Who Pays for a Carbon Tax?[1]

Corbett A. Grainger*
Charles D. Kolstad**

December 1, 2008

Abstract: We use the 2006 Consumer Expenditure Survey and emissions estimates from an input-output model to estimate the partial equilibrium incidence of a carbon tax. We find that a carbon tax (or fully-auctioned cap-and-trade program) is regressive using two measures of income and we illustrate the main determinant of the regressivity: consumption patterns for energy intensive goods. We discuss policy options to offset the adverse distributional effects of a carbon emissions policy, namely redistribution of revenues and financing cuts in preexisting regressive taxes.

Keywords: distributional incidence; carbon tax; tradable permits;

***JEL* Classifications:** Q52; Q58; H22

* Department of Economics, University of California, Santa Barbara.
**Department of Economics and Bren School, University of California, Santa Barbara; Resources for the Future; and National Bureau of Economic Research.

[1] We would like to thank Don Fullerton, Gilbert Metcalf and Margaret Walls for comments. We are responsible for all errors. Grainger acknowledges the financial support from the National Science Foundation, grant No. 0114437. E-mail addresses for the authors: grainger@econ.ucsb.edu and kolstad@econ.ucsb.edu.

I. Background

There are currently several proposals being considered in congress for a national greenhouse gas policy in the United States, and a policy is likely to emerge under the Obama Administration. Most proposed policies rely on a national cap and trade program for limiting and reducing carbon emissions. Like a carbon tax, a cap and trade program for greenhouse gas emissions has the effect of inducing a price on carbon; this means that for the first time in the U.S. a price will be placed on each ton of CO_2 emitted. That price per unit of carbon emitted will ultimately be paid by consumers, shareholders, and workers. How these costs are distributed among these groups and among income classes is a great concern to policymakers and the general public.[2] That is the issue we address here.

Without loss of generality, we analyze the effect of a carbon tax; the consequences of a carbon price induced by a fully-auctioned cap and trade system should be identical. Our results suggest that the burden as a percent of annual income is much higher among lower income groups than higher income groups. This policy is less regressive when considering the burden as a percentage of lifetime income. We examine existing regressive taxes and suggest ways in which the regressive nature of a carbon tax may be ameliorated by pairing it with a reduction in other taxes.

Economists have studied the relative efficiency of quotas, emissions intensity targets, effluent taxes, cap-and-trade schemes, and other approaches to controlling emissions, but until recently relatively little attention has been paid to who actually pays for environmental regulations. Although the efficiency of an environmental policy is a

[2] In addition to the distribution across income groups, there may be variation in the spatial distribution of costs and benefits (Burtraw et al, 2008).

critical consideration for a policymaker, stable environmental policies should take steps to guarantee that the burden of the regulation does not fall disproportionately on one income group.

Companies facing regulations on greenhouse gas emissions take costly steps to reduce their emissions levels, but the burden is ultimately borne by consumers, workers, or shareholders in the firm.[3] The costs of compliance are passed on through changes in consumer prices, stock returns, wages, and other returns to factors of production. While an emissions reduction can be achieved in many ways, each method has different costs and consequences. In the case of an emissions tax, there is an additional cost associated with the payment of the tax. Of course, this is not a net cost to society since the cost of a tax payment is exactly equal to the gain to the government. If a permit is initially auctioned by the government, the same transfer occurs.[4] There may, in addition, be additional costs or inefficiencies generated by the interaction of the tax or permit payment with other taxes, such as an income tax (Goulder, et al., 1997).

In this paper we use 2006 consumption data, emissions factors and 1997 data on the structure of the US economy to develop initial estimates of which income groups ultimately bear the cost of a price on carbon. Our estimates are admittedly first order and partial equilibrium. We assume all costs are passed on to consumers; workers and capital owners bear none of the costs. Furthermore, we only estimate the burden of the carbon tax, not taking into account consumer and firm response to a higher carbon price in terms

[3] This is true regardless of statutory incidence; that is, the costs of reducing emissions are ultimately passed on, regardless of the point of compliance.
[4] In the case of a grandfathered cap-and-trade program, scarcity rents are created, which can actually benefit shareholders. The distributional impact of a cap-and-trade program depends critically on the allocation method (i.e. auctioning vs. grandfathering). See Parry, 2004.

of reductions in carbon emissions. Finally, we do not examine the incidence of the benefit of a carbon tax, in terms of the benefits of a marginal reduction in climate change.

