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THE INCIDENCE OF A U.S. CARBON TAX: A LIFETIME AND REGIONAL ANALYSIS

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ABSTRACT

This paper measures the direct and indirect incidence of a carbon tax using current income and two measures of lifetime income to rank households. Our results suggest that carbon taxes are more regressive when annual income is used as a measure of economic welfare than when proxies for lifetime income are used.

Further, the direct component of the tax, in any given year, is significantly more regressive than the indirect component. In fact, for 1987, the indirect component of the tax is mildly progressive. We observe a modest shift over time with the direct component of carbon taxes becoming less regressive and the indirect component becoming more regressive. These effects mostly offset each other and the distribution of the total tax burden has not changed much over time.

In addition we find that regional variation has fluctuated over the years of our anlaysis. By 2003 there is little systematic variation in carbon tax burdens across regions of the country.

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1. Introduction

Economists have long argued that market based instruments are more efficient than regulations as a means of addressing the social damages arising from polluting activities. By market-based instruments we mean policies that force firms to "internalize" the cost of polluting activities. In the context of climate change arising from greenhouse gas (GHG) emissions, the polluting activity is the release of carbon dioxide and other greenhouse gases.[1] Carbon taxes and cap and trade systems are two examples of market based instruments that create a cost to emissions. A carbon tax does this directly by taxing the carbon content of fuels while a cap and trade system imposes a cost by requiring the surrender of valuable permits in proportion to the carbon content of fossil fuels.[2]

U.S. greenhouse gas emissions equaled 7,147 million metric tons of CO_2 equivalent ($MMCO_2e$) in 2005, an increase of 17 percent over 1990 levels. Carbon dioxide emissions account for the vast bulk of emissions and equaled 6008.6 $MMCO_2$ in that year. A consensus is emerging in the United States that climate change is a critical issue requiring a reduction in GHG emissions. Several bills have been proposed in the current Congressional legislative session to control greenhouse gas emissions.[3] And at the end of May, President Bush called for the United States along with other major greenhouse gas emitting countries to "set a long-term goal for reducing greenhouse gases" (Stolberg (2007)). The recent releases of reports by Intergovernmental Panel on

[1] The major greenhouse gases include carbon dioxide, methane, nitrous oxide, and various fluorocarbons and other gases.
[2] While this analysis focuses on energy-related carbon emissions only, a carbon tax or cap and trade system can incorporate all greenhouse gases, typically by using the 100 year global warming potential coefficient for the various gases to convert to a CO_2 equivalent.
[3] Paltsev et al. (2007) describe and conduct an economic analysis of climate mitigation scenarios based on these proposals.

Climate Change Fourth Assessment Report's Working Groups provide additional evidence to support the role of anthropogenic warming. Working Group I describes the build-up of greenhouse gas concentrations and the role of human activity clearly:

> Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture.
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> Intergovernmental Panel on Climate Change (2007), p. 2

A major concern with either a carbon tax or a cap and trade program to reduce emissions is that the burden of the costs arising from the policy will fall disproportionately on poorer households – or in the terminology of incidence analysis, the policies will be regressive.[4] Metcalf (1999, 2007) argues that even if a carbon tax is regressive, a carbon tax reform (combining a carbon tax with a revenue neutral reduction in some other tax) can be distributionally neutral or even progressive if desired.

In this paper, we focus on a related but different point. We measure to what extent a carbon tax is regressive in a lifetime income framework.[5] We also decompose the burden of the tax into direct and indirect components. The direct component measures household burdens from their direct consumption of fuels (gasoline, home heating, and electricity) while the indirect component measures the increase in the cost of other goods resulting from the higher fuel costs used in their production. We look at

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[4] The costs of a regressive policy as a share of income fall as income rises. The opposite holds for a progressive policy. We are focusing only on the higher costs of fossil fuels arising from the policies. We do not focus on the use of the funds from a carbon tax or from auctioning permits in this paper.

[5] Without loss of generality we will frame the policy as a carbon tax. The analysis is identical for a cap and trade program where the permits are auctioned.

three different years, 1987, 1997, and 2003 to see how the incidence pattern would change had a carbon tax been in effect in these three time periods.

Our results suggest that in general, carbon taxes appear to be more regressive when income is used as a measure of economic welfare than when consumption (current or lifetime) is used to measure incidence. Further, the direct component of the tax, in any given year, is more regressive than the indirect component. In fact, for 1987, the indirect component of the tax is actually mildly progressive, as the higher income groups tend to pay a larger fraction of their "income" in carbon taxes.

Studying the intertemporal distribution, we find that between 1987 and 2003, direct taxes have become marginally less regressive, while indirect taxes have become marginally more regressive. As a result, the distribution of the total tax burden has not changed much over time.

Carbon taxes are also thought to have uneven regional effects. We report the average carbon tax paid per household across regions and find that the regional variation is at best modest. By 2003 variation across regions is sufficiently small that one could argue that a carbon tax is distributionally neutral across regions. Not surprisingly much of the variation that we do observe arises from the direct carbon tax rather than the indirect tax. In other words, differences in driving patterns and weather conditions drive the variation rather than the choice of energy intensive commodities in different regions.

In the next section, we explore different methods used to measure incidence and motivate the lifetime measure of consumption employed in Bull et al.(1994). Section III details our data and methodology. Section IV presents results for the economic incidence of the tax. Section V explores the geographic incidence of the tax. Section VI concludes.

II. Measurement of Incidence

Tax incidence measures the ultimate impact of a tax on the welfare of members of society. The economic incidence of a tax may differ markedly from the statutory incidence due to price changes. For a carbon tax, the short run economic incidence is likely to differ markedly from the economic incidence. While the statutory incidence of an upstream tax on gasoline may be on the refinery owner, the economic incidence is likely to be on final consumers as the tax is shifted forward to consumers in the form of higher prices. Measuring the incidence of a tax requires numerous assumptions and we begin the analysis by setting out our assumptions and methodology.

First, we must determine the appropriate unit of observation, which could be an individual or a household. For this study, we use the household as a unit. Second, we must choose the appropriate time frame of analysis. As we discussed in the introduction, the choice of the time frame for the analysis is extremely important. Early tax incidence analysis used current income as the base i.e. it compared the tax liability over a short period to income earned over that period. Following Friedman (1957) and the permanent income hypothesis, there was a realization that consumption decisions are made over a longer time horizon. Hence income should be measured as the present discounted value of lifetime earnings and inheritances. Failing to do so creates substantial measurement problems, particularly at the low end of the income distribution. For example, elderly people drawing down their savings in retirement will look poor when in fact, they may be comfortably well off in a lifetime context. In other words, many low-income people are not necessarily poor.[6] Caspersen and Metcalf (1993) report cross tabulations on income

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[6] Pechman (1985) realized that income data for the low income groups suffered from substantial income mismeasurement. Since then, the approach adopted by him and several others, including in this paper, is to

and consumption that show that a large fraction of households are in consumption deciles substantially above their income deciles.

Poterba (1989) follows the approach of using current consumption as a proxy for permanent income, since if consumer behavior is consistent with the permanent income hypothesis, then consumers would set current consumption proportional to permanent income. However, as we mentioned earlier, using data from the 1987 Consumer Expenditure Survey, Bull et al. (1994) show that consumption, instead of being smooth, closely tracks current income over the lifecycle. Moreover, energy consumption also shows a marked lifetime pattern.

This could be problematic for the incidence measurement. Suppose that as people grow old their energy consumption becomes a larger share of their total consumption, and suppose, as well, that over a lifetime the energy tax has a proportional incidence, then using current consumption to measure lifetime income, the energy tax would appear regressive.

As an alternative to current consumption, we use an adjusted lifetime measure for consumption that is intended to correct for long-run predictable swings in behavior. This measure was first employed in Bull et al. (1994). Ideally, a lifetime measure of incidence would be constructed by taking the ratio of lifetime energy taxes to lifetime earnings. Unfortunately, the lack of any sufficiently long longitudinal panel data set precludes such an approach.[7]

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discard the bottom half of the lowest decile i.e. to only look at the bottom 5-10 percent in the bottom decile, rather than the entire 10 percent.

[7] The Panel Study of Income Dynamics (PSID) has good data on income but lacks detailed data on consumption which we would require. Other authors have used it to study the lifetime incidence of alcohol and cigarette taxes (Lyon and Schwab, 1995) and gasoline taxes (Chernick and Reschovsky, 1992).

To proxy for lifetime consumption, we therefore use the age profile of people sampled in a particular year by the Consumer Expenditure Survey (a more detailed detailed description of the calculation is presented in Bull et al. (1994)). In particular, we first classify people into different subsamples based on their educational level, since the pattern of income and consumption will be quite different for people with vastly different human capital stocks. For each sub sample, we then calculate a "typical" path of consumption through the averages for the age groups. For a given person in the sub sample we know the ratio of their current consumption to the average for their age group. We then compute their lifetime consumption by multiplying this ratio by the present value of the typical lifetime path.

