 29 percent for diesel fuel. The implied elasticities are thus even lower than the consensus values of about -0.2 for short-term price elasticities, not to mention long-term. With regard to effectiveness of taxation in reducing energy demand, the DOE report does not conform to what we consider to be the consensus for price elasticity of demand.

EFFECTIVENESS: HAND-CRANKED AND OTHER POLICY EXPERIMENTS

We have applied two approaches to assess the effectiveness of the two proposed energy-environmental taxes for reducing carbon emissions and achieving other national priorities. First, we make calculations by hand to compare the two tax approaches for effectiveness in reducing carbon emissions. Second, to account for any offsetting effects of lower energy prices caused by tax-induced conservation, we apply two macroeconomic models: the EIA Annual Energy Outlook model and the Edmonds-Reilly model.

Hand Calculations of Tax Effect on Emissions

A $1 per gallon gasoline tax would initially generate roughly $112 billion in revenue. The tax would slightly more than double the 1988 retail price of gasoline of $0.96 per gallon. Carbon taxes of $1.17, $1.67, and $2.08 per million BTU on natural gas, oil products, coal would drive up the retail price of those fuels by 29, 27, and 141 percent, respectively. (See Tables 3 and 4.) The price of coal-fired electricity would increase 38 percent.

The effect of the two taxes on energy consumption following the adjustment to higher prices would be quite different, according to our hand calculations.[19] Under the carbon tax, U.S. annual consumption would decline by at least 12 quadrillion BTU (quads), a 17 percent drop from current fossil energy consumption of about 69 quads. By contrast, the gasoline tax would reduce U.S. energy consumption about 4.2 quads. The carbon tax would therefore be almost three times as effective in reducing energy demand.

The difference between the two taxes in carbon emissions reduction, however, would be greater because the carbon tax would cause greater demand reduction in coal, which is carbon intensive compared to other fuels. The carbon reduction under the carbon tax would total 189-272 million tons versus about 87 million tons under a gasoline tax.[20] The low end of this range exceeds the annual carbon emissions of all but five countries. Revenues from the carbon and gasoline taxes adjusted for price response would total $93 and $79 billion respectively.

The effectiveness of the carbon tax relative to the gasoline tax may appear suspect, especially since the latter doubles the cost of that fuel while the weighted average energy price increase for the carbon tax is about 28 percent. We believe there are two reasons for the disparity in outcomes. The first is that there are diminishing marginal demand reductions in response to price increases[a]. (See Figure 3.) Higher prices cause individuals to reduce their fuel use--by buying more-efficient cars or driving less--but substitution becomes increasingly difficult or undesirable, even as prices increase. Assuming constant elasticity of substitution, a 100 percent tax-based increase in the price of gasoline does not double the reduction in consumption relative to a 50 percent tax. In other words, much of the decrease in demand is captured in the first 50 percent price increase. The carbon tax produces much of its emissions reduction from the relatively light--but more broadly based--taxes on oil products. For example, while 27 percent of the carbon reduction is from a 27 percent tax on oil products, 61% of the reduction is from a 141% tax on coal. Second, and more obviously, coal has a higher carbon content than gasoline, and so BTU for BTU, reducing coal consumption has a greater effect on carbon emissions than reducing oil consumption.

(a) Assuming constant elasticity of substitution.

We also tested the effect of extending the gasoline tax to diesel fuel used by heavy trucks as well as some light vehicles, increasing the tax rate per gallon by about 10 percent to account for the higher per-gallon BTU content of diesel. Because we assumed the same initial tax revenues and the same elasticity of demand, the resulting emissions reduction was in proportion to the amount of energy subject to taxation. And when we tested the effect of reducing the gasoline and diesel tax to raise $112 billion--that is, to match the revenues of the gasoline-only tax rate, we got a slightly different result. Applying an equal amount of total tax to the larger amount of energy--all gasoline and all diesel, including that consumed by transport trucks--reduced emissions by an additional 8 million tons per year more, or about 9 percent.

Equilibrium Analysis Using a Department of Energy Model

These simple estimates neglect an important feedback of energy taxes: prices would fall somewhat with reduced demand, thus reducing the price increase caused by and the effectiveness of any tax. We apply the Energy Information Administration (EIA) Annual Energy Outlook Forecasting Model in an attempt to find an equilibrium solution. In addition, the model purports to yield GNP and inflationary impacts of energy price changes.[21] The Department of Energy uses this model in matters that affect national energy policy.

The EIA model is a partial equilibrium model, which means that it solves for balance between the energy industry and the rest of the U.S. economy.

It was built from several models which represent supply and price for coal, natural gas, oil products, and electricity. Energy end use is treated in one sub-model, divided into residential, commercial, industrial and transportation sectors. However, the model includes little engineering or technical detail on end-use efficiency--it is mostly econometric.

After successfully reproducing a scenario identical to DOE's Annual Energy Outlook Base Case, we introduced a gasoline tax of $1 per gallon over the years 1990-92.[22] The $1 tax was then held constant until the year 2000. A separate test of the carbon tax was made by introducing coal, oil product, and natural gas price increases similar to those applied in our hand-cranked model.[23] We also tested the sensitivity of the model by imposing a $10 per gallon price increase.

These EIA model runs gave suspect results. The carbon tax scenario--which increased the prices of coal and oil products by percents comparable to our hand-cranked experiment--reduced year 1992 total demand for energy by less than 7 percent. (See Table 5.) Similarly, the gasoline tax--doubling the real price of gasoline by 1992--cut 1992 gasoline demand by about 11 percent; by 2000, gasoline demand was about 8 percent lower. Most surprisingly, the $10 per gallon tax on gasoline had a relatively small effect on the demand for that fuel. It is also interesting to note that the gasoline tax, regardless of magnitude, has no effect whatsoever on real GNP. In the EIA model, real GNP is only responsive to changes in the world oil price and three industrial prices.[24] Because the gas tax did not affect any of these variables, real GNP was left unchanged.

These results reflect long-term price elasticities which are lower than even the short-term estimates suggested by most of the economics literature, and perhaps some modelling peculiarities which make the model's results non-reproducible. This problem seems to extend to the results for GNP effects. The model's assumptions determine its results and, unfortunately, these cannot easily be changed by the model user.[25]

Equilibrium Modelling with Edmonds-Reilly

The Edmonds-Reilly Long-Term Energy Economic Model With Carbon Dioxide Emissions was designed specifically to permit user changes in such critical assumptions as price-elasticities of demand. We used it and found that imposition of the carbon and gasoline tax in 2000 reduces U.S. carbon emissions by 284 and 92 million tons, respectively, in that year.[26] (See Tables 6 and 7.) Our hand calculations estimated 189-272 and 87 million tons reduction for the carbon and gasoline taxes, respectively. We have used the same price elasticities of demand in both the hand-cranked and Edmonds-Reilly modelling efforts, although ours are lower than Edmonds recommends. The Edmonds-Reilly model thus suggests that a carbon tax would be up to three times more effective in reducing carbon emissions than a gasoline tax. This result is important because the Edmonds-Reilly model is an equilibrium model, meaning that it should reflect any offsetting effects of lower energy prices caused by softer energy demand.[27]

MACROECONOMIC IMPACTS

A Short Review

The Department of Energy painted an unpleasant macroeconomic picture of a gasoline tax.[27] A 25 cent tax, according to DOE, would save annually less than $6 billion (present value 1985 dollars) in crude oil import costs and about $1 billion in national security costs. Consumers would pay an additional $6.5 billion directly. DOE further estimates the present value of macroeconomic losses over a seven-year period would exceed $100 billion. This estimate accounts for DOE's conclusion that the cost of a gasoline tax--or an oil import tariff--would greatly outweigh its benefits.[28] The macroeconomic losses from the fee overwhelm the benefits, and the fee is deemed an unwise economic idea.

The mechanism by which the DOE model arrives at this result is remarkably simple: GNP is reduced in proportion to an increase in the price of energy, in this case gasoline. In economic terms, there is an energy price-GNP feedback elasticity, and a single equation reduces GNP in response to this assumed value for each fuel. The energy-GNP feedback elasticity is the estimated percentage reduction in GNP caused by a 1 percent increase in energy prices.[29]

But the DOE analyses can be challenged on the basis that it assumes economic feedback reduces GNP every year into infinity. In Energy Security, a hypothetical 25-cent per gallon gasoline tax imposed in 1988 immediately hypothetical 25-cent per gallon gasoline tax imposed in 1988 immediately cut real GNP about $23 billion per year relative to the base case. By 1995, the tax still reduced GNP by almost $17 billion per year. This assumption bears closer scrutiny.