Our aim is to obtain a first-order estimate of the extent to which a price on carbon is progressive or regressive by examining consumption patterns and associated emissions for different parts of the income distribution. In what follows, we focus on a carbon tax, noting that a fully-auctioned emissions trading program (with a correctly chosen quota) would generate the same results, albeit through a different mechanism.

II. First-Order Incidence Estimate

The *economic incidence* of a tax refers to how the ultimate net costs are distributed in an economy, usually referring to how different income groups are impacted. Fullerton (2009) discusses six ways environmental policies may have distributional impacts; forward cost-shifting is one of the major drivers of the incidence of environmental policy. The distribution of costs and benefits determines the winners and losers from environmental policy. A progressive policy places a larger burden, as a percentage of wealth, on richer households, while a regressive policy places larger percentage burdens on lower income groups.

To completely capture the incidence of a carbon tax, we would want to take into account carbon-reducing abatement activities or behavioral changes in examining the extent to which consumers or factors of production bear the cost of the tax.[5] We would also want to estimate the incidence of those abatement activities and how the government uses or refunds the revenues from the taxes or permits. A general equilibrium analysis of

[5] Metcalf et al (2008) use a calibrated model to estimate the incidence of alternative greenhouse gas policies under various assumptions about forward and backward shifting. Their results depend on various factors, including the breadth of the tax, whether other countries act, and short- vs. long-run effects.

the issue would also take into account the changes in relative prices in the economy induced by the tax or costly permits.

A much more modest approach would fix economic activities at their current level and apply a price of carbon, assuming that there is no behavioral or secondary price response in the economy—the carbon price is passed through in its entirety to consumers and consumers do not adjust behavior. Such an analysis will overstate the burden on consumers since in actuality factors of production will bear some of the cost and, further, a higher price of carbon will induce actions to reduce carbon consumption and thus tax burden. The extent to which a carbon tax is small and applies throughout the economy will limit the inaccuracy of our estimates.

In our analysis, we examine the effects of a price of $30 per ton of carbon dioxide, equivalent to approximately $110 per ton of carbon.[6] Although there is a great deal of uncertainty regarding what price of carbon may emerge from the current policy debate in the US, this figure is in the midrange of the current proposals before Congress (Paltsev et al, 2007).

We begin with data from the 2006 Consumer Expenditure Survey (CES) from the Bureau of Labor Statistics. The CES provides annual consumption patterns for households in each income quintile in the U.S. for a variety of products and services. For each income group, the CES tells us what the average household's expenditure is for shelter, electricity, gasoline, vehicles, food, clothing, insurance, and a host of other goods and services. Because the size of households varies by income, we then calculate per-capita expenditures for an "average" individual in each household quintile. A breakdown of the per-capita expenditures of some of the goods and services is shown in Table 1. For

[6] A $30 tax per ton of carbon dioxide is equivalent to a tax on carbon of $110 per ton (=$30*(44/12)).

example, according to the CES, an average person from a household in the lowest income quintile spent roughly $583 in 2006 on gasoline and motor oil, which was about 5.8% of their net annual income, whereas the corresponding percentage for a person in the wealthiest quintile is only 0.8%.

Table 1: Selected Per-Capita Expenditures by Income Quintile (2006)

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Mean Household Income					
Gross	$9,974	$26,657	$44,933	$70,975	$149,963
After-Tax	$9,969	$26,346	$43,799	$68,497	$141,738
Income Range	<$18,370	$18,370 -$35,095	$35,095 -$56,222	$56,222 -$88,774	>$88,774
Mean Number Persons/Household	1.7	2.2	2.5	2.8	3.1
Mean Per-Capita (After Tax) Income	$5,864	$11,975	$17,520	$24,463	$45,722
Mean Per-Capita Expenditures:					
Food & Alcohol	2,004	2,091	2,435	2,760	3,617
Shelter	2,826	2,911	3,308	3,874	5,815
Fuel (non-transport)					
Natural Gas	180	194	191	205	245
Electricity	496	492	495	503	567
Fuel Oil & Other Fuel	51	48	48	55	72
Telephone Services	373	392	436	463	500
Water & Other Public Services	129	140	153	167	197
Household Operations, Supplies, Furnishings, Equipment & Apparel	1,222	1,354	1,722	2,065	3,449
Transportation & Vehicle Exp.	2,411	3,171	4,081	4,870	7,065
Gasoline & Motor Oil	583	738	873	1,010	1,132
Healthcare	874	1,116	1,059	1,126	1,318
Other Expenditures	2,063	2,602	3,660	5,060	9,292
Total Per-Capita Expenditures	$12,006	$13,738	$16,572	$19,892	$30,371

Source: Consumer Expenditure Survey (2006). Figures are annual per-capita expenditures in 2006 dollars. The less emissions-intensive consumption categories were aggregated here for exposition only; all subcategories were used in the estimates produced in this paper.