For example, suppose an individual is a 35-year-old PhD whose energy consumption is 80 percent of the average for her age and education group. Let's say the present discounted value of total lifetime energy consumption for a person with a PhD is $80,000. Then for this individual, the imputed lifetime energy consumption is $64,000.

This procedure allows the age profile of each variable to be different. This flexibility helps to control for any confounding effects on the incidence calculation that predictable lifetime patterns of consumption behavior introduce in the cross-section. For example, suppose an alternative lifetime correction method was used where the share of consumption received at age 35 was used as the correction method. If 5 percent of consumption occurs on average at age 35 for a person in a given educational class, then that person's imputed lifetime consumption is 20 times their current consumption. Suppose that the lifetime incidence correction did not renormalize for each variable studied, but rather used the same correction factor for energy consumption. Then one would multiply current energy consumption by 20 to impute lifetime energy consumption. But if in reality, 10 percent of energy consumption is spent on average at age 35 for a person in a given educational class, then that person's imputed lifetime energy consumption should be 10 times their current energy consumption. Failing to renormalize the incidence correction for each of the variables studied in this example would incorrectly double lifetime energy consumption, biasing incidence results.

Using consumption as the base for measuring income also addresses the problem of transitory income shocks. For instance, a downward shock to income may push the recipient into a lower income decile, while leaving their energy consumption unchanged (especially if the income shock is temporary). In this case, the ratio of energy taxes to income would be higher than it would be under a correct lifetime measure. Similarly, an upward shock to income may push the recipient into a higher income decile, while leaving their energy consumption unchanged. Here, the ratio of energy taxes to income is lower than it would be under a correct lifetime measure. The combination of these effects would lead an income-based lifetime incidence correction to be biased toward regressivity. When lifetime incidence is measured against consumption, however, such transitory effects are less likely to lead to bias, since energy consumption and total consumption are likely to react together to income shocks, if they react at all.

The final issue in an incidence analysis is how to allocate the tax burden. Taxes on energy can be passed forward into higher consumer prices or backward in the form of lower returns to factors of supply (capital, labor, and resource owners). A number of large-scale general equilibrium models suggest that in the short to medium run, the burden of a carbon tax will be passed forward into higher consumer prices. See, for example, Bovenberg and Goulder (2001) and Paltsev, et al. (2007) for recent studies indicating that the short-run burden of a carbon tax will be essentially on consumers. Based on the results of these and similar studies, we assume that the burden of the carbon tax falls on consumers.

III. Methodology and Data

For purposes of our analysis, we consider the effect of a carbon tax set at a rate of $15 per metric ton of carbon dioxide assuming it were in effect in three different years: 1987, 1997, and 2003. This allows us to see how changing consumption patterns over time influence the distribution of the tax. Because we are considering a carbon tax in different years, we deflate the tax rate to keep it constant in year 2005 dollars. Using the CPI deflator, the tax rates we consider are $8.73 in 1987, $12.33 in 1997, and $14.13 in 2003. The incidence calculations require two types of data. First, to assess the impact of the carbon tax on industry prices and subsequently on prices of consumer goods, we use the Input-Output matrices provided by the U.S. Bureau of Economic Analysis. Second, once we have the predicted price increases for the consumer goods, we need to assess incidence at the household level. For this, we used data from the U.S. Bureau of Labor Statistics Consumer Expenditure Survey for various years. In this section, we explain briefly our use of these two different data sets.

Energy related emissions of CO_2 were 4,821 million tons in 1987, 5,422 million tons in 1997, and 5,800 million tons in 2003. Given the tax rates and ignoring initial reductions in emissions, the tax would raise $42.1 billion in 1987, $66.9 billion in 1997, and $82.0 billion in 2003.[8]

[8] An analysis by the Energy Information Administration suggests that a $15 tax on CO_2 would reduce emissions by about five percent in the short-run (see Energy Information Administration (2006)).

We assume the tax is levied on coal at the mine mouth, natural gas at the well head, and on petroleum products at the refinery. Imported fossil fuels are also subject to the tax. As noted above we assume in all cases that the tax is passed forward to consumers in the form of higher energy prices. Metcalf (2007) estimates that a tax of $15 per metric ton of CO_2 applied to average fuel prices in 2005 would nearly double the price of coal, assuming the tax is fully passed forward. Petroleum products would increase in price by nearly 13 percent and natural gas by just under 7 percent. The tax is also passed on indirectly to other industries that use these energy sources as inputs.

The procedure for evaluating the effect of a carbon tax as it is passed through the economy is discussed in detail in Fullerton (1995) and Metcalf (1999). We provide a summary of the methodology in the Appendix. The starting point for the analysis is the use of Input-Output matrices available from the Bureau of Economic Analysis. In particular, we use the Summary Make and Use matrices from the I-O tables for 1987, 1997, and 2003. The Make matrix shows how much each industry makes of each commodity and the Use matrix shows how much of each commodity is used by each industry. Using these two matrices for each year, we derive an industry-by-industry transactions matrix which enables us to trace the use of inputs by one industry by all other industries. Various adding-up identities along with assumptions about production and trade allow the accounts to be manipulated to trace through the impact of price changes (and taxes) in one industry on the products of all other industries in the economy.

For each year, we cluster the industry groups provided in the I-O tables into 60 categories. For 2003, we separate out aggregate mining into two separate groups, mining and coal mining using the split provided in the 2002 benchmark I-O files. We do a similar split to break out electricity and natural gas from other utilities. This was not a problem for the 1987 and 1997 benchmark I-O files, where these splits already existed.

Once we obtained the effect of the tax on prices of consumer goods, we used data from the Consumer Expenditure Survey (CEX) to compute energy taxes paid by each household in the survey. The CEX contains data on household income and expenditures for numerous consumption goods. We combine commodities to work with 42 categories of personal consumption items. Having computed the average price increase for each industry using the Input-Output tables from the Bureau of Economic Analysis, we translate those price increases into corresponding price increases for these consumer items. This is also discussed in detail in the Appendix, and we provide tables showing the recorded price increases in each year for each consumer item as a result of the tax.

IV. Results

Table 1 presents our results for incidence using annual income as our measure of economic welfare. We have grouped households by annual income and sorted the households into ten income deciles from the poorest ten percent of the population to the richest ten percent. Confirming conventional wisdom, the carbon tax is quite regressive when measured relative to current income for all three years. The burden in the lowest decile in 1997 and 2003, for example, is over four times the burden in the top decile when measured as a fraction of annual income.

TABLE AND FIGURE 1 ABOUT HERE

Figure 1 shows that the overall burden distribution has not changed substantially across the sixteen year period when annual income is used to rank households. There is a slight flattening of the average tax rate curve across the three years. The burden has fallen by roughly one half a percentage point in the bottom three deciles while only falling roughly two-tenths of a percentage point in the top three deciles. The overall burden is declining slightly over time from 1.54 percent of income in 1987 to 1.30 percent by 2003. This in part reflects the greater energy efficiency of the economy. Aggregate energy intensity in the United States (measured as energy consumption relative to real GDP) fell by 23 percent between 1987 and 2003.[9]

Table 2 (and Figure 2) show the burden of the direct component of the tax in the three years. The direct component of the tax is highly regressive – the average tax rate in the bottom decile is 4.9 times the average tax rate in the highest decile in 1987, 6.3 times in 1997 and 5.7 times in 2003. As with the total burden, the direct burden is declining slightly over the sixteen year period. The overall direct burden declines from 0.79 percent of income in 1987 to 0.73 percent in 1997 and to 0.58 percent by 2003.

TABLE AND FIGURE 2 ABOUT HERE

Table 3 and Figure 3 shows that the indirect burden is relatively constant over this time period. The regressivity of the indirect portion of the tax has increased slightly with the burden in the lowest decile rising from 2.5 times the burden in the top decile in 1987 to 3.6 times in 2003. That the indirect component of the tax is regressive but to a lesser extent than the direct component is consistent with the observation of Herendeen, Ford, and Hannon (1981) that indirect and direct energy consumption profiles differ in shape.

TABLE AND FIGURE 3 ABOUT HERE

In summary, had a carbon tax been in effect in 1987, 1997, and 2003, the tax would have looked quite regressive using annual income as a measure of household well being. Using an annual income approach, the regressivity is increasing slightly over this

[9] See Metcalf (2007b) for an analysis of the determinants of changes in energy intensity.

time period. The overall burden falls a bit with the decline primarily attributable to declines in the direct burden of the tax.

Turning to the measures of incidence using consumption as a proxy for lifetime income, the results change dramatically. Table 4 (and Figure 4) shows the distribution of the carbon tax in the three years when households are sorted by current consumption. Now we find that the total carbon tax is less regressive, with the ratio of average taxes paid by the bottom and the top varying from about 1.6 to 1.8 across the three years.