The feedback elasticity superficially seems to be justified both on theoretical and empirical grounds. If money is taken out of consumers pockets and not used productively or returned, the GNP is reduced. A few statistical studies seem to bear out this obvious principle. In particular, a study by Michael R. Darby found that over time in the United States GNP growth was reduced by 0.025 percent for every 1 percent exogenous crude oil price increase.[31] It is this elasticity, slightly adjusted downward for gasoline, that DOE employed to estimate the GNP losses caused by a gasoline tax. Other economists use a feedback elasticity twice as large. However, it should be noted that using an elasticity derived from an analysis of exogenous price changes to measure the impacts of a domestic taxation policy is itself open to question.

We were unable to reproduce this result using EIA'a PC-AEO Forecasting Model, at least for a gasoline tax. A $1 per gallon increase in the price of gasoline in that model left GNP unchanged. The difference is a function of different approaches that DOE and we took. The analysis for Energy Security did not employ an integrated model such as the one we examined, but instead used a slight variant of the Darby elasticity in a separate spreadsheet analysis.

But what is implied economically by this elasticity? The way in which DOE uses the Darby feedback elasticity means that a permanent increase in the world price of oil or gasoline will reduce real GNP by the same proportion in, say, the tenth year as in the first. Implicitly, the feedback elasticity means that even in the long run capital and labor cannot substitute for energy, or at least not at a comparable cost. This meaning, however, would be rejected by anyone familiar with the remarkable substitution of labor, capital, and ingenuity for energy over the past two decades, or with myriad engineering-economic studies which suggest cost-effective substitutions cut energy demand by one-third to one-half. Using an alternative GNP loss function that allowed for adjustment, Hillard Huntington at Stanford University estimated that the DOE oil tariff case should cause not a $173 billion but a $10 billion GNP loss.[32]

The authors of Energy Security did not consider a "revenue-neutral" case, in which additional revenues from an energy tax would be used to reduce revenues from other taxes. A revenue-neutral case could have a small macroeconomic effect--which could even be positive depending on how the taxes are cut. Considering the revenue-neutral case makes it possible to remove the potential regressiveness of a gasoline tax. For example, state sales taxes on food could be reduced. In a revenue neutral case this would not be at issue, but in the DOE analysis revenues increase dramatically and it is essential, if the impact on the nation is to be fully gauged, that it be clearly stated how the revenues are to be used, and what likely effect they would have. Economic theory holds that decreasing the borrowing demands of the government should decrease interest rates, which would in turn stimulate real GNP. It also maintains that the positive effect on real GNP of government spending will outweigh the negative effects from taxation.[33] The GNP conclusions of the Edmonds-Reilly model are similar to DOE's in Energy Security.

More work needs to be done in the area of energy price-GNP feedback effects. If Energy Security and the current Edmonds-Reilly model are correct, the costs of energy taxes will likely always outweigh the benefits even if the environmental benefits of reduced consumption could be quantified. However, logic suggests that the opposite should be the case.

Inflationary Impacts

Energy was widely perceived as having caused much of the high U.S. inflation during the seventies. Whether or not that hypothesis is correct, the perception lingers and extends to the imposition of energy taxes. That is, many policy makers would consider excise taxes on energy to carry a grave inflationary threat. However, energy taxes could be inflationary, deflationary, or inflation neutral--depending on how they are imposed and how they are counted in the economy.

The Consumer Price Index (CPI) strongly affects public perception of inflation, but it is constructed in ways which can distort that perception. The most important characteristic in this regard is that it would account for the inflationary impact of excise taxes on energy, but would not count a tax reduction on incomes. Thus, a "tax shift" in which energy taxes substituted for income taxes would, with the current CPI index, be inflationary, even if in reality the net effect on the economy were deflationary. Nevertheless, the perception of inflation would be a problem because of the way the CPI is constructed. A immediately-introduced gasoline tax of $1 per gallon would lead to a reported 2-3 percent inflationary effect, while an equivalent tax distributed over all fossil energy would have a similar impact.[34] The tax would, however, be phased in over five years and would have a proportionally lower annual effect on reported inflation rates.

A tax shift could be accomplished with nearly zero reported inflation only if the CPI were adjusted to reflect the offsetting tax reduction. If a gasoline tax merely offset an equivalent reduction in sales taxes on food and other necessities, the CPI would show a zero percent change. But if the tax were offset by an income tax reduction, the CPI would show a one-time inflationary impact.

The Producer Price Index would also report fuel taxes as inflationary even if they were 100 percent rebated to consumers. That effect would result because the index measures costs to producers, but rebates on income or social security taxes would not reduce producers' production costs. The GDP deflator, because it would reflect both the energy taxes and the tax rebates, might more accurately reflect underlying inflation.

A tax without rebates could even have deflationary impacts. This effect, in fact, is exactly what would be expected from a GNP reduction such as that suggested by Energy Security and the EIA model itself. A price increase for gasoline caused by a tax, for example, would decrease consumer demand for fuels. Consumers' incomes would be reduced in proportion to the tax and they would thus have less discretionary income. In general, consumers would reduce their demand for energy to compensate for the income loss. It is also possible, though less likely, that consumers would sacrifice other purchases in order to maintain current levels of energy use. But whether consumers reduced their demand for energy or for other goods, the reduction in overall demand would reduce inflationary pressures.

A tax shift thus should either be deflationary or have little net effect. With the higher energy prices brought by taxes, consumers would either reduce their demand for energy services or substitute energy-efficiency alternatives in order to maintain them. Unless energy-efficiency services were unable to expand to meet increased demand, the main effect would be reduced price pressure on energy supplies. Still, delays in substituting efficiency for energy would cause some increase in producer prices--and some decrease in purchasing power. The net effects would, we believe, be small.

INCOME AND REGIONAL IMPACTS

The potential equity impacts of energy taxes raise emotions and block legislation. While richer persons consume higher levels of energy and absolute energy taxes would be lower for lower income persons, the percentage of income consumed by a fuel tax could be higher for low income groups. The possibility of the latter rightly concerns many legislators.

The United States does not generate reliable data on transportation energy consumption by income level. A major, nationwide survey of transportation energy use by income level was conducted in 1985, but methodological problems diminish its reliability.[35] The data were collected in personal interviews: consumers were simply asked how much they spent on energy or how many miles per gallon their cars obtained, and consumers may not accurately know the answers to such questions.

The survey data show a decline in gasoline use as a function of income. The impact of a $1 per gallon gasoline tax would, nevertheless, have an important impact on the cost of transportation in America's low income families. (See Table 9 and Figure 4.) Even though consumption drops sharply--according to the survey data--below $10,000 per year income per family, the tax would still cost the typical low-income family $500-750 per year, or 5-8 percent of family income. A middle class family in the $35,000 income range would pay about $1,500 in taxes with a $1 per gallon gasoline tax, or about 4 percent of total income.

A solution to the problem of how to protect the poor from being pushed over an energy tax cliff has always vexed energy policy makers.[36] One mechanism would be to provide an earned-income tax refund in proportion to the tax burden. A precedent exists in the current income tax system whereby low income families can collect what amounts to a negative income tax--they get a tax "refund" even if they had no income or paid no tax.

The use of such a rebate mechanism to reduce the impact of energy taxes on the poor has been criticized by advocates for the poor. They object that low income persons would have to file a tax return to obtain the rebate, and many low income persons would simply not understand that they could get money by filing a return. This result has been observed in some states where such mechanisms have been put in place. Educational programs to promote tax filings have not been adequately funded or have not worked well.

Advocates of the poor also note that poor persons would be required to pay higher energy costs throughout the year, but would receive the rebate well after the burden was imposed. One solution to this problem would be to "prebate" the taxes, but this would require up-front funds from the government as well as considerable political foresight. Another solution would be to distribute the funds monthly through social welfare systems such as social security. It has been estimated that a combination of income tax, social security, Aid to Families with Dependent Children, and similar programs would reach 95 percent of low income families.[37]

The amount of funds needed for rebates to mitigate this problem depends on the income level one chooses to protect. Taking, for example, all families with incomes 125 percent of the poverty level would include about 18 million families. Assuming a range of consumption per family of 500-750 gallons of gasoline per year, a $1 per gallon tax would impose on this group a tax burden of $9-14 billion per year. This burden could be offset with 11-18 percent of total adjusted gasoline tax revenues.[38]

If the entire tax were rebated on a per capita basis, a major income transfer from wealthier to poorer households would occur. The average family consumption level of roughly 1,000 gallons per year would mean that most low income families would receive $100 to $500 per year more than they would be taxed.

The tax per family under a carbon tax would be lower in direct impact, but would be less equitably distributed than would a gasoline tax. (See Table 10.) The apparently inequitable estimated tax distribution derives from relatively high reliance on oil and electricity by lower income families and the comparatively higher tax that would be applied or passed through to these energy carriers.