For a more disaggregated look at the impact on different income groups, Table 2 shows consumption patterns for the top and bottom of the income distribution. For those households earning more than $150,000 per year[7], the average person spends $1,176 on gasoline and motor oil, or an average of 1.7% of their annual net per-capita income. On the other end of the distribution, those households earning less than $5,000 annually, the average per-capita expenditures on gasoline and motor oil is about $604.[8]

Table 2. Average Per-Capita Expenditures for Low- and High-Income Groups

Income Range	<$5,000	$5,000 -$9,999	$120,000 -$149,999	>$150,000
Mean Household Income (Gross)	$439	$8,006	$132,682	$236,545
Mean After-Tax Income	$316	$8,019	$126,314	$220,861
Mean Number Persons/Household	1.6	1.6	3.1	3.2
Mean Per-Capita (After-Tax) Income	$198	$5,012	$40,746	$69,019
Average Per-Capita Expenditures				
Food & Alcohol	2,043	1,908	3,529	4,203
Shelter	3,148	2,638	5,574	7,801
Fuel (non-transport)				
Natural Gas	163	160	222	300
Electricity	447	468	560	643
Fuel Oil & Other Fuel	61	29	75	92
Telephone Services	359	358	508	533
Water & Other Public Services	112	117	204	225
Household Operations, Supplies, Furnishings, Equipment & Apparel	1,518	1,186	3,265	4,956
Transportation & Vehicle Exp.	1,400	821	3,891	5,417
Gasoline & Motor Oil	604	496	1,161	1,176
Healthcare	651	593	1,255	1,558
Other Expenditures	2,438	1,696	8,352	13,310
Total Per-Capita Expenditures	$12,943	$10,469	$28,596	$40,213

Source: Consumer Expenditure Survey (2006). Figures are annual per-capita expenditures in 2006 dollars. The less emissions-intensive consumption categories were aggregated here for exposition only; all subcategories were used in the estimates produced in this paper.

[7] According to the Current Population Survey done by the Census (2006), this corresponds to approximately the 94th percentile of households.
[8] This corresponds to about the 3rd percentile of households. As shown in Table 2, the per-capita expenditure on gasoline for the lowest income group actually exceeds the average per-capita income for that group. This is driven partially by the fact that retirees living off of savings, students, and the temporarily unemployed may have little (or no) income. For this reason, it may be preferable to use lifetime income (as proxied by current expenditures) to measure the regressivity of a carbon tax; this will be discussed later.

To estimate the consumption consequences of a carbon price, we need to look at how that price would ripple through the economy, ultimately being borne by the consumer. For instance, food production requires fuel to run tractors (with associated carbon emissions), but it also requires fertilizer, for which carbon was emitted during its production.

The standard input-output tables for the US, produced by the US Bureau of Economic Analysis, divide the economy into a large number of industrial sectors. The IO table for a particular year indicates for each sector *j*, how much was purchased from each of the other sectors $i=1,2,\ldots,n$ to produce \$1 of output for sector *j*. It is thus a straightforward calculation to translate a vector of final demands in these industrial categories into total production in each of the categories, satisfying both final demand and intermediate demand. This same technique can be used to calculate how a tax on direct carbon emissions in each sector will ripple through the economy to increase the price of final consumption for the sector.

More formally, let A be a n x n input-output matrix, where the coefficients a_{ij} represent the inputs (in \$) from sector *j* necessary to produce \$1 worth of output for sector *i*. Let *c* be a vector of final demands for goods in each industry (in dollars), and let *x* be a vector of total output (in dollars) for the various sectors of the economy. Leontief, in his Nobel Prize-winning work,[9] formulated this input-output model such that

$$Ax + c = x \Leftrightarrow x = (I - A)^{-1} c \text{ ,}$$

where I is the identity matrix.[10]

[9] See, for example, Leontief, 1986.
[10] We are clearly assuming that (I-A) is regular so that it is invertible; in practice, this assumption generally holds true.