TABLE AND FIGURE 4 ABOUT HERE

The next two tables and figures demonstrate that nearly all of this regressivity can be accounted for by the direct component of the tax, since the indirect component is roughly proportional between the top and bottom deciles. Even the direct component is less regressive than when we used current income to construct average tax rates. The ratio of direct taxes paid by the bottom and top deciles ranges between about 2.4 and 2.6 the three years. This is nearly half the ratio when we used current income as the welfare measure. The indirect burden is slightly progressive in 1987 but becomes essentially proportional in the latter two years.

TABLES AND FIGURES 5, 6 ABOUT HERE

Turning to the measures of average tax burdens using lifetime consumption (Tables 7, 8, and 9), we see that this correction flattens the distribution even more. Indeeed, the burden is now slightly progressive over the bottom half of the income distribution. The incidence of the total carbon tax is nearly proportional, with the ratio of burden in the lowest to top decile varying from 1.3 to 1.4 across the three years. Both the direct and the indirect components of the tax are the least regressive using this measure.

As with the current consumption proxy for lifetime income in 1987, the indirect tax using our lifetime income measure is marginally progressive.

TABLES AND FIGURES 7-9 ABOUT HERE

In summary, incidence calculations based upon annual income imply much steeper regressivity than do calculations based upon lifetime income proxies. Moreover, the inter-temporal variation in incidence is reduced substantially using measures based on lifetime consumption rather than those using income. We suspect this occurs in large part because transitory income shocks exacerbate the apparent regressivity of the tax when measured against income.

V. Regional Incidence of the Tax

In this section, we will focus on the regional incidence of the tax. Policy makers are often concerned that a tax might disproportionately burden one region or part of the country at the expense of another. To measure the geographic burden of the tax, we group households by region and measure their average tax rate using weighted averages of the tax burdens.[10] Results are shown in Tables (and Figures) 10, 11 and 12. Variation in the average tax rates peaks in 1997 and is quite modest by 2003. The maximum difference in the average rate across regions is less than two-thirds of a percentage point in 1987. The maximum difference rises to 0.9 percentage points in 1997 and then falls to just over one-third of a percentage point in 2003. It is quite remarkable how small the differences are across the regions given the variation in weather conditions and driving patterns across the regions.

TABLE AND FIGURE 10 ABOUT HERE

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[10] As with the distributional tables across income, we drop the bottom five percent of the income distribution from the analysis before carrying out the regional analysis.

Tables 11 and 12 indicate that the bulk of the variation across regions in carbon tax payments arises from the direct portion of the tax. This is perhaps not surprising given that purchased commodities are increasingly traded across regions in the United States leading to homogenization of the indirect carbon tax effect.

TABLES AND FIGURES 11, 12 ABOUT HERE

VI. Conclusion

This paper measures the incidence of carbon taxes using a lifetime incidence framework. We analyze the household burden of a $15 per metric ton tax on CO_2 in constant 2005 dollars at three different points in time. The burden is measured ranking households by current income, current consumption and lifetime consumption as the basis for the incidence measures. The methodology involves first working with the economy-wide Input-Output tables from the Bureau of Economic Analysis to assess how the $15 tax would affect the industrial sector, in particular the prices of energy goods and other industrial goods in which these energy goods serve as inputs. We then use this information to calculate the increase in prices of consumer goods as a result of the tax. Once we obtain the price increase in 42 categories of consumer goods, we calculate the burden of the tax on households using consumption data from the Consumer Expenditure Survey.

As the paper discusses, energy taxes have different incidence effects across the lifecycle. Therefore, it is important to measure the burden of taxes in terms of lifetime incidence, not just their burden in a given year. To take account of the lifetime incidence, we use two proxies. First we use current consumption following work of Poterba (1989).

Second we use lifetime-corrected consumption introduced in Bull et al. (1994) and explained in detail in the Appendix to that paper.

Our results suggest that when the total lifetime effect of a carbon tax is taken into account, the regressivity of the tax decreases. This is particularly true when we use lifetime-corrected consumption to rank households, rather than current consumption. While the direct tax effect continues to be regressive to varying extents depending upon the incidence measure we use, the indirect effect is much more proportional, thus mitigating the effect of direct taxes on total taxes. This is particularly true for the year 1987 when the indirect tax appears to be mildly progressive.

In addition to looking at the economic incidence of the tax, we studied the incidence of the tax across regions. These data show that the variation across regions is relatively modest with the variation decreasing over time.

Our results suggest that a carbon tax is far less regressive than is generally assumed when the analysis is done on a lifetime basis. This suggests that concerns over the distributional impact of a shift to a carbon tax may be overstated. It should be emphasized that we have not addressed how the revenues of the tax are utilized, either to lower other taxes, reduce the deficit, or finance new spending. Metcalf (2007) presents an analysis of a carbon tax reform that is distributionally neutral when evaluated in an annual income framework. The results of this analysis suggest that such a reform may be progressive when analyzed in a lifetime income framework.

Our results also suggest an interesting area for future research. If a carbon tax applies only to indirect energy consumption, then it would be almost distributionally neutral, and accomplish that without any additional changes to the tax code. Future research should explore whether environmental objectives could be achieved with such a tax, and evaluate the other economic consequences of applying the tax to the indirect base only.

References

Armington, Paul S. (1969), “A Theory of Demand for Products Distinguished by Place of Production,” International Monetary Fund Staff Papers 16, pp. 159-176

Bovenberg, A. Lans and Lawrence Goulder. "Neutralizing the Adverse Industry Impacts of CO2 Abatement Policies: What Does It Cost?," C. Carraro and G. E. Metcalf, *Distributional and Behavioral Effects of Environmental Policy.* Chicago: University of Chicago Press, 2001, 45-85.

Boyd, R. and N.D. Uri (1991), “The Impact of a Broad based Energy Tax on the U.S. Economy,” Energy Economics, pp. 259-273

Bull, Nicholas, Hassett, Kevin A. and Gilbert E. Metcalf (1994), “Who Pays Broad-Based Energy Taxes? Computing Lifetime and Regional Incidence,” The Energy Journal, Vol. 15, No. 3

Caspersen, E. and Gilbert Metcalf (1993), “Is a Value Added Tax Progressive? Annual Versus Lifetime Measures,” National Tax Journal

Chernick, H. and A. Reschovsky (1992), “Is the Gasoline Tax Regressive?,” Institute for Research on Poverty Discussion Paper No. 980-92

Energy Information Administration (2006). "Emissions of Greenhouse Gases in the United States 2005", Washington, DC: Energy Information Administration.

Energy Information Administration (2006). "Energy Market Impacts of Alternative Greenhouse Gas Intensity Reduction Goals," Washington, DC: EIA, SR/OIAF/2006-01.

Friedman, M.A. (1957), *A Theory of the Consumption Function*. Princeton University Press

Fullerton, Don and Gilbert E. Metcalf (1998), “Environmental Taxes and the Double Dividend Hypothesis: Did You Really Expect Something for Nothing?,” Chicago-Kent Law Review 73, No. 1, pp. 221-256

Fullerton, Don (1995), “Why Have Separate Environmental Taxes?,” NBER Working Paper no. 5380

Goulder, L.H. (1992), “Carbon Tax Design and U.S. Industry Performance,” Tax Policy and the Economy 6, pp. 59-104

Hannon, B. (1982), “Analysis of the Energy Cost of Economic Activities: 1963 to 2000,” Energy Systems Policy 6(3), pp. 249-278

Hannon, B., et al (1978), “Energy and Labor in the Construction Sector,” Science 202 (204), pp. 37-47

Herendeen, R.A., C. Ford and B. Hannon (1981), “Energy Cost of Living, 1972-1973,” Energy 6(12), pp.1433-1450

Hudson, E.A. and D.W. Jorgenson (1974), “U.S. Energy Policy and Economic Growth, 1975-2000,” Bell Journal of Economics 5(0), pp. 461-514

Intergovernmental Panel on Climate Change (2007). "Contribution of Working Group I to the Fourth Assessment Report," Geneva Switzerland: IPCC.

Jorgenson, D.W. and P.J. Wilcoxen (1992), “Reducing U.S. Carbon Dioxide Emissions: An Assessment of Different Instruments,” Harvard Institute of Economic Research Discussion Paper No. 1590

Leontief, W. (1986) Input-Output Economics, 2nd Edition, New York: Oxford University Press

Lyon, A. and R. Schwab (1995), “Consumption Taxes in a Life-Cycle Framework: Are Sin Taxes Regressive?,” Review of Economics and Statistics, 77, 3, pp. 389-406

Metcalf, Gilbert E. (1999), “A Distributional Analysis of Green Tax Reforms,” national Tax Journal, Vol. 52, no.4 (December), pp. 655-682

Metcalf, Gilbert E. (2005), “Tax Reform and Environmental Taxation,” NBER Working Paper No. 11665

Metcalf, Gilbert E. (2007), “A Proposal for a U.S. Carbon Tax Swap: An Equitable Tax Reform to Address Global Climate Change," The Hamilton Project, Brookings Institution, October 2007.