A different sort of equity impact could arise from the carbon tax: an income redistribution from corporations and their stockholders to consumers. This situation could arise if taxes were paid on industrial energy use but rebated through the income tax system. The employees of such firms would receive rebates just as would all tax payers, but the net effect on the firms themselves would be an increase in taxation. This effect could be offset with a rebate of the corporate income tax, but this solution would have the effect of rewarding companies which were not energy intensive--if the corporate tax were rebated equally--while penalizing energy intensive companies.

The regional impacts of energy taxes would vary somewhat by tax type. With a gasoline tax, western states would incur average or above average tax burdens on a per capita basis. Gasoline tax incidence would range between extremes of $363 and $562 per year for the average New Yorker and the average Wyoming citizen, for example, while the national average would be around $400. (See Table 9 and Figures 5 and 6.)

The absolute total of tax paid by industry due to a carbon tax could vary among states by a factor of ten. This comparison, however, exaggerates the actual state-by-state impact because it is calculated on the basis of the tax paid per capita, and individuals would not themselves pay the tax. Rather, the comparison merely identifies those states where industrial energy consumption is unusually high in proportion to population, and thus suggests those areas which will most likely resist the carbon tax. We compare the per capita impacts of a carbon tax by assuming that industries and businesses merely pass on the taxes paid on energy use. Because we compare effects without making adjustments for demand reduction due to the tax-induced price increases, the comparisons should be considered relative and maximum levels.

The industrial impact might indeed be serious if energy costs compose a large share of the cost of products, especially if the manufacturer or provider must compete with foreigners. The relative tax ratios with other nations is not at issue, moreover, for it is the overall price level due to all factors that matters. A carbon tax would heavily affect certain industries such as chemicals, steel, and aluminum, increasing the cost of manufacturing certain goods by as much as 8 percent in some cases. Moreover, a rebate mechanism to such industries would only relieve the burden if it were in proportion to the tax paid. Otherwise, the tax would amount to an income transfer from energy intensive to other industries. Rebating the tax in proportion to the tax paid would negate the effect of the tax. The state-by-state comparisons suggest that a carbon tax would fall more evenly across the country.

SUMMARY AND CONCLUSION

Our results suggest that either a gasoline tax or a carbon tax would effectively reduce U.S. carbon emissions. Both taxes would induce energy conservation which would reduce carbon emissions significantly. A carbon tax, however, could eliminate two to three times as much carbon as a gasoline tax, assuming the taxes were initially set to generate approximately equal revenues. The carbon tax could--if energy supply prices did not fall and stimulate demand--reduce current U.S. carbon emissions by 14-20 percent (~189-272 million tons of carbon). The gasoline tax could reduce emissions by 6 percent (~87 million tons). These estimates do not include growth in emissions because of future economic growth, which would by the year 2000 offset the reductions and result in virtually constant emissions levels compared to the present.

A tax on fossil fuel carbon content initially equivalent to the $1 per gallon gasoline tax--which would raise $112 billion in revenues per year--would increase natural gas, oil product, and coal prices by 29, 27, and 141 percent, respectively. However, price-induced conservation would eventually reduce revenues from the carbon and gasoline taxes to $93 billion and $79 billion, respectively. This conservation effect would similarly diminish the effectiveness of either tax, unless occasionally increased to offset declining energy prices. Our low estimate for carbon emissions reduction comes from assuming that coal price increases are passed on to electric power consumers because the utilities have little choice for several years. This issue is a key uncertainty in the range of our estimates.

A gasoline tax could provide more national security and trade deficit-reduction benefits than would a carbon tax. It would permit the United States to cut insecure crude oil imports by about two million barrels per day, one-eighth more than a carbon tax. The direct crude oil import savings would be worth an additional $20 billion per year. However, the energy demand reduction due to a carbon tax would reduce non-tax energy expenditures at least $45 billion per year versus $32 billion due to a gasoline tax, at today's energy prices.

The gasoline tax would initially cost the average American about $430 per year, while initially the carbon tax would cost about $200 directly and $230 in costs passed-through by businesses to consumers. However, either tax could be reduced to a zero tax increase by using the revenues to offset other taxes, particularly income taxes. A gasoline tax would--in the absence of rebates--be more burdensome on low-income families than a carbon tax. The former would cost the average low income household $500-750 per year, while the latter would cost $275-$350. Either tax could be made income-neutral or even progressive through income tax rebates, sales tax offsets, or social benefits such as health care or energy efficiency services.

The overall economic impact of gasoline or carbon taxes could be near zero or even positive--assuming revenues were returned to the economy through a tax shift or were used for deficit reduction. If the government allocated the revenues to unproductive uses, however, losses could total almost 0.8 percent of GNP annually.

Inflationary impacts from either tax would be negligible if the tax merely replaced other taxes. But a change would be necessary in the formula for calculating the Consumer Price Index (CPI). The CPI currently incorporates excise but not income taxes. This definition would count a gasoline or carbon tax as inflationary even if the revenues were returned to taxpayers via income tax reductions or social benefits.

Only very large taxes could achieve popular goals for carbon emissions reduction. For example, a carbon tax initially set to raise $300 billion per year would be necessary to cut U.S. carbon emissions in the year 2000 by 20 percent compared to the present. Accomplishing such goals will most likely require a mix of energy tax, regulatory, and research and development policies.

In summary, the choice of a carbon versus a gasoline tax as a tool for reducing the risk of climatic change depends on one's belief regarding the need to take action. If one believes that the evidence clearly calls for priority action to reduce carbon emissions, then the choice should be a carbon tax. However, if one believes that only actions that increase public welfare or are most effective in achieving complementary public goals such as oil import reduction are justified in reducing the risk of climatic change, then a gasoline tax would be the preferable choice between the two policy tools.

Table 1: Carbon Coefficients and Carbon Tax Rates Assumed for the Analysis

Fuel	Average CO2 Emissions Content (kg C/MMBTU)	Equivalent Tax (per MMBTU)
CARBON TAX:		
Natural Gas	14.6	$1.17
Oil Products	20.8	$1.67
Coal	25.2	$2.08
GASOLINE TAX[a]:		
Gasoline	20.8	$8.00
Diesel	20.8	$8.00

Note: The gasoline tax must be extended to diesel fuel for light vehicles or the tax will become ineffective as new car buyers switch to diesel powered vehicles. The tax per gallon of diesel is $1.11 per gallon--higher than the gasoline tax to account for the greater energy content of diesel fuel.

Source: Emissions coefficients from Edmonds and Reilly IEA/ORAU Global Energy Economic Model. Taxes were indexed to natural gas based on their carbon content to raise revenues initially equivalent to a $1 per gallon gasoline tax.

Table 2a: Estimated Energy Price Elasticities of Demand, Transportation Sector

Source	Short-Run Estimate	Long-Run Estimate
Douglas Bohi[(a)]	Range from Literature Review: -0.11 to -0.41 Conclusion: -0.20	Range from Literature Review: -0.36 to 0.77 Conclusion: -0.7, or more elastic
Carol Dahl[(b)]	Avg. value from gasoline demand studies: -0.29	-1.02
Gately/Rappoport[(c)]	-----	-0.34 to -0.377
Edmonds/Reilly CO_2 Model	-----	-0.7

(a) Douglas Bohi, Analyzing Demand Behavior, (Resources For the Future, 1981). Elasticities refer to gasoline demand.

(b) Carol Dahl, "Gasoline Demand Survey," The Energy Journal, Vol 7, No. 1, 1986. Elasticities refer to gasoline demand.

(c) Dermot Gately and Peter Rappoport, "The Adjustment of U.S. Oil Demand to the Price Increases of the 1970s," The Energy Journal, Vol. 9 No. 2, 1988. Elasticities refer to total U.S. oil demand.

Table 2b: Estimates of Energy Price Elasticities of Demand: Other Sectors

Source	Short-Run Estimate	Long-Run Estimate
Douglas Bohi(a)		
Residential gas	-0.10	-0.50
Residential oil	-0.13 to -0.3	-1.1 to -1.76
Residential electricity	-0.20	-0.7
Industrial oil	-0.11 to -0.22	-0.8 to -2.82
Industrial gas	-0.07 to -0.21	-0.45 to -1.5
Industrial electricity	-0.04 to -0.22	-0.5 to -1.0
Electric utilities gas	-0.06	-1.43
Electric utilities oil	-0.10	-1.50
Electric utilities coal	-0.09 to -0.46	-0.67 to -01.15

(a) Douglas Bohi, Analyzing Demand Behavior, (Resources For the Future, 1981). The estimates for residential gas and electricity, industrial electricity (long-run), and electric utility gas and fuel oil (short-run) are, in Bohi's view, the most defensible among alternative measures. Elasticities for the remaining sectors and fuels are simply ranges drawn from the literature; no recommendation is implied.