A straightforward extension of this traditional input output model is to calculate the emissions necessary for production of final consumption goods, accounting for emissions of all primary and intermediate processes necessary to produce final goods (Leontief, 1970; Hendrickson, et al, 2006). Let g be a vector with the j^{th} element equal to the greenhouse gas emissions (in CO2-equivalent) per $1 of output for that sector. For a consumption vector c, the resulting total emissions e (a scalar) are then given by

$$e = g'x = g'(I - A)^{-1} c .$$

This method essentially traces emissions through an economy and provides us with estimates of emissions attributable to the consumption of final goods. Now if a tax of τ dollars per ton emissions of CO2-equivalent were levied, the total tax paid, associated with a consumption vector c, would be τe.

The input-output matrix for the US is regularly compiled and published by the Bureau of Economic Analysis. The vector of emissions factors, g, is not as readily available, though can be estimated from available data. Researchers at Carnegie-Mellon University (Hendrickson et al., 2006) have estimated these emissions factors and developed an easily used version of the 1997 US input output tables to allow the tracing of greenhouse gas emissions throughout the economy.[11]

Using the Carnegie Mellon version of the US input-output model (the "CMU Model"), we are able to estimate the amount of emissions associated with each consumption category in the Consumer Expenditure Survey (CES).[12] The greenhouse

[11] The CMU model (the Economic Input Output Life Cycle Assessment (EIO LCA) model) is available online at http://www.eiolca.net/about.html. There are 491 sectors in the model.
[12] Because consumption data were from the most recent Consumer Expenditure Survey available (2006), we adjusted expenditures using the Consumer Price Index (CPI) to make prices compatible with 1997 conditions. Because energy prices have increased more than the average price levels, we apply specific deflators for gas, natural gas, electricity, utilities, and non-energy goods.

gas emissions for most product and service categories listed in the CES are also calculated in the CMU Model. For those that did not have an identical match, we used the emissions estimates for a closely-related product category.[13] In practice, for any product category, the model tells us how many tons of greenhouse gases are emitted to create $1 Million worth of output. Because the process is linear, we can then calculate the number of tons of CO_2-equivalent that were emitted so that an average consumer in each income quintile could purchase his or her bundle of goods and services.[14] It is then a straightforward calculation to determine how much the average consumer in each income quintile would pay for a given price on carbon induced by a tax or permit price.

Using this method implies an aggregate level of US greenhouse gas emissions in 2006 to be about 7,898 Tg CO2-equivalent, compared to the EPA's greenhouse gas inventory estimate of 7,260 Tg CO2-equivalent (US EPA, 2006).[15] Considering that the CMU model is calibrated to the 1997 economy, our implied emissions estimate for 2006 is remarkably close to observed data. On a per-capita basis, this implies an 'average' consumer's emissions of about 26.4 metric tons of CO2e,[16] compared to estimates of 24.3 by the EPA.

[13] For example, the CES provides consumption data for beef, pork, and other meats. For each of these, the GHG emissions for the category "meat processed from carcasses" was used. This includes emissions from all inputs and activities leading up to the processing of the meat (e.g. cattle ranching and farming, grain farming, power generation, fertilizer manufacturing, etc.).

[14] Emissions resulting from combustion in motor vehicles and the use of natural gas are not included in the CMU Model, as the model only calculates the greenhouse gases associated with the production and distribution of these goods. We add the emissions from using gasoline and natural gas using the standard EPA estimates, imputed by using the average price for these fuels in 2006 to determine the amount purchased. There is evidence that poorer households drive older, less fuel-efficient cars, which would imply that emissions per gallon of gasoline for these income groups could actually be higher (West and Williams, 2004). We assume that each income quintile has similar driving habits and vehicles, though differences across income groups would lead to slightly different incidence estimates. In this case, it would increase the regressivity, though accounting for behavioral responses by income group would lead to a greater decrease in quantity demanded for low-income groups, which would have an offsetting effect.

[15] Tg stands for teragram and is equal to 10^{12} grams which is a million metric tons.

[16] This is based on a July, 2006 U.S. Census population estimate.