Metcalf, Gilbert E (2007b). "An Empirical Analysis of Energy Intensity and Its Determinants at the State Level," Medford, MA: Tufts University Department of Economics.

Musgrave, R., K. Case and H. Leonard (1974), “The Distribution of Fiscal Burdens and Benefits,” Public Finance Quarterly 2, pp. 259-311

Paltsev, Sergey; John M. Reilly; Henry D. Jacoby; Angelo C. Gurgel; Gilbert E. Metcalf; Andrei P. Sokolov and Jennifer F. Holak (2007). "Assessment of U.S. Cap-and-Trade Proposals," Cambridge, MA: MIT Joint Program on the Science and Policy of Global Change, Report No. 146.

Pearce, David (1991), “The Role of Carbon Taxes in Adjusting to Global Warming,” The Economic Journal 101, pp. 938-948

Pechman, J. A. (1989), “Who Paid the Taxes, 1966-1985?,”Washington D.C.: The Brookings Institution

Poterba, James (1989), “Lifetime Incidence and the Distributional Burden of Excise Taxes,” The American Economic Review, Vol. 79, No. 2, Papers and Proceedings of the Hundred and First Annual Meeting of the American Economic Association (May), pp. 325-330.

Stolberg, Sheryl Gay (2007). "Bush Proposes Goal to Reduce Greenhouse Gas Emissions." *New York Times*, June 1, 2007.

Tullock, Gordon (1967), “Excess Benefit,” Water Resources Research 3, No. 2, pp. 643-644

Appendix

1. Using the Input-Output Accounts (based on Fullerton, 1995, and Metcalf, 1999)

The Input-Output accounts trace through the production of commodities by industries and the use of those commodities by industries. The Bureau of Economic Analysis provides two kinds of matrices that help us to track such transactions through the economy. The Make-matrix, M_{IxC}, shows how much each industry makes of each commodity, and the Use-matrix, U_{CxI}, shows how much of each commodity is used by each industry. Combining these two, we can derive the industry-by-industry transactions matrix by dividing each entry of M_{IxC} by its column sum and multiplying the resulting matrix by the use matrix, U_{CxI}. Using the resulting matrix, it is possible to trace the use of inputs by one industry by all other industries. Further, it is also possible to trace through the impact of price changes in one industry on the products of all other industries in the economy. Below we detail some of the steps involved.

Tracing price changes through the economy on the basis of Input-Output accounts dates back to work by Leontief (1986). The model makes a number of important assumptions, the most important of which are (1) goods are produced and sold in a perfectly competitive environment such that all factor price increases are passed forward to consumers, (2) domestic and foreign goods are sufficiently different so that the price of domestic goods can adjust following changes in factor prices (Armington, 1969) and (3) input coefficients (the amount of industry *i* used in the production of industry *j*) are constant. Thus, input substitution is not allowed as factor prices change. This last assumption means that price responses are only approximate as they don't allow for product mix changes as relative prices change. In effect, the Input-Output accounts can be used to trace first-order price effects through the economy.

Two sets of equations define the basic Input-Output accounts. The first set relates the demand for goods from an industry to the value of output from that industry:

$$
\begin{aligned}
&x_{11} p_1 + x_{12} p_1 + \ldots\ldots + x_{1N} p_1 + d_1 p_1 = x_1 p_1 \\
&x_{21} p_2 + x_{22} p_2 + \ldots. + x_{2N} p_2 + d_2 p_2 = x_2 p_2 \\
&. \\
&. \\
&. \\
&x_{N1} p_N + x_{N2} p_N + \ldots. + x_{NN} p_N + d_N p_N = x_N p_N
\end{aligned}
\qquad [1]
$$

Where x_{ij} is the quantity of the output from industry i used by industry j, p_i is the unit price of product i, d_i is the final demand for output i and x_i is the total output of industry i. These N equations simply say that the value of output from each industry must equal the sum of the value of output used by other industries (intermediate inputs) plus final demand. Without loss of generality, we can choose units for each of the goods so that all prices equal 1. This will be convenient as the expenditure data in the Input-Output accounts can then be used to measure quantities prior to any taxes that we impose.

The second set of equations relates the value of all inputs and value added to the value of output:

$$
\begin{aligned}
&x_{11} p_1 + x_{21} p_2 + \ldots\ldots + x_{N1} p_N + v_1 = x_1 p_1 \\
&x_{12} p_1 + x_{22} p_2 + \ldots. + x_{N2} p_N + v_2 = x_2 p_2 \\
&. \\
&. \\
&. \\
&x_{1N} p_1 + x_{2N} p_2 + \ldots. + x_{NN} p_N + v_N = x_N p_N
\end{aligned}
\qquad [2]
$$

Where v_i is value added in industry i. Define $a_{ij}=x_{ij}/x_j$, the input of product i as a fraction of the total output of industry j. The system [2] can be written as

$$
\begin{aligned}
&(1-a_{11})p_1 - a_{21}p_2 - \ldots\ldots - a_{N1}p_N = v_1/x_1 \\
&-a_{12}p_1 + (1-a_{22})p_2 - \ldots. - a_{N2}p_N = v_2/x_2 \\
&. \\
&. \\
&. \\
&-a_{1N}p_1 - a_{2N}p_2 - \ldots. - a_{NN}p_N = v_N/x_N
\end{aligned}
\qquad [3]
$$

These equations can be expressed in matrix notation as

$$(I - A')P_1 = V \qquad [3A]$$

Where I is an NxN identity matrix, A is an NxN matrix with elements a_{ij}, P_I is an $Nx1$ vector of industry prices, p_i, and V is the $Nx1$ vector whose ith element is v_i/x_i. Assuming that $(I - A')$ is nonsingular, this system can be solved for the price vector:

$$P_I = (I - A')^{-1}V \qquad [4]$$

With the unit convention chosen above, P_I, will be a vector of ones. However, we can add taxes to the system in which case the price vector will now differ from a vector of ones as intermediate goods taxes get transmitted through the system. Specifically, let t_{ij} be a unit tax on the use of product i by industry j. In this case, the value of goods used in production (grossed up by their tax) plus value added now equals the value of output:

$$
\begin{aligned}
&x_{11}p_1(1+t_{11}) + x_{21}p_2(1+t_{21}) + \ldots\ldots + x_{N1}p_N(1+t_{N1}) + v_1 = x_1p_1 \\
&x_{12}p_1(1+t_{12}) + x_{22}p_2(1+t_{22}) + \ldots. + x_{N2}p_N(1+t_{N2}) + v_2 = x_2p_2 \\
&. \\
&. \\
&. \\
&x_{1N}p_1(1+t_{1N}) + x_{2N}p_2(1+t_{2N}) + \ldots. + x_{NN}p_N(1+t_{NN}) + v_N = x_Np_N
\end{aligned}
\qquad [5]
$$

This set of equations can be manipulated in a similar fashion to the equations above to solve for the price vector:

$$P_I = (I - B')V \qquad [6]$$

where B is an NxN matrix with elements $(1+t_{ij})a_{ij}$.

We regrouped industries in the Input-Output Accounts into 58 industry groupings. For the years 2003 and 1997, a separate industry for coal mining was created out of the industry group including all mining. This was done using the split between mining and coal provided in the 1994 benchmark Input-Output accounts. For the year 1987, we used the benchmark Input-Output table which already has coal mining as a separate industry.

Tax rates are computed as the ratio of tax required tax revenue from the industry divided by the value of output from that industry. For the carbon tax, the tax rate equals

$$t_{4.} = \frac{20}{\sum_{j=1}^{N} x_{4j}}$$

where the tax is designed to collect $20 billion from the coal industry (industry 4). This tax is applied to all variables in the third equation of Equation [5]. Other industry level taxes are computed in a similar manner.

Equation [6] indicates how price changes in response to the industry level taxes. We next have to allocate the price responses to consumer goods. The Input-Output accounts provide this information by means of the PCE Bridge tables for each year that show how much of each consumer item is produced in each industry. Let Z be an NxM matrix, where z_{ij} represents the proportion of consumer good j $(j=1,..,M)$ derived from industry i $(i=1,\ldots,N)$. The columns of Z sum to 1. An example of the Z-matrix is provided in Appendix Table 2 for a subset of consumer goods. If P_c is a vector of consumer goods prices (an $Mx1$ vector), then

$$P_c = Z'P_{1.}$$

The consumer prices derived using this methodology are then applied to consumption data in the CEX. The consumer prices derived using this methodology is provided in Appendix Table 1 for all three years.