Table 3: Carbon Tax: Assumptions and Results of Hand Calculations

Assumptions	Natural Gas	Oil	Coal	TOTAL[a]
Price Elasticity	-0.5	-0.5	-0.5	
Carbon Emissions Tax, ($/Million BTU)[b]	1.17	1.67	2.08	
Base Energy Price, 1987 ($/Million BTU)	4.10	6.09	1.47	
Price Increase Due to Carbon Tax (%)	29	27	141	
Baseline Carbon Emissions (1987, MT C)	271	637	470	1,378

Results	Natural Gas	Oil	Coal	TOTAL[a]
Initial Emissions Reduction (MT C)	32	73	166	272
Initial Emissions Reduction (%)	12	12	35	20
Energy Savings (Quadrillion BTU)	2.2	3.5	6.6	12.3
Initial Tax Revenue ($ Billion)	22	52	38	112
Adjusted Tax Revenue ($ Billion)	19	46	28	93

Source: Battelle Memorial Institute, Pacific Northwest Laboratories.

(a) May not sum to total due to rounding error. Emissions totals are not adjusted for feedstock consumption. Future growth in emissions is not included.

(b) The taxes are indexed to natural gas according to the carbon content of the delivered fuels.

Table 4: Gasoline Tax: Assumptions and Results of Hand Calculations

Assumptions	Gasoline	TOTAL
Price Elasticity	-0.5	
Gasoline Tax (1988/Million BTU)[a]	8.00	
Base Energy Price, 1987 ($/Million BTU)	7.30	
Price Increase Due to Gasoline Tax (%)	104	
Baseline Carbon Emissions (1987, MT C)	291	291

Results	Gasoline	TOTAL
Initial Emissions Reduction (MT C)	87	87
Initial Emissions Reduction (%)	30	6
Initial Energy Savings (Quadrillion BTU)	4.2	4.2
Initial Tax Revenue ($ Billion)	112	112
Adjusted Tax Revenue ($ Billion)	79	79

Source: Battelle Memorial Institute, Pacific Northwest Laboratories.

(a) A $1 per gallon gas tax is equivalent to $8 per million BTU tax.

Table 5: Tax Modelling Results Applying the PC-AEO Model

	Real GNP (10^9 $1982)		Gross Energy Use (QBTU)		Motor Gasoline Use (QBTU)	
Scenarios	1992	2000	1992	2000	1992	2000
AEO Base (a)	4434	5368	83.3	90.6	13.70	13.50
Carbon Tax (b)	4357 (-1.7)	5357 (-0.2)	78.0 (-6.4)	86.9 (-4.1)	13.06 (-4.7)	13.17 (2.4)
$1/Gallon Motor Fuels (c)	4434 (0)	5368 (0)	81.7 (-1.9)	89.4 (-1.3)	12.16 (-11.2)	12.34 (-8.6)

NOTE: Percentage changes relative to the AEO Base are shown in parentheses.

(a) From "Annual Energy Outlook 1989," DOE/EIA-0383.

(b) Carbon tax applied in 1990 as follows: Coal - $\$1.74/10^6$ BTU; Oil - $\$1.43/10^6$ BTU; Natural Gas $\$1.00/10^6$ BTU.

(c) Motor Fuels tax phased in over 3 years.

Table 6: Carbon Tax: Assumptions and Results of Edmonds-Reilly Model Simulations for 2000

Assumptions:	Natural Gas	Oil	Coal	TOTAL
Price Elasticity	-0.5	-0.5	- 0.5	
Price Increase Due to Carbon Tax (%)	25	25	100	
Baseline Carbon Emissions (1987, MT C)	352	591	660	1,613(a)

Results	Natural Gas	Oil	Coal	TOTAL
Initial Emissions Reduction (MT C)	12	62	215	289
Initial Emissions Reduction (%)	4	11	33	18

Source: Authors and David Barns, Pacific Northwest Laboratory, using Edmonds-Reilly IEA/ORAU Long-Term Global Energy-Economic Model

(a) Natural gas, oil, and coal sum to only 603 MT C. The difference is due to synthetic fuels and flaring.

Table 7: Gasoline Tax: Assumptions and Results of Edmonds-Reilly Model Simulations for 2000

Assumptions	Gasoline	TOTAL
Price Elasticity	-0.5	
Price Increase Due to Gasoline Tax (%)	100	
Baseline Carbon Emissions (1987, MT C)	591	1613
Initial Emissions Reduction (MT C)	92	92
Initial Emissions Reduction (%)	16	6

Source: Authors and David Barns, Pacific Northwest Laboratory, using Edmonds-Reilly IEA/ORAU Long-Term Global Energy-Economic Model

(a) Due to modeling constraints, the tax was actually applied to all transportation oil uses, including heavy-duty diesel vehicles. Thus, the tax leveled in this model fell on a broader class of vehicles than our hand-cranked case.

Table 8: Estimated Energy-GNP Feedback Elasticities

Sources	Estimate (1 percent Increase in Energy Price Leads to following percent decrease in real GNP)	Notes
Interrelationships of Energy and the Economy (DOE-PPA, 1981)	- 0.04 to - 0.05	Real GNP to real oil price. Estimated with DGEM model; elasticity shift from medium - to high price scenario.
Darby (1982)	(1) - 0.021	Real GNP to real price oil. Estimated on quarterly 1957-1976 data.
	(2) - No effect	Price control effect dominant. Estimated on quarterly 1949-1980 data.
Broadman/Hogan Harvard University (1986)	- 0.05	GDP to oil price shock.
Motor Fuels Tax (DOE-EIA 1987)	- 0.021	Real GNP to price of imported crude. Source: Darby paper.
Edmonds/Reilly CO_2 Model (PNL, 1988)	- 0.05	Real GNP to the price of energy Model services.
PC-AEO Forecasting Model (DOE/EIA, 1989)	- 0.03 to - 0.04	Real GNP to world oil price and 3 industrial prices: coal, electricity, natural gas.

Table 9: Estimated Impact on Residential Energy Use, By Income Level

FUEL CONSUMPTION[1]

Annual Income	Annual Energy Use Gas	Elec	Oil	Estimated Annual Carbon Tax: $/Household
	(Quadrillion BTU)			
<$5k	.42	.16	.1	137
$5-10k	.70	.31	.23	153
$10-15k	.67	.32	.17	152
$15-20k	.49	.23	.14	120
$20-25k	.45	.24	.12	122
$25-35k	.90	.50	.21	141
$35-50k	.70	.40	.16	115
$50k+	.67	.33	.11	101

NOTE: 1) National total by income category. Taxes per MMBTU for natural gas, electricity, and oil are, respectively, $1.00, $1.21 and $1.43.

Table 10: Gasoline and Carbon Tax Incidence per Capita, Estimated by State[1]
(Combined Taxes on Commercial and Residential Sector Energy Use)

STATE	ANNUAL TAX ESTIMATE GAS TAX ($Million)	ANNUAL TAX ESTIMATE CARBON TAX ($Million)	(A) ANNUAL PER CAPITA GAS TAX ($)	(B) ANNUAL PER CAPITA CARBON TAX ($)	A - B ($)
ALABAMA	1,926	724	480	409	301
ALASKA	229	291	467	na[2]	467
ARIZONA	1,576	535	486	393	323
ARKANSAS	1,146	421	492	407	315
CALIFORNIA	11,158	7,131	434	504	160
COLORADO	1,501	621	467	420	277
CONNECTICUT	1,327	508	418	389	259
DELAWARE	242	360	361	na[2]	361
FLORIDA	5,510	1,811	475	385	320
GEORGIA	3,178	1,198	529	426	333
HAWAII	336	208	319	425	124
IDAHO	435	144	454	373	311
ILLINOIS	4,562	1,878	401	392	238
INDIANA	2,517	1,208	463	449	244
IOWA	1,262	540	466	420	277
KANSAS	1,165	564	490	459	261
KENTUCKY	1,723	713	472	421	281
LOUISIANA	2,052	1,104	462	477	216
MASSACHUSETTS	2,354	1,000	406	401	235
MAINE	558	222	480	419	291

Table 10: Gasoline and Carbon Tax Incidence on Individuals, Estimated by State, continued