Table 3: Estimated Per-Capita Annual Emissions by Income Quintile

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Household Income Range (after taxes)	<$18,370	$18,370-$35,095	35,095-$56,222	$56,222-$88,774	>$88,774
Mean Per-Capita (After Tax) Income	$5,864	$11,975	$17,520	$24,463	$45,722
Mean Per-Capita Annual Expenditures	$12,006	$13,738	$16,572	$19,892	$30,371
Mean Per-Capita Emissions					
Food & Alcohol	3.10	3.12	3.51	3.91	4.92
Shelter	1.38	1.36	1.40	1.46	2.01
Fuel (non-transport)					
Natural Gas	1.53	1.65	1.63	1.75	2.09
Electricity	6.89	6.84	6.88	6.99	7.89
Fuel Oil & Other Fuel	0.28	0.26	0.26	0.30	0.39
Telephone Services	0.08	0.09	0.10	0.10	0.11
Water & Other Public Services	1.20	1.30	1.42	1.55	1.83
Household Operations, Supplies, Furnishings, Equipment & Apparel	0.99	1.10	1.39	1.64	2.51
Transportation & Vehicle Expense	0.45	0.58	0.76	1.00	1.95
Gasoline & Motor Oil	4.49	5.68	6.72	7.77	8.71
Healthcare	0.19	0.24	0.22	0.24	0.28
Other Expenditures	0.56	0.54	0.66	0.81	1.24
Total Per-Capita Emissions	21.14	22.76	24.95	27.51	33.93

Source: Authors' calculations using Consumer Expenditure Survey (2006) data and the CMU model described above. Figures are in metric tons of CO2-equivalent.

The total per-capita emissions were calculated for each quintile's 'average' consumption bundle by simply adding the emissions for each product in the bundle for that year. Annual per-capita emissions estimates are shown for each income quintile in Table 3. As shown in the table, the average person in a household from the poorest income quintile consumed goods and services associated with 21.1 tons of CO2-equivalent in 2006, while the average person in the top quintile was responsible for about emissions of 33.9 tons of CO2-equivalent. Similarly, Table 4 shows the breakdown of emissions by the top and bottom income groups. Individuals in households earning more than $150,000 were, on average, responsible for 39.7 tons of CO2-equivalent, while individuals earning less than $5,000 annually were responsible for an average of 21 tons of CO2-equivalent.

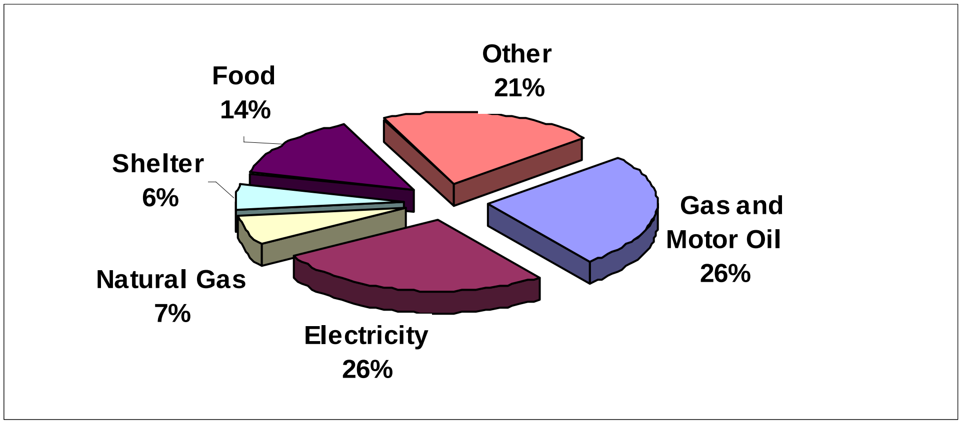
Table 4. Average Per-Capita Emissions for Low- and High-Income Groups

Income Range	<$5,000	$5k-$9,999	$120k-$149,999	>$150,000
Mean Per-Capita (After-Tax) Income	$198	$5,012	$40,746	$69,019
Mean Per-Capita Expenditures	$12,943	$10,469	$28,596	$40,213
Mean Per-Capita Emissions				
Food & Alcohol	3.03	2.94	4.83	5.50
Shelter	1.44	1.33	1.85	2.67
Fuel (non-transport)				
Natural Gas	1.39	1.36	1.89	2.55
Electricity	6.21	6.51	7.78	8.94
Fuel Oil & Other Fuel	0.33	0.16	0.41	0.50
Telephone Services	0.08	0.08	0.11	0.12
Water & Other Public Services	1.04	1.08	1.90	2.09
Household Operations, Supplies, Furnishings, Equipment & Apparel	1.34	1.01	2.52	3.45
Transportation & Vehicle Exp.	0.66	0.24	1.68	2.74
Gasoline & Motor Oil	4.65	3.82	8.93	9.05
Healthcare	0.14	0.14	0.27	0.33
Other Expenditures	0.68	0.52	1.16	1.72
Total Per-Capita Emissions	20.99	19.19	33.32	39.65

Source: Authors' calculations using Consumer Expenditure Survey (2006) data and the CMU model described above. Figures are in metric tons of CO2-equivalent.