<u>Appendix Table 1: Consumer Goods Price Increases as a Result of the Carbon Tax</u>

	CEX categories	**1987**	**1997**	**2003**
1	food at home	0.57%	0.65%	0.70%
2	food at restaurants	0.47%	0.56%	0.58%
3	food at work	0.61%	0.75%	0.86%
4	tobacco	0.54%	0.60%	0.67%
5	alcohol at home*	0.47%	0.56%	0.58%
6	alcohol on premises*	0.47%	0.56%	0.58%
7	clothes	0.53%	0.52%	0.40%
8	clothing services	0.75%	0.38%	0.41%
9	jewelry	0.54%	0.45%	0.43%
10	toiletries	0.87%	0.85%	0.72%
11	health and beauty	0.70%	0.38%	0.42%
12	tenant occupied non-farm dwellings	0.14%	0.21%	0.31%
13	other dwelling rentals	0.65%	0.41%	0.42%
14	furnishings	0.64%	0.62%	0.55%
15	household supplies	0.78%	0.77%	0.71%
16	electricity	10.18%	13.15%	12.55%
17	natural gas	16.87%	16.61%	12.28%
18	water	1.20%	0.73%	0.63%
19	home heating oil	7.67%	10.33%	9.56%
20	telephone	0.20%	0.21%	0.26%
21	domestic services	0.70%	0.41%	0.49%
22	health	0.44%	0.37%	0.39%
23	business services	0.14%	0.21%	0.50%
24	life insurance	0.28%	0.21%	0.31%
25	automobile purchases	0.67%	0.59%	0.90%
26	automobile parts	0.70%	0.64%	0.65%
27	automobile services	0.75%	0.34%	0.40%
28	gasoline	9.67%	7.64%	7.73%
29	tolls	0.65%	0.30%	0.64%
30	automobile insurance	0.14%	0.21%	0.31%
31	mass transit	0.95%	0.70%	0.90%
32	other transit	0.96%	0.50%	0.62%
33	air transportation	1.93%	1.82%	1.86%
34	books	0.43%	0.32%	0.34%
35	magazines	0.45%	0.31%	0.49%
36	recreation and sports equipment	0.52%	0.56%	0.42%
37	other recreation services	0.60%	0.36%	0.51%
38	gambling	0.39%	0.28%	0.31%
39	higher education	0.56%	0.27%	0.30%
40	nursery, primary, and secondary education	0.60%	0.33%	0.34%
41	other education services	0.62%	0.26%	0.30%
42	charity	0.74%	0.43%	0.41%

Notes:
1. Values for alcohol have been set equal to food on premises
2. These price increases are calculated using a $15 per metric ton carbon tax

Appendix Table 2: Bridge Matrix For 2003 For a Sub-Set of Consumption Goods

Industry Groups	Food at Home	Food at Restaurants	Food at Work	Tobacco products	Clothes	Clothing Services
Farms	0.0436	0.0000	0.0469	0.0000	0.0000	0.0000
Forestry, fishing, and related activities	0.0048	0.0000	0.0035	0.0000	0.0000	0.0000
Oil and gas extraction	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Coal Mining	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mining, except oil and gas	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Support activities for mining	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Electric Utilities	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Natural Gas Utilities	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Other Utilities	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Construction	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Food and beverage and tobacco products	0.5204	0.0000	0.7894	0.5768	0.0000	0.0000
Textile mills and textile product mills	0.0000	0.0000	0.0000	0.0000	0.0056	0.0000
Apparel and leather and allied products	0.0000	0.0000	0.0000	0.0000	0.4085	0.0000
Wood products	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Paper products	0.0000	0.0000	0.0000	0.0000	0.0091	0.0000
Printing and related support activities	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Petroleum and coal products	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chemical products	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000
Plastics and rubber products	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000
Nonmetallic mineral products	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Primary metals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fabricated metal products	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Machinery	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Computer and electronic products	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Electrical equipment, appliances, and components	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Motor vehicles, bodies and trailers, and parts	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Other transportation equipment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Furniture and related products	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Miscellaneous manufacturing	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000
Wholesale trade	0.1159	0.0000	0.1291	0.1741	0.0790	0.0000
Retail trade	0.2938	0.0000	0.0000	0.2457	0.4909	0.0000
Air transportation	0.0008	0.0006	0.0013	0.0000	0.0013	0.0000

Rail transportation	0.0022	0.0001	0.0028	0.0000	0.0000	0.0000
Water transportation	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000
Truck transportation	0.0203	0.0000	0.0268	0.0034	0.0035	0.0000
Transit and ground passenger transportation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pipeline transportation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Other transportation and support activities	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Warehousing and storage	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Publishing industries (includes software)	0.0000	0.0000	0.0000	0.0000	0.0010	0.0000
Motion picture and sound recording industries	0.0000	0.0098	0.0000	0.0000	0.0000	0.0000
Broadcasting and telecommunications	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Information and data processing services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Finance	0.0000	0.0000	0.0000	0.0000	0.0000	0.0161
Legal services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Miscellaneous professional, scientific and technical services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Computer systems design and related services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Management of companies and enterprises	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Administrative and support services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Waste management and remediation services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Educational services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ambulatory health care services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hospitals and nursing and residential care facilities	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Social assistance	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Performing arts, spectator sports, museums, and related activities	0.0000	0.0043	0.0000	0.0000	0.0000	0.0000
Amusements, gambling, and recreation industries	0.0000	0.0008	0.0000	0.0000	0.0000	0.0000
Accommodation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0049
Food services and drinking places	0.0000	0.9843	0.0000	0.0000	0.0000	0.0000
Other services, except government	0.0000	0.0000	0.0000	0.0000	0.0009	0.9790
Government and Misc.	-0.0025	0.0000	0.0000	0.0000	-0.0017	0.0000

Table 1: Distribution of Total Burden: Annual Income

Decile	1987	1997	2003
Bottom	3.91	4.29	3.70
Second	3.27	3.33	3.02
Third	2.64	2.91	2.33
Fourth	2.37	2.37	2.04
Fifth	1.92	1.94	1.74
Sixth	1.65	1.67	1.51
Seventh	1.52	1.53	1.30
Eighth	1.40	1.36	1.24
Ninth	1.21	1.16	1.02
Top	1.03	0.88	0.82

Source: Authors' calculations. The table reports the within decile average ratio of carbon tax burdens to income.

Figure 1

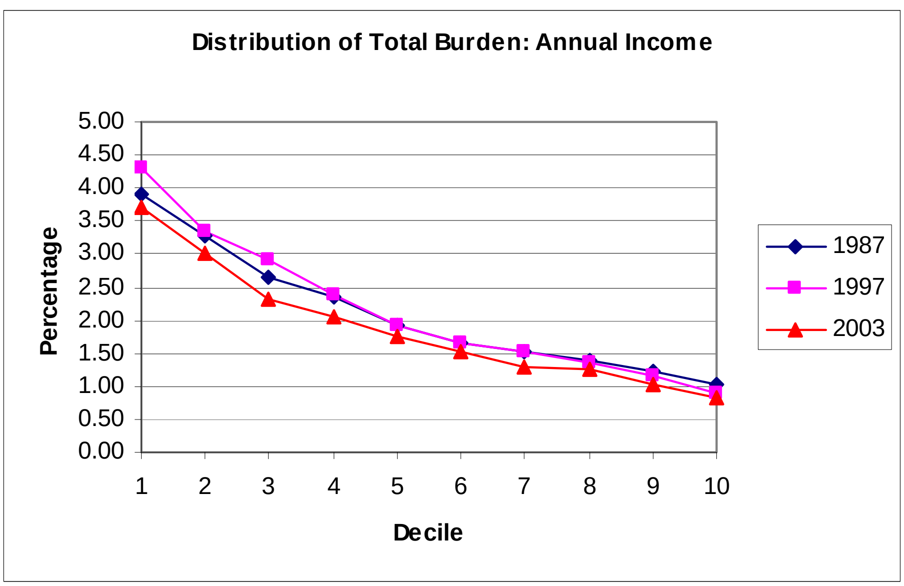


Table 2: Distribution of Direct Burden: Annual Income

Decile	1987	1997	2003
Bottom	2.68	2.87	2.11
Second	2.17	2.14	1.71
Third	1.68	1.83	1.34
Fourth	1.52	1.48	1.17
Fifth	1.18	1.18	0.96
Sixth	0.99	0.98	0.83
Seventh	0.94	0.89	0.70
Eighth	0.83	0.80	0.62
Ninth	0.70	0.65	0.53
Top	0.54	0.46	0.37

Source: Authors' calculations. The table reports the within decile average ratio of carbon tax burdens to income