STATE	ANNUAL TAX ESTIMATE GAS TAX ($Million)	ANNUAL TAX ESTIMATE CARBON TAX ($Million)	ANNUAL PER CAPITA GAS TAX ($)	ANNUAL PER CAPITA CARBON TAX ($)	ANNUAL PER CAPITA GAS-CARB TAX ($)
MARYLAND	1,960	700	442	387	285
MICHIGAN	4,000	1,654	443	411	262
MINNESOTA	1,879	774	461	414	278
MISSISSIPPI	1,173	494	458	419	270
MISSOURI	2,584	988	518	425	323
MONTANA	406	172	529	441	318
NEBRASKA	698	320	470	430	270
NEW HAMPSHIRE	465	171	455	396	289
NEW JERSEY	3,310	1,677	437	450	217
NEVADA	515	227	537	463	304
NEW MEXICO	761	317	526	445	311
NEW YORK	5,779	2,370	328	363	194
NORTH CAROLINA	3,075	1,019	491	391	330
NORTH DAKOTA	326	152	543	453	319
OHIO	4,683	1,957	439	412	257
OKLAHOMA	1,671	658	520	430	319
OREGON	1,240	437	466	391	305
PENNSYLVANIA	4,331	1,966	368	395	203
RHODE ISLAND	375	153	385	386	229
SOUTH CAROLINA	1,602	493	482	376	336

Table 10: Gasoline and Carbon Tax Incidence on Individuals, Estimated by State[1], continued

STATE	ANNUAL TAX ESTIMATE GAS TAX ($Million)	ANNUAL TAX ESTIMATE CARBON TAX ($Million)	ANNUAL PER CAPITA GAS TAX ($)	ANNUAL PER CAPITA CARBON TAX ($)	ANNUAL PER CAPITA GAS-CARB ($)
SOUTH DAKOTA	359	134	544	419	355
TENNESSEE	2,522	917	530	421	339
TEXAS	8,547	3,770	526	457	299
UTAH	715	309	435	416	249
VERMONT	252	88	476	393	313
VIRGINIA	2,747	1,030	478	407	301
WASHINGTON	1,970	821	447	414	264
WEST VIRGINIA	783	320	413	397	247
WISCONSIN	1,939	795	414	396	248
WYOMING	291	147	620	522	328
USA TOTAL	105,875	46,305	460	401	280

NOTES: 1. Tax incidence is defined as the total of estimated payments for the use of residential and commercial sector energy sources. Tax rates are defined in Table 1, except for electricity, which is unique in each state and is calculated on the basis of the fuel mix in power generation in that state.

2. na = Not available. These values have been omitted due to unusual circumstances which distort the values. For example, Alaska's carbon tax total would amount to more than $700 per capita if jet fuel were included. However, much of this fuel is consumed for trans-Pacific flights. The tax payments on that fuel would of course not be borne by Alaskans.

SOURCE: Battelle Memorial Institute, Pacific Northwest Laboratories, calculated using "State Energy Data System Public Use File, 1960-1986," on floppy diskettes, Energy Information Administration, 1987.