Figure 1 shows the breakdown of emissions for the "average" consumer in 2006 by major consumption category. The most carbon-relevant sectors are fossil-fuel intensive; gasoline, electricity, food and natural gas are the goods purchased by consumers with the highest associated emissions. As it turns out, perhaps unsurprisingly, these are the goods that drive the distribution of the costs of a carbon tax.

Figure 1. Breakdown of Carbon Tax Burden for 'Average' Consumer



Source: Author's calculations using Consumer Expenditure Survey (2006) data and the CMU Model described above.

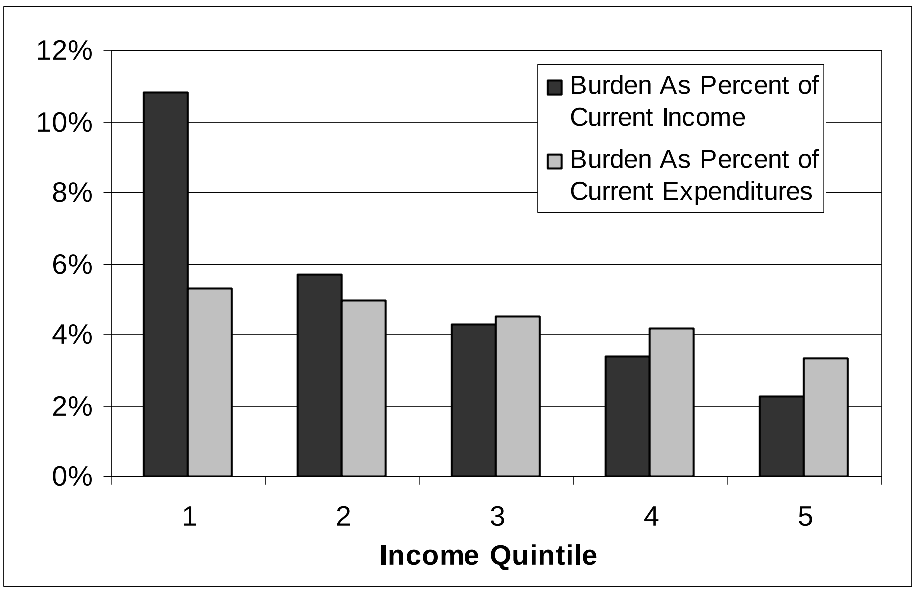
For a tax of $30 per ton CO_2-equivalent (based on the emissions estimates in Table 2), [17] an average person in the poorest income group would pay around $634 per year, while an average person in the wealthiest quintile would pay $1,018 annually. Although wealthier people would pay more in absolute terms, as a percentage of annual income, lower income groups bear a disproportionate share of the burden. The poorest quintile's burden (as a share of annual income) is 5.1 times that of the wealthiest quintile's. This is seen graphically in Figure 2, where the percentage of per-capita expenditures on a carbon tax is plotted against income groups.

There is a debate among economists as to whether current income or lifetime income should be used in the calculation of the incidence of a policy. Because annual income is volatile, and because it tends to increase and then decrease with age, a person's annual income may not be a good proxy for their relative income over their lifetime. However, lifetime income is far more difficult to measure. Current expenditures can be used as a proxy for lifetime income if consumption is relatively smooth over a person's

[17] This is in the ballpark of current policy proposals. See Paltsev, et al., 2007.

lifespan.[18] In this case, calculating the burden as a percent of lifetime income rather than current income results in a less regressive policy, though some authors find that using current expenditures as a proxy for lifetime income exaggerates the decrease in regressivity (Caspersen and Metcalf, 1994). When comparing the burden as a percentage of annual expenditures, a person's burden in the lowest income quintile is about 1.6 times that of the highest quintile.