Figure 2

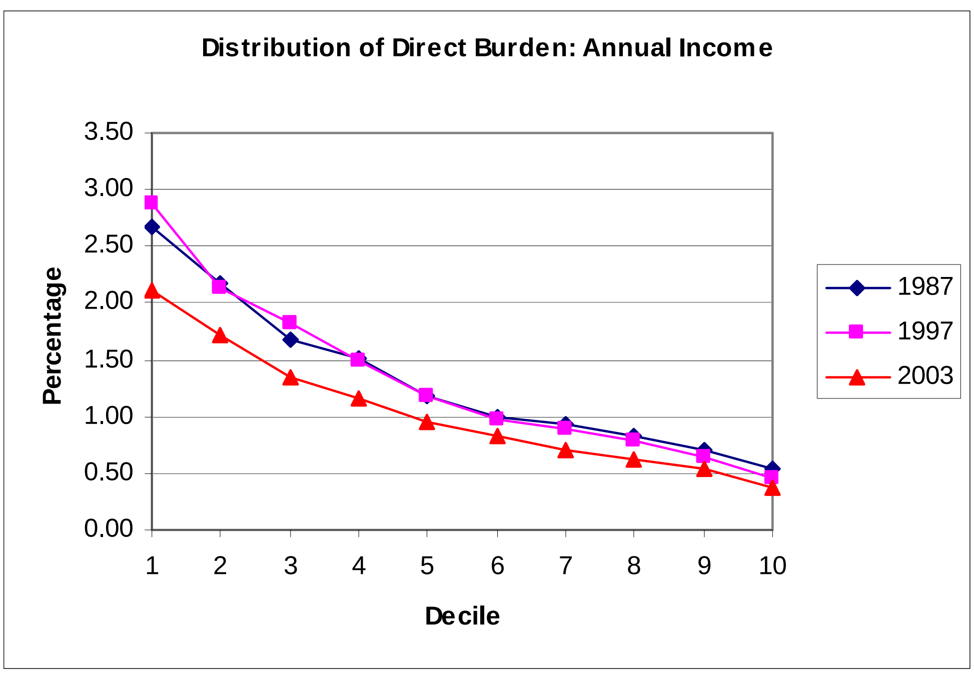


Table 3: Distribution of Indirect Burden: Annual Income

Decile	1987	1997	2003
Bottom	1.23	1.42	1.60
Second	1.10	1.19	1.31
Third	0.96	1.08	0.99
Fourth	0.84	0.89	0.88
Fifth	0.74	0.75	0.78
Sixth	0.66	0.69	0.68
Seventh	0.58	0.64	0.61
Eighth	0.57	0.56	0.63
Ninth	0.52	0.51	0.49
Top	0.49	0.43	0.45

Source: Authors' calculations. The table reports the within decile average ratio of carbon tax burdens to income.

Figure 3

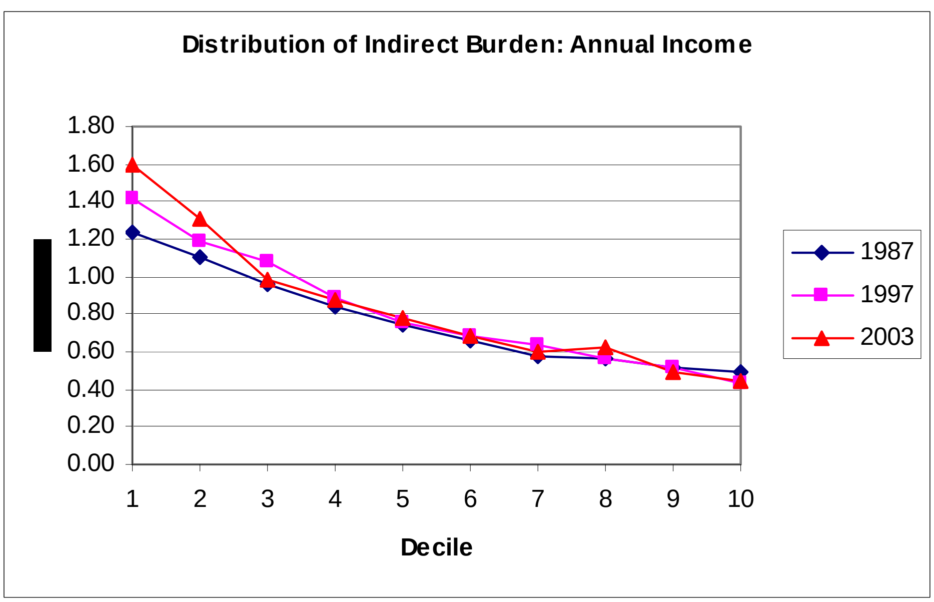


Table 4: Distribution of Total Burden: Current Consumption

Decile	1987	1997	2003
Bottom	1.88	1.76	1.45
Second	1.83	1.63	1.41
Third	1.63	1.57	1.31
Fourth	1.60	1.42	1.29
Fifth	1.53	1.38	1.24
Sixth	1.45	1.31	1.17
Seventh	1.41	1.27	1.16
Eighth	1.32	1.18	1.07
Ninth	1.28	1.11	1.01
Top	1.16	1.00	0.90

Source: Authors' calculations. The table reports the within decile average ratio of carbon tax burdens to income.

Figure 4

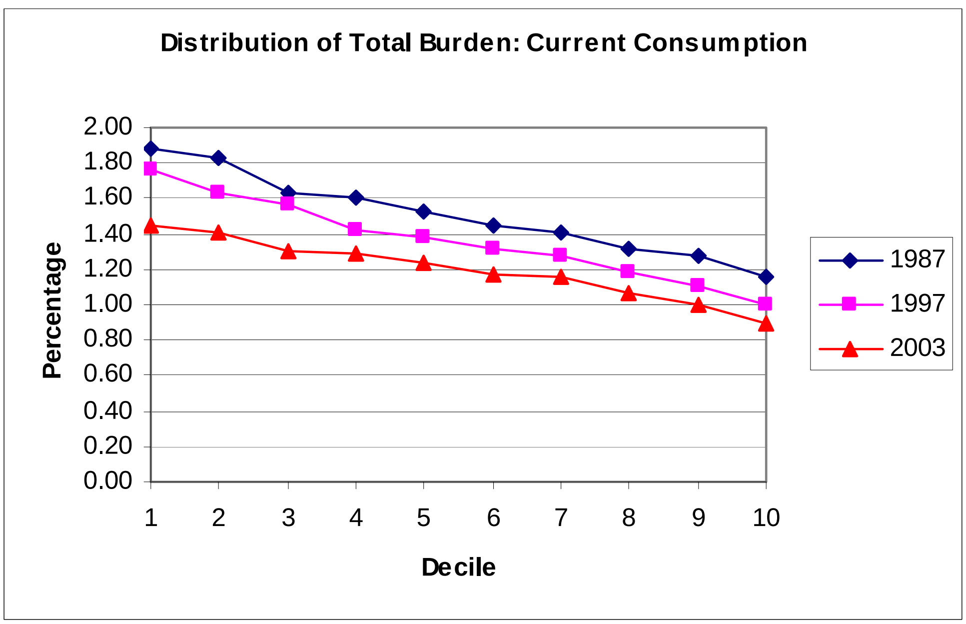


Table 5: Distribution of Direct Burden: Current Consumption

Decile	1987	1997	2003
Bottom	1.37	1.26	0.94
Second	1.33	1.13	0.92
Third	1.12	1.07	0.81
Fourth	1.08	0.92	0.79
Fifth	1.00	0.87	0.73
Sixth	0.90	0.80	0.65
Seventh	0.86	0.77	0.64
Eighth	0.76	0.67	0.54
Ninth	0.72	0.59	0.48
Top	0.58	0.49	0.38

Source: Authors' calculations. The table reports the within decile average ratio of carbon tax burdens to income.