Figure 1: Gasoline Prices in Selected Countries, 1988

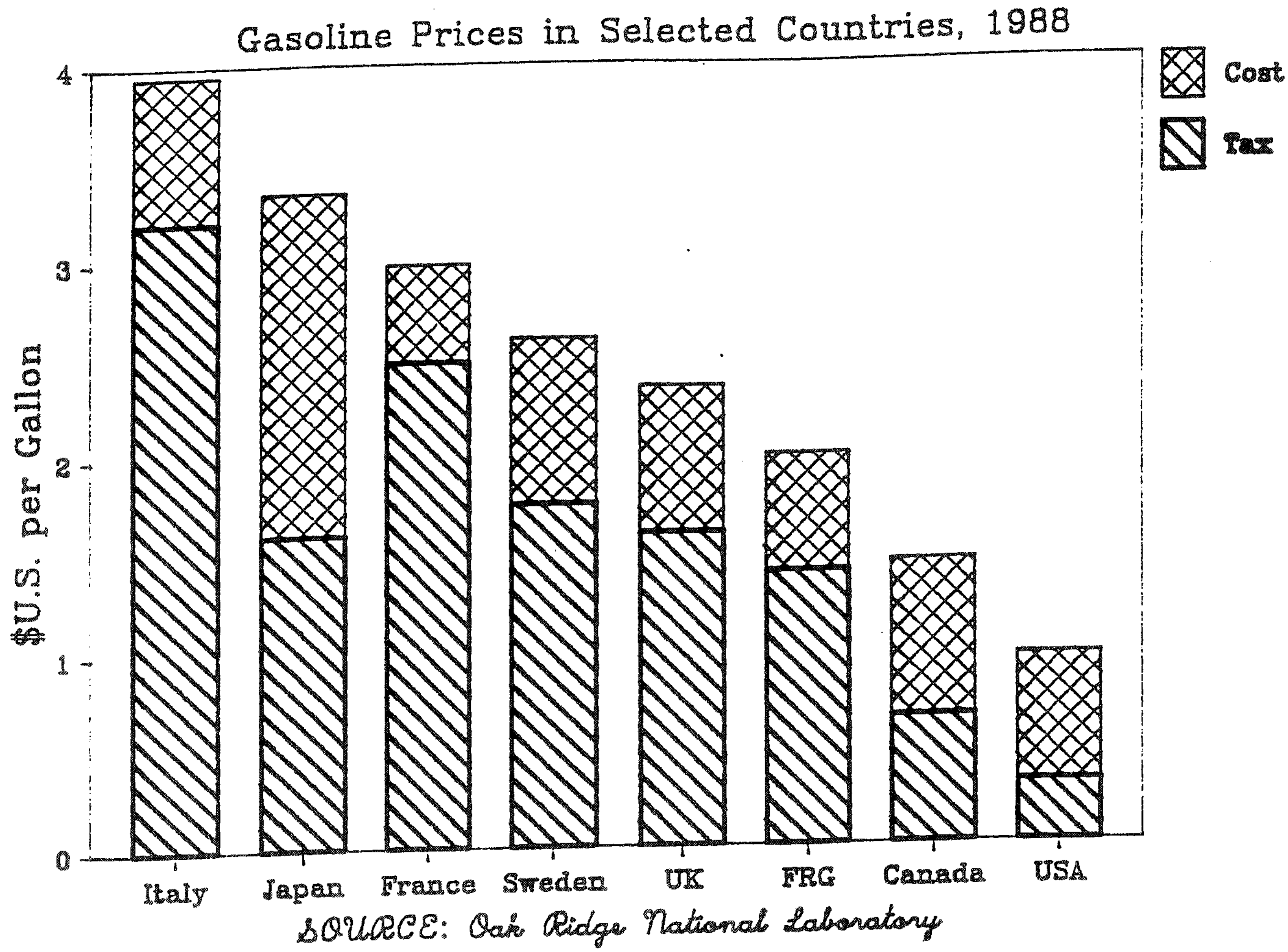


Figure 2: U.S. Auto Fuel Economy and Gasoline Prices, 1973-88

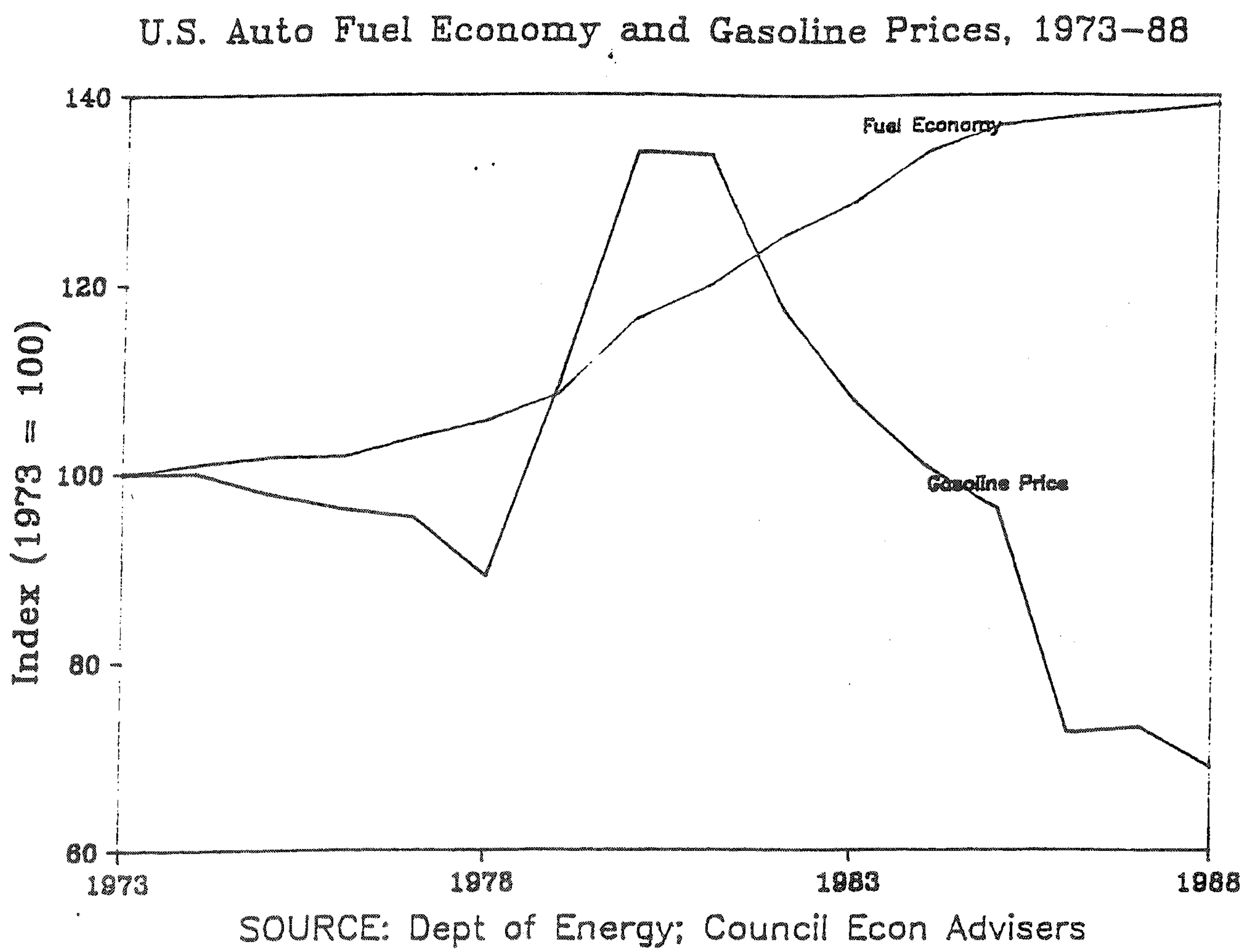


Figure 3: The Diminishing Effect of Price or Tax Increases on Energy Demand

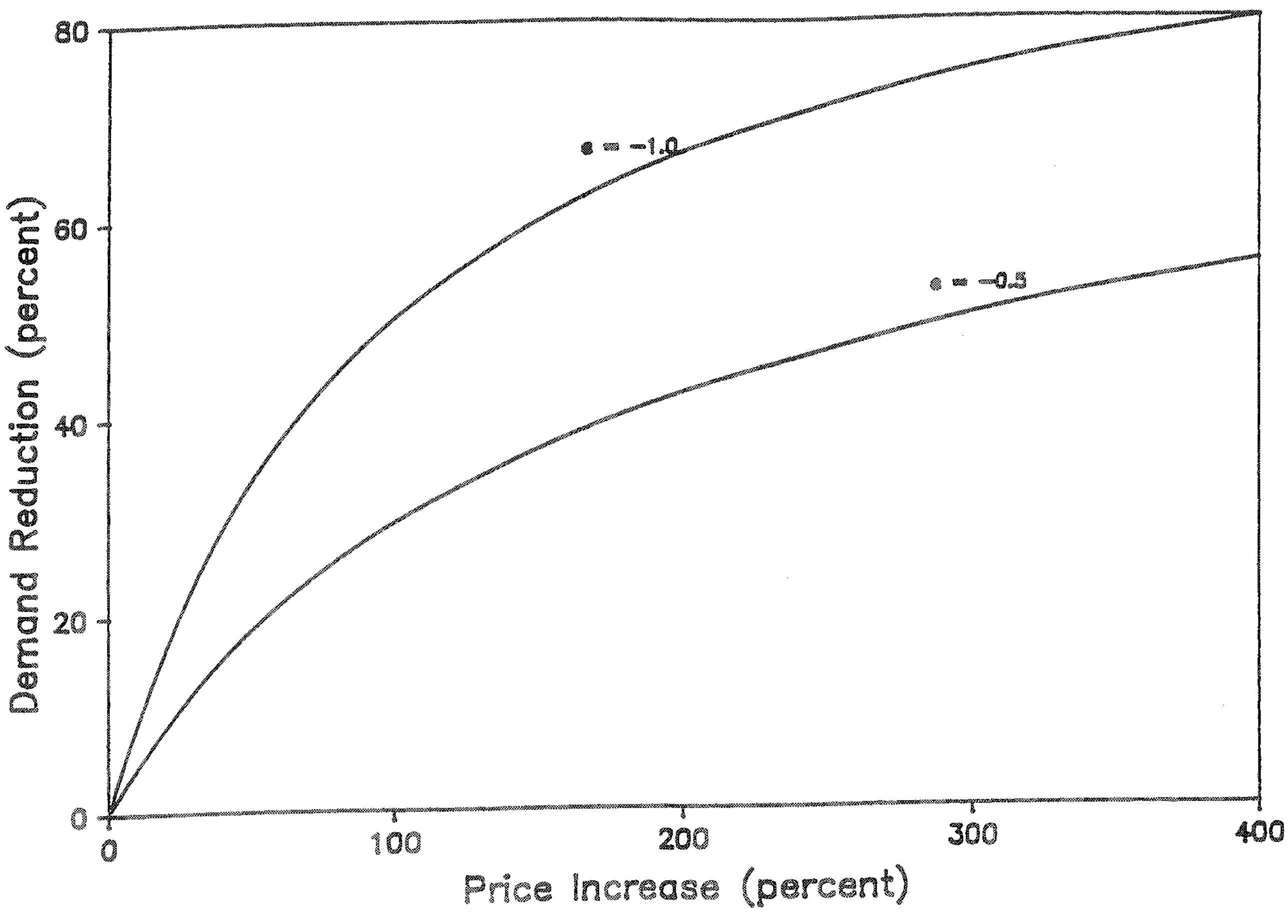
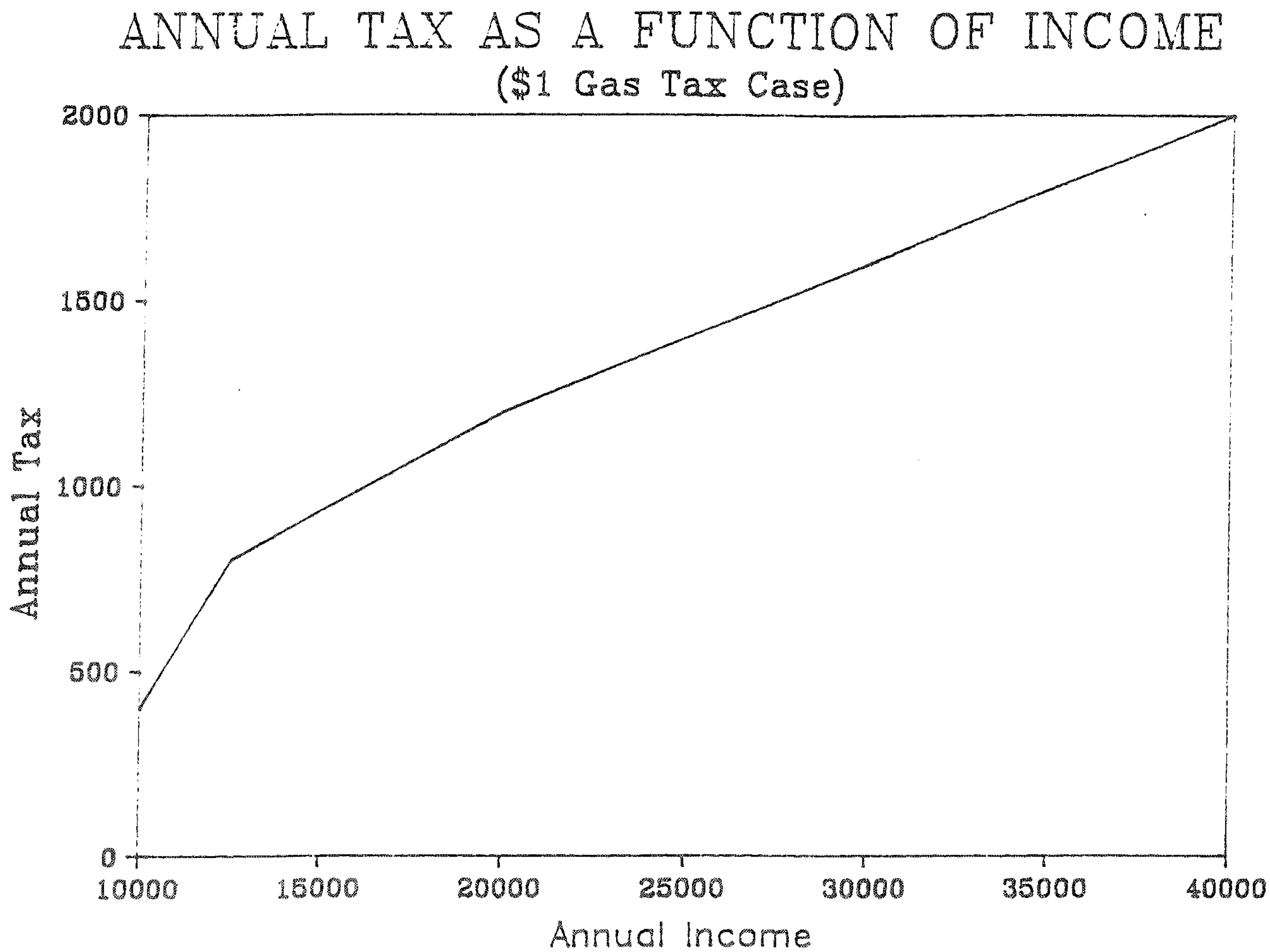