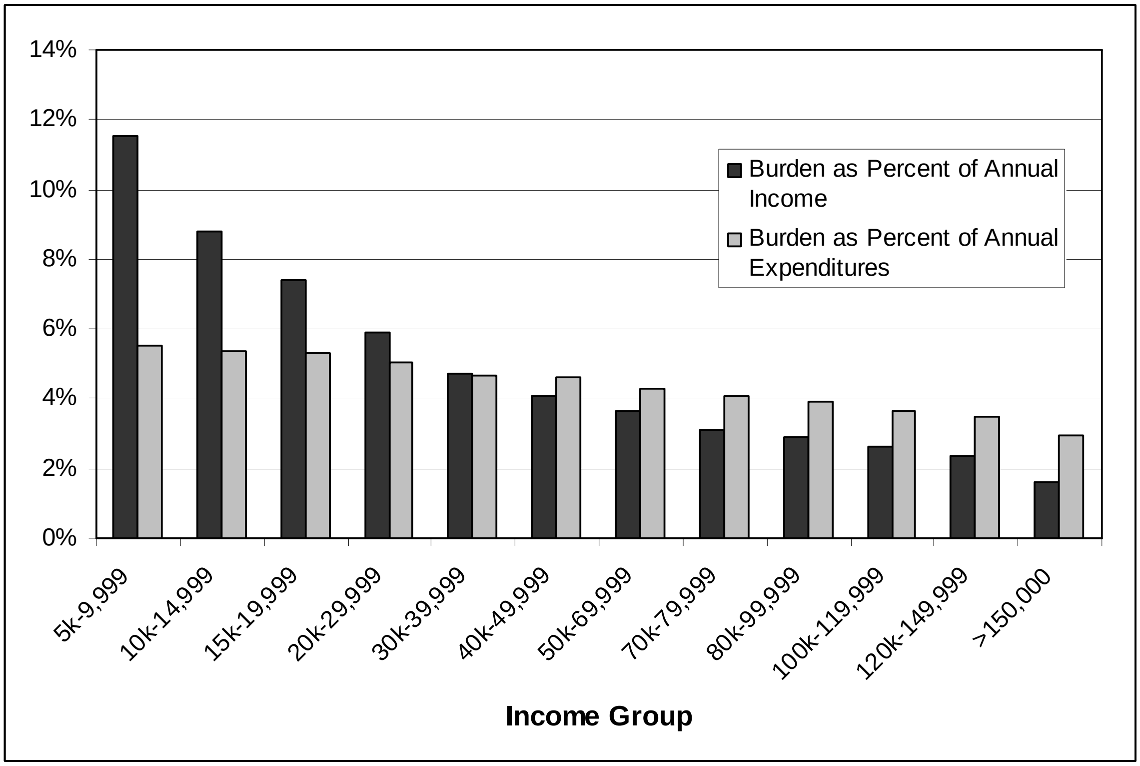
Figure 2. Per-Capita Carbon Tax Burden by Income Group



Per capita CO2 tax ($30/ton CO2e) as a percent of annual per-capita net income and current expenditures. Taxes (i.e. greenhouse gas emissions) were estimated using consumption data from the Consumer Expenditure Survey and associated emissions from the Economic Input Output model from Carnegie Mellon University.

[18] According to the lifetime income hypothesis, consumption is relatively smooth across time because people make contemporaneous consumption decisions based on their lifetime (and not current) income. For example, students may take out loans to support themselves during college because they anticipate earning income after graduating, and workers forgo consumption and save so that they have money for retirement.

Figure 3. Per-Capita Carbon Tax Burden by Income Group



Per capita CO2 tax ($30/ton CO2e) as a percent of current per-capita net income and current expenditures. Taxes (i.e. greenhouse gas emissions) were estimated using consumption data from the Consumer Expenditure Survey and associated emissions from the Economic Input Output model from Carnegie Mellon University.

Comparing individuals from the extreme ends of the income distribution yields even more regressive estimates of the incidence of a carbon tax. Figure 3 shows the annual burden as a percent of annual income and annual expenditures (lifetime income) by income. An individual from a household earning between $5,000 and $9,999[19] would pay an average of 11.5% of annual income, or 5.5% of annual expenditures for this carbon tax. Alternatively, an individual from a household earning more than $150,000 annually would be responsible to pay 1.6% of annual income, or 3% of annual

[19] Individuals from households earning less than $5,000 would be responsible for 230 percent of their average annual income and 4.9 percent of their annual expenditures. This underscores the importance of exercising caution in interpreting annual income figures for low income groups in the CES, as discussed in the text.

expenditures. The ratio of the burdens (as a percent of annual income) for these two groups is about 7.2, whereas the ratio is 1.9 for the corresponding lifetime burdens.

A carbon tax, given the assumptions above, would be regressive, but the degree of regressivity depends on the income measure used. This finding is consistent with other studies of the household incidence of carbon emission policies.[20] Furthermore, as discussed briefly in the next section, the overall regressivity of a policy depends critically on how the revenues are used.