Figure 5

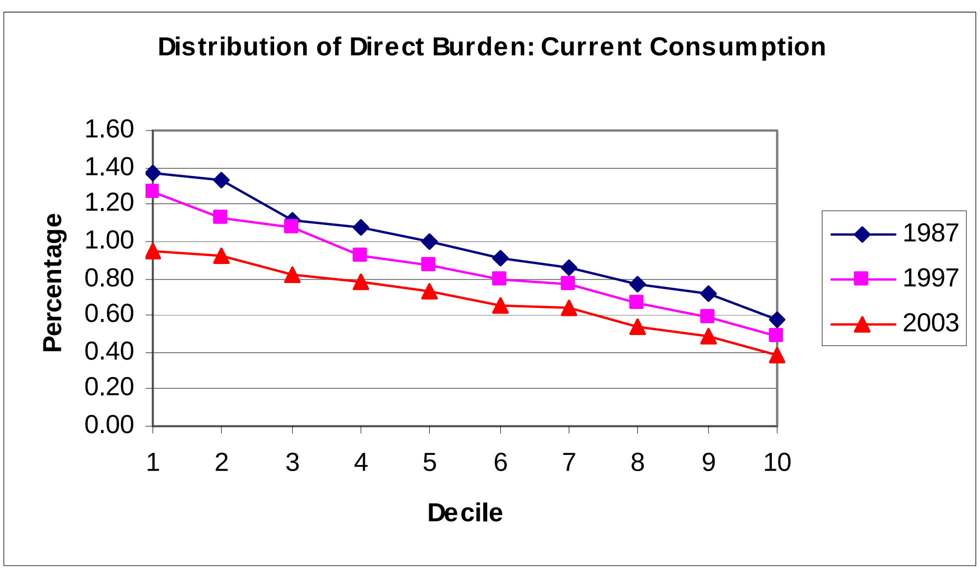
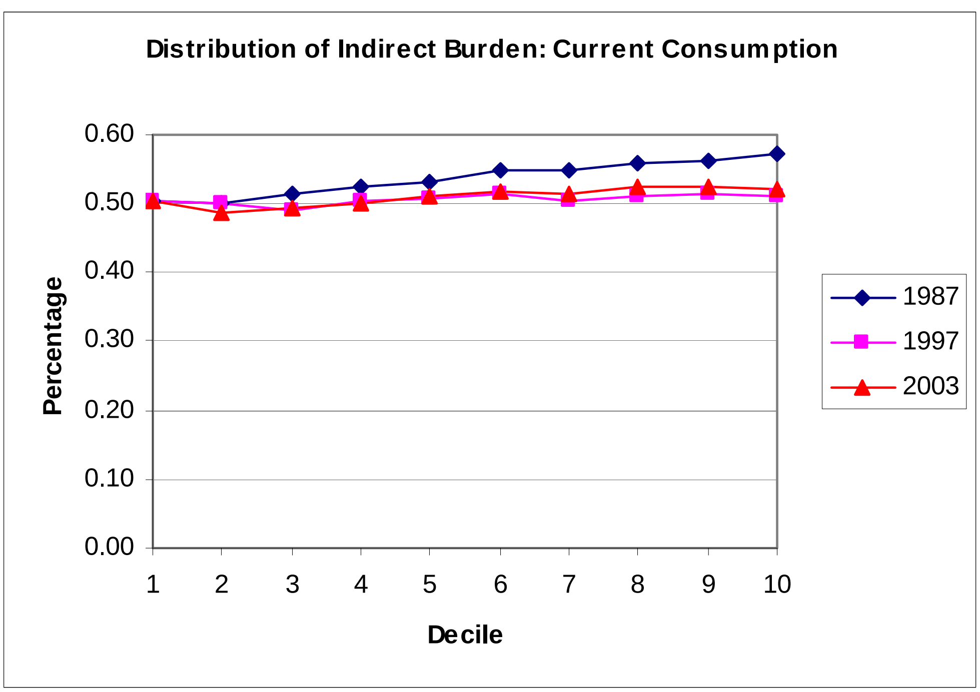


Table 6: Distribution of Indirect Burden: Current Consumption

Decile	1987	1997	2003
Bottom	0.51	0.50	0.50
Second	0.50	0.50	0.49
Third	0.51	0.49	0.50
Fourth	0.52	0.51	0.50
Fifth	0.53	0.51	0.51
Sixth	0.55	0.51	0.52
Seventh	0.55	0.51	0.51
Eighth	0.56	0.51	0.53
Ninth	0.56	0.52	0.52
Top	0.57	0.51	0.52

Source: Authors' calculations. The table reports the within decile average ratio of carbon tax burdens to income.

Figure 6



<u>Table 7: Distribution of Total Burden: Lifetime Consumption</u>

Decile	1987	1997	2003
Bottom	1.61	1.58	1.18
Second	1.47	1.38	1.15
Third	1.49	1.33	1.24
Fourth	1.59	1.39	1.23
Fifth	1.55	1.42	1.28
Sixth	1.50	1.39	1.21
Seventh	1.46	1.35	1.17
Eighth	1.48	1.33	1.08
Ninth	1.29	1.21	1.03
Top	1.22	1.12	0.94

Source: Authors' calculations. The table reports the within decile average ratio of carbon tax burdens to income.

<u>Figure 7</u>

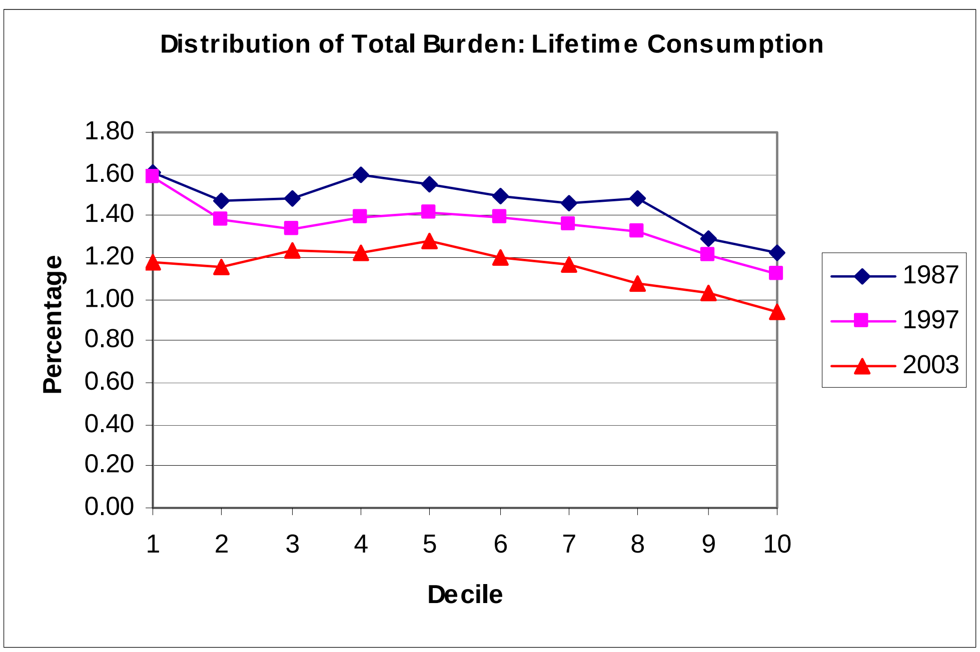


Table 8: Distribution of Direct Burden: Lifetime Consumption

Decile	1987	1997	2003
Bottom	1.10	1.12	0.68
Second	0.94	0.87	0.65
Third	0.95	0.83	0.76
Fourth	1.07	0.89	0.72
Fifth	1.02	0.90	0.79
Sixth	0.96	0.89	0.70
Seventh	0.93	0.85	0.65
Eighth	0.93	0.82	0.57
Ninth	0.74	0.70	0.51
Top	0.66	0.61	0.42

Source: Authors' calculations. The table reports the within decile average ratio of carbon tax burdens to income.

Figure 8

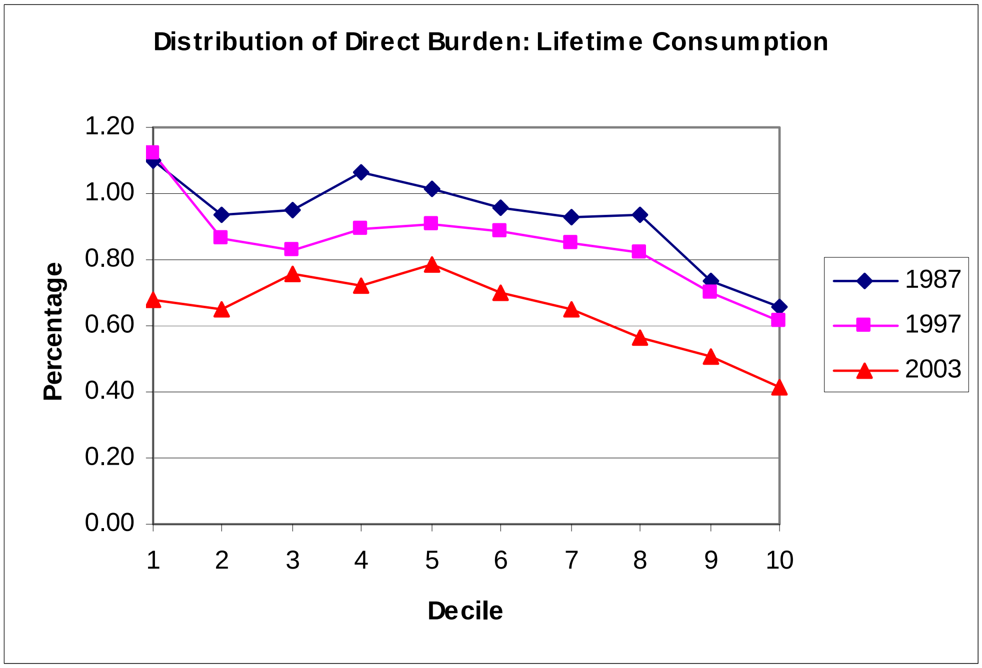


Table 9: Distribution of Indirect Burden: Lifetime Consumption

Decile	1987	1997	2003
Bottom	0.52	0.52	0.50
Second	0.53	0.51	0.51
Third	0.53	0.50	0.51
Fourth	0.53	0.50	0.51
Fifth	0.53	0.51	0.50
Sixth	0.53	0.51	0.50
Seventh	0.53	0.51	0.51
Eighth	0.55	0.51	0.51
Ninth	0.55	0.51	0.53
Top	0.56	0.52	0.52

Source: Authors' calculations. The table reports the within decile average ratio of carbon tax burdens to income.