Figure 4: The Impact of a Gasoline Tax on Consumers, By Income Level



Source: Energy Information Administration

Figure 5: The Distribution of Gasoline Tax Impacts by State

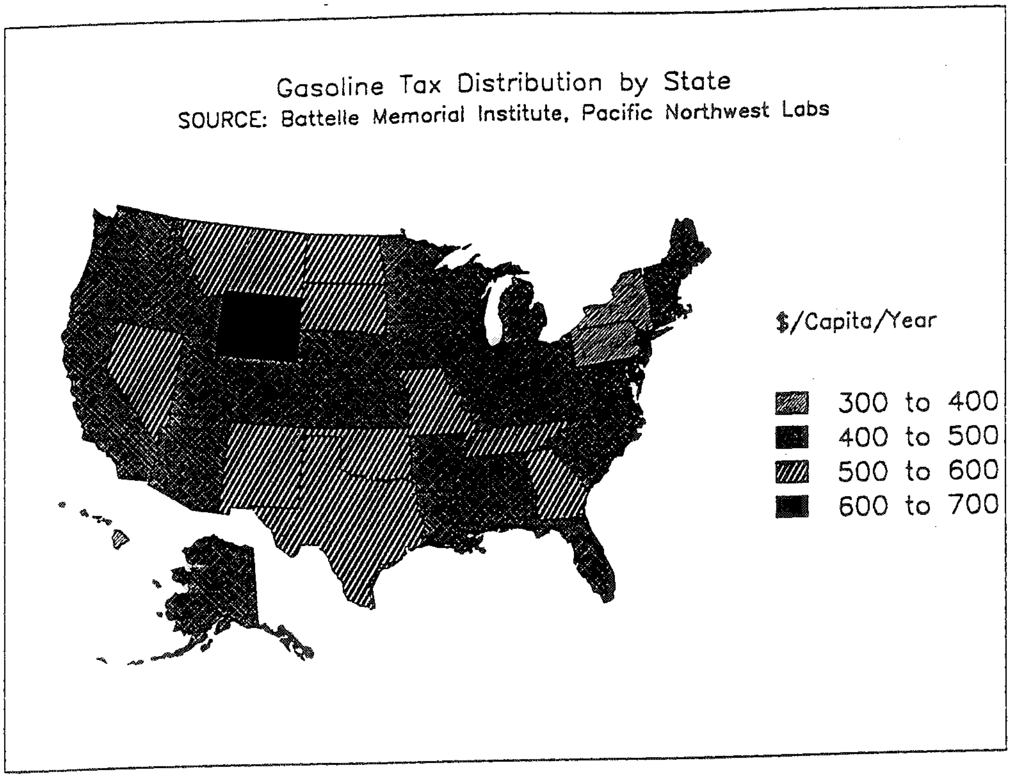
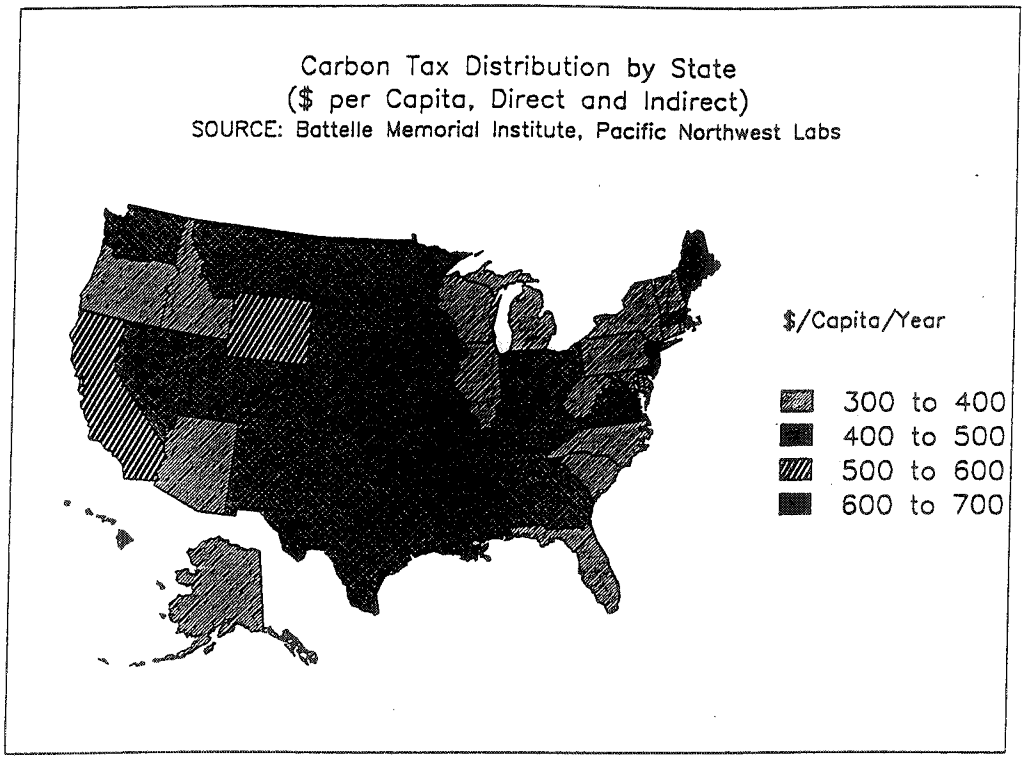


Figure 6: The Distribution of Carbon Tax Impacts by State



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1. Tom Stoel, et al, Blueprint for the Environment, Washington, D.C., November 1988.

2. The Changing Atmosphere, Report of the Toronto Conference on the Changing Atmosphere, June 1988.

3. We test an alternative analytical approach in which the price elasticity of coal is applied not through the ultimate weighted price increase on coal-electric power, but directly on coal purchased by electric utilities. The former method results in less carbon emissions reduction. It is an important test because the 10-year period considered here is relatively small for major fuel shifts out of coal.

4. Douglas R. Bohi, Analyzing Demand Behavior: A Study of Energy Elasticities (Washington: Resources for the Future, Johns Hopkins University Press, 1981); J.A. Edmonds, "A Review of Price Elasticities of Demand," Institute for Energy Analysis, 1981; Carol A. Dahl, "Gasoline Demand Survey," The Energy Journal, Vol. 7, No. 1, 1986; Dermot Gately and Peter Rappoport, "The Adjustment of U.S. Oil Demand to the Price Increases of the 1970s," The Energy Journal, Vol.9, No.2 1988.

   The first three references above are comprehensive reviews of the empirical literature on elasticities. They present specific estimates of the gasoline elasticity for transportation. Gately and Rappoport examine overall U.S. oil demand behavior under different assumptions about the long-run asymmetry of response as prices fall.

   See also Hillard G. Huntington, "Should GNP Impacts Preclude Oil Tariffs?," The Energy Journal, Vol. 9, No. 2, 1988; and Fred S. Singer, "The Case for a Variable Import Fee on Oil," Department of Transportation.

5. Bohi, Analyzing Demand Behavior.

6. In chapter 7 of Analyzing Demand Behavior, Bohi presents ranges of elasticities gleaned from his review of the literature by sector and by fuel. He also presents his best judgement about which general results are the most defensible. In most cases he does not recommend a specific elasticity. Nonetheless, a general trend emerges that short-run elasticities are very inelastic and in the neighborhood of zero to -0.2, and long-run elasticities are also inelastic, ranging between -0.5 and -1.0. Bohi notes that long-run elasticities in excess of unity occur only in the least defensible studies.