Figure 9

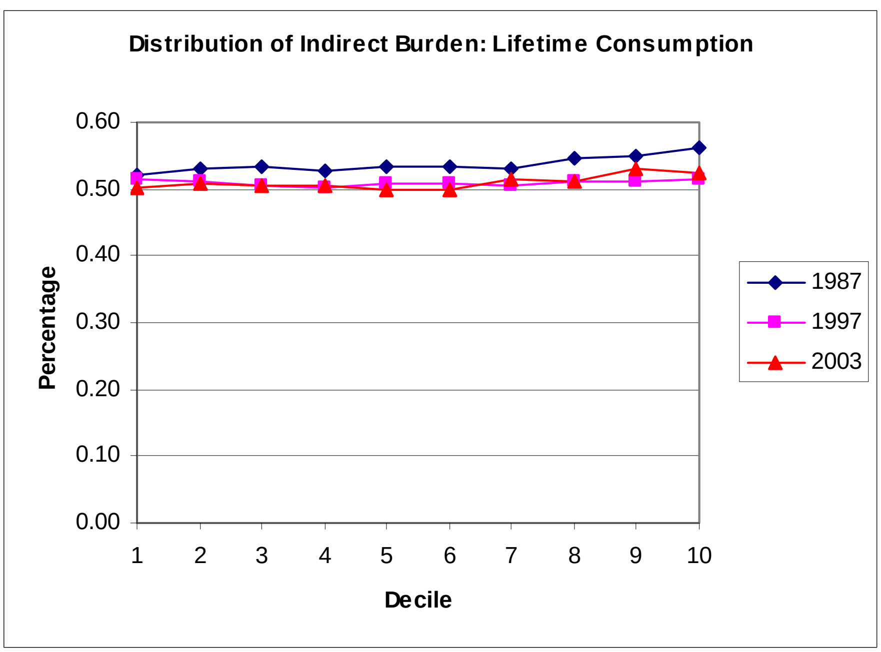


Table 10: Regional Distribution of Total Burden: Annual Income

Decile	1987	1997	2003
New England	1.80	1.64	1.69
Mid Atlantic	2.02	1.95	1.67
South Atlantic	1.93	2.02	1.67
East South Central	2.06	2.47	1.85
East North Central	1.98	1.86	1.68
West North Central	2.22	1.76	1.48
West South Central	2.06	2.28	1.81
Mountain	1.95	2.09	1.84
Pacific	1.64	1.58	1.66

Source: Authors' calculations. The table reports the within decile average ratio of carbon tax burdens to income.

Figure 10

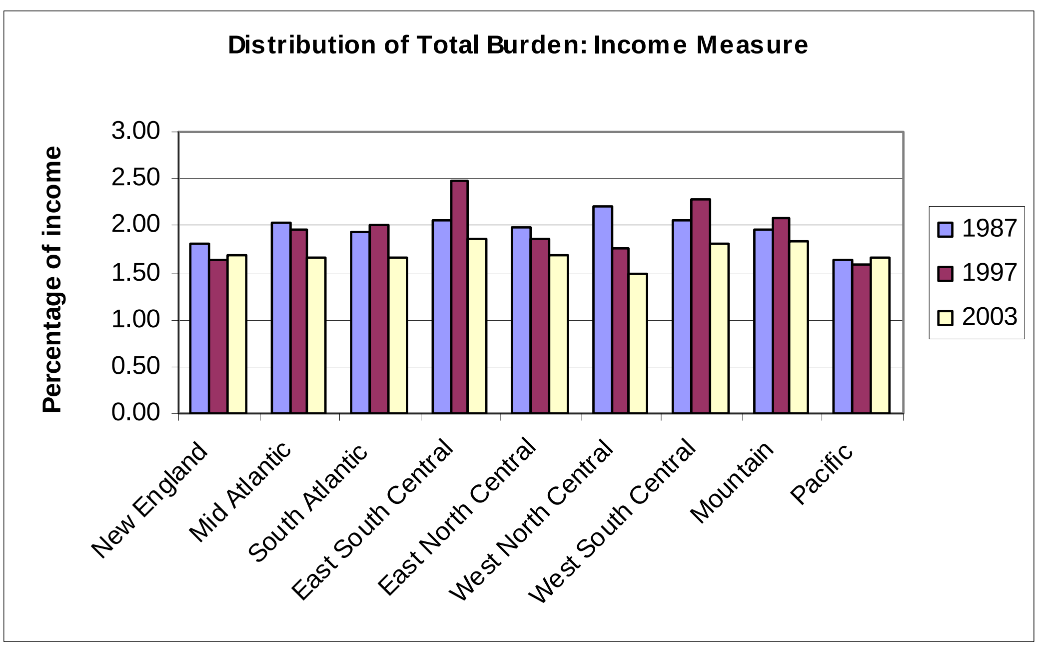


Table 11: Regional Distribution of Direct Burden: Annual Income

Decile	1987	1997	2003
New England	1.07	1.00	0.93
Mid Atlantic	1.28	1.18	0.90
South Atlantic	1.22	1.22	0.90
East South Central	1.37	1.60	1.10
East North Central	1.27	1.11	0.92
West North Central	1.31	0.95	0.71
West South Central	1.27	1.46	1.03
Mountain	1.21	1.24	0.93
Pacific	0.93	0.89	0.85

Source: Authors' calculations. The table reports the within decile average ratio of carbon tax burdens to income.

Figure 11

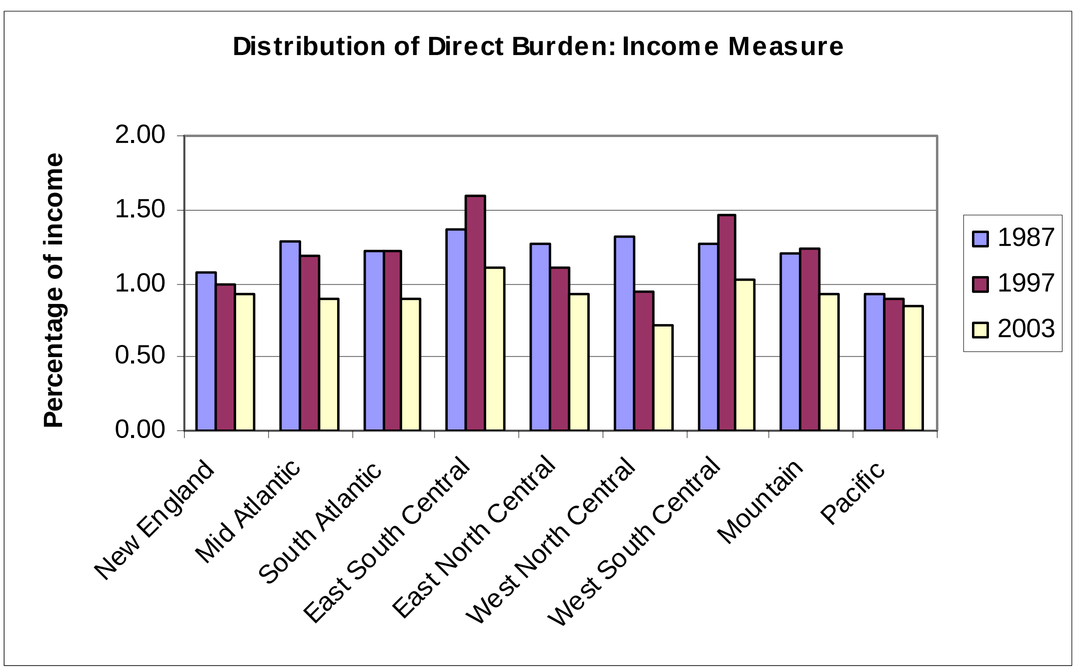


Table 12: Regional Distribution of Indirect Burden: Annual Income

Decile	1987	1997	2003
New England	0.73	0.64	0.76
Mid Atlantic	0.74	0.76	0.76
South Atlantic	0.72	0.80	0.77
East South Central	0.69	0.87	0.75
East North Central	0.71	0.75	0.76
West North Central	0.91	0.81	0.77
West South Central	0.79	0.82	0.78
Mountain	0.74	0.85	0.91
Pacific	0.71	0.69	0.81

Source: Authors' calculations. The table reports the within decile average ratio of carbon tax burdens to income.

Figure 12