7. Edmonds, "A Review of Price Elasticities of Demand."

8. Dahl's best estimate for this long-run elasticity is derived from strictly cross-sectional data. Dahl notes that cross-sectional data estimations effectively capture longer-run adjustments to price changes, and are preferable to flow models. Dahl goes on to decompose the price elasticity of gasoline demand into two separate elasticities. Using estimates from each of these individual elasticities, Dahl then derives the implied result, which is -0.49 in the short-run and -1.12 in the long-run.

9. Gately and Rappoport employ a log-linear demand function, with lagged-price effects out to ten years. Unlike previous authors, they measured price response against oil price increases in all sectors, not just the transportation sector. This factor is likely unimportant in explaining the lower elasticity estimate, since Bohi's review of the elasticities for non-transportation uses of oil, such as residential and industrial fuel oil, finds these elasticities to be higher than those in the transportation sector.

10. Conceptually this "own-price" elasticity estimate represents the responsiveness of demand for a fuel when its price increases and all other energy prices are assumed to remain unchanged. Application of a carbon tax, however, would simultaneously increase all fossil fuel and electricity prices, causing a fairly complex set of interfuel substitutions to occur. The resulting change in demand for any given fuel would therefore be less than the case when only its price increased; put another way, the price elasticity would be smaller. In our fairly simple analysis, however, we do not examine the potential for interfuel substitution. To acknowledge this limitation, we employ own-price elasticities of -0.5, instead of -0.7 as suggested by the literature.

11. This issue is discussed in detail by David Greene in "CAFE Did It: An Analysis of the Effects of Federal Fuel Economy Regulations and Gasoline Price on New Car MPG, 1978-1989," draft paper prepared for the Office of Policy, Planning and Analysis, U.S. Department of Energy, May 1989.

12. H.G. Broadman and W.W. Hogan, "Oil Tariff Policy in an Uncertain Market," Energy and Environmental Policy Center, Harvard University.

13. Assuming $1.67 per million BTU.

14. The following example illustrates this point. Assume imports of oil are 4 million barrels per day and the world price is $18 per barrel. Now suppose U.S. demand increases by 1 million barrels per day, and this increases the world price to $20 per barrel. The total oil import bill increases to $100 million from $72 million per day--a $28 million increase. Thus, the country as a whole is paying $28/barrel for the additional one million barrels, although the private cost of the marginal barrel is still $20/barrel. In effect, the U.S. pays an $8 premium for the last barrel imported. The tariff would, in effect, require importers to pay the total social cost of their oil demand.

15. This conclusion has been criticized as ignoring the economic efficiency benefits of foreign trade.

16. See appendices D and E of Energy Security: A Report to The President of the United States, DOE/S-0057, U.S. Department of Energy, March 1987.

17. For additional detail on the assumptions and methodology of the gasoline tax beyond that provided in Energy Security, see the EIA report, "Cost and Benefit of a Motor Fuels Tax," SR/EAFD/87-02, March 1987.

18. The study employed three EIA models: the Intermediate Future Forecasting System, the Gas Analysis Modeling System, and the Oil Market Simulation Model. A base case was developed from the low world oil price scenario of Energy Information Administration, "Annual Energy Outlook 1986," U.S. Department of Energy.

19. These calculations were straightforward. We assumed price elasticities based on the literature, as discussed, and applied them to the assumed percentage price increases. The price increase ratio for the gasoline tax was simply the $1 per gallon tax divided by the 1988 average U.S. gasoline price, as reported by the Energy Information Administration. The price increase ratios for natural gas, oil, and coal under the carbon tax were estimated from the tax rates--distributed on the basis of carbon content, as described in the text--divided by 1988 prices. Applying the elasticities to these price increase ratios gave factors for long-term adjusted energy demand, excluding growth, and these factors were multiplied by actual energy demand by fuel type to obtain adjusted energy demand.

20. This very large range is a function of one choice: To evaluate consumer response for coal price increases at the point of utility coal consumption or consumer electric consumption. The former applies Bohi's price elasticity of coal demand for electric utilities, but assumes that utilities are relatively free to switch fuels. Such a magnitude of switching may not be realistic over a 10-year period. The latter assumes that the utilities do not switch from coal but simply pass on the price increase to consumers. The response is somewhat lower because the relative price increase on electricity--which includes the large expense of transmission and distribution--is less than the price increase for coal itself.

    The carbon emissions reduction resulting in the Edmonds-Reilly model may be over optimistic also because of the time period over which the model is initialized, which allows a longer period of adjustment than is available in reality.

21. This model is available for use on the more-powerful personal computers, and is based on LOTUS 1-2-3 software.

22. It is not literally true that we introduced a "tax," but rather that we increased the assumed price of the fuels involved to reflect the equivalent of a tax. This somewhat clumsy mechanism is the only way in which tax policy can be simulated with the model as it was designed. One major problem with this approach is that the supply models have to be shut off to prevent the tax from being erased, thus eliminating the supply response to a perceived price increase.

23. Tax rates were held constant in real terms.

24. Personal communication on February 8, 1990 with Ron Earley, Energy Information Administration, U.S. Department of Energy. In the DOE-EIA publication "Assumptions for the Annual Energy Outlook 1989," Earley is listed as the contact for macroeconomic assumptions.

25. The model is quite cumbersome to use. It has not been made transparent for the user, and thus it does not meet another key criterion for modelling validity: transparency. This conclusion is particularly important because results from use of the model have had and could continue to have an impact on national energy policy.

    For example, it is difficult to ascertain the complete set of price elasticities applied. Certain ones are listed in Energy Information Administration, "Assumptions for the Annual Energy Outlook 1989," DOE/EIA-0527(89), U.S. Government Printing Office, Washington, 23 June 1989. These include: Residential electricity, -0.187 to -0.446; residential gas, -0.268 to -0.456; residential distillate, -0.240 to -0.502, depending on geographical region. Price elasticities for gasoline and diesel fuel appear to be about -0.2 and virtually zero, respectively.

26. The difference between our results and those from the Edmonds-Reilly model can partly be explained by the fact that the Edmonds-Reilly model we used only allows the user to change the price of all transportation fuels. Hence, jet fuel and diesel are taxed with gasoline. In our hand-cranked experiment only gasoline is taxed, except of course in the sensitivity test we conducted.

27. One additional reason for the higher carbon emissions reduction of this run of the Edmonds-Reilly model is the effect of the carbon tax in reducing economic growth through an energy-GNP feedback elasticity. This effect is discussed later in the text, but it is important to note that Jae Edmonds agrees that this elasticity is probably not an accurate measure of GNP effects because it was estimated using actual energy price increases not offset elsewhere in the economy. That is, a tax increase offset by reduced sales taxes, for example, should not be analogous to increases in the world oil price. Personal communication, James A. Edmonds to W. Chandler and A. Nicholls, October 1989.

28. See Appendix E of <u>Energy Security</u>. An expanded description of how the DOE estimated the effects of the gasoline tax can be found in the Energy Information Administration service report, "Cost and Benefit Analysis

of a Motor Fuels Tax."

29. See Appendix D of Energy Security.

30. The DOE analysis assumes that for gasoline the feedback elasticity is -0.019. This elasticity implies that a 100 percent gasoline price increase from taxation will cause a 1.3 percent decrease in real GNP. The value of the primary energy-GNP feedback elasticity seems to hover between 0.02 and 0.05. This value is comparable to assumptions made by other analysts.

31. Michael R. Darby, "The Price of Oil and World Inflation and Recession," American Economic Review, September 1982.

32. Huntington, "Should GNP Impacts Preclude Oil Tariffs?

33. See for example Frank C. Wykoff, Macroeconomics: Theory, Evidence, and Policy. (Prentice-Hall, 1981.) See pages 87-101 for the standard macroeconomic argument that government expenditure multipliers are greater in magnitude than tax multipliers.

34. U.S. Department of Labor, Bureau of Labor Statistics, Chapter 19: "The Consumer Price Index," Reprint from BLS Handbook of Methods, Bulletin 2285, U.S. Government Printing Office, 1988. See "CPI Appendix 2, Relative Importance of All Components in the Consumer Price Indexes: U.S. City Average, December 1986."

35. Energy Information Administration, "Residential Transportation Energy Consumption Survey: Consumption Patterns of Household Vehicles 1985," U.S. Department of Energy, 9 April 1987.

36. See William U. Chandler and Holly L. Gwin, "Gasoline Conservation in an Era of Confrontation," in Daniel Yergin, The Dependence Dilemma: Gasoline Consumption and America's Security (Cambridge, Massachusetts: Harvard University Center for International Affairs, 1980).

37. Robert H. Williams, "A $2 A Gallon Political Opportunity," in Yergin, The Dependence Dilemma.

38. U.S. Department of Commerce, Statistical Abstract of the United States (Washington: U.S. Government Printing Office, 1989.