III. Policy Implications

The regressive nature of pollution control policies is often a concern of politicians, but these new revenues could be used to benefit those harmed disproportionately by the new policy. Because the carbon tax discussed here would generate substantial revenues for the government, it is important to consider how these revenues might be spent so that the burden does not fall disproportionately on lower income groups. As discussed elsewhere in the literature (e.g. Parry et al, 2005), a carbon tax could be made less regressive, or even progressive, by "recycling" the revenue into tax cuts elsewhere in an economy. This could be achieved by targeting income tax cuts at lower income groups, reducing (or even eliminating) other federal taxes, or by increasing spending on government programs targeted at lower income groups. Here we

[20] Other economic studies of carbon taxes (e.g. Metcalf, 2008; Wier et al. 2005) generally find that they are regressive, but the degree varies based on the methodology, assumptions, and income basis (annual vs. lifetime). For example, Metcalf (2008) uses 2003 consumption data to estimate the partial equilibrium incidence of a carbon tax. For a $15 carbon tax, he finds that an average consumer in the lowest income decile would experience a decrease in disposable income of 3.4%, whereas the wealthiest income decile's disposable income would decrease by 0.8%. Wier et al (2005) find that the poorest decile spent 0.8% of disposable income on the Danish carbon tax, while the wealthies spent about 0.3% of their disposable income. For a review of other policies, see Parry, et al. (2005).

briefly discuss these options; for a more thorough (partial equilibrium) discussion of a revenue-neutral carbon tax swap, see Metcalf (2008).

To make the carbon tax discussed above (or a cap-and-trade program) distributionally neutral, lump-sum transfers, which are essentially cash payments that do not alter incentives or behavior, could be used. A more practical alternative would be in the form of reductions in the income tax burden for individuals based on their annual income. In practice, the carbon tax here could be made distributionally neutral by directing transfers (or income tax credits) in the amounts of $504, $416, $358, and $280 to individuals in the first four income quintiles, respectively. This would place a burden on each individual of around 2.23% of net annual income (equal to the burden of the highest income group),[21] offsetting the regressive effects of the carbon tax while leaving substantial tax revenues in the hands of the government.

Alternatively, revenues from a carbon tax could be used to finance cuts in other taxes.[22] The study of the incidence of taxes is a major subfield of public finance, and many empirical (and theoretical) studies have focused on the distributional incidence of payroll taxes, value-added taxes[23], sales taxes, and excise taxes. The literature generally finds these taxes to be regressive, though the degree varies widely due to assumptions about income, the amount of pass-through, and other factors (Fullerton and Metcalf,

[21] The analogous per-capita transfers to make the carbon tax distributionally neutral on a lifetime income basis would be $232, $222, $194, and $158 for the first through fourth income quintiles. This would result in a burden to income ratio of around 3.35% on a lifetime income basis.

[22] To the extent that the pre-existing taxes are distortionary, under certain conditions this may even lead to an efficiency gain (Goulder, et al., 1997).

[23] The literature on the incidence of a value-added tax (VAT) generally finds that such a policy is regressive. Caspersen and Metcalf (1994) find that a value added tax on food, housing and healthcare is mildly regressive, with the ratio of the median tax liability to income for the lowest income decile equal to 2.3, and for the highest decile 1.1. When using proxies for lifetime income, the degree of regressivity declines. Because there is no federal VAT in the US, revenues from a carbon tax could not be used to finance reductions in the VAT.

2002). For example, Poterba's (1989) study of the incidence of a gasoline tax finds that the bottom quintile's burden as a percent of current income is 5.3 times as high as that of the highest income quintile's. When calculating the burden as a share of current expenditures, he finds that it is less regressive—about 1.5 times as high.[24]

One candidate for revenue recycling would be to use revenues to finance cuts in the payroll tax. The costs of a payroll tax are regressive, and although part of the burden is paid by the employer, most studies find that the burden falls almost entirely on workers through reductions in wages (Fullerton and Metcalf, 2002). The Federal Insurance Contributions Act (FICA) tax is regressive in its very nature because beyond the Wage Base limit (currently $102,000 per year), any additional earnings are untaxed. Therefore the tax, as a percentage of income, effectively declines as income increases beyond that level.[25]

In order to fully analyze how to finance cuts in pre-existing taxes to create a distributionally neutral (or even progressive) bundle of taxes, we would need to analyze the general equilibrium effects of the overall tax system. However, a back-of-the-envelope estimate using the figures from the prior section suggests that the total revenues from a wide-reaching carbon tax of $30 per ton would equal approximately $237 Billion, or about 9.4% of the Federal budget in 2006. Although this is most likely an upper bound on actual revenues, because of reasons discussed above, a carbon tax could yield

[24] West and Williams (2004) also study the incidence of a gasoline tax, but they estimate the elasticity of demand for each income group and find that the tax is less regressive if one accounts for this behavioral response.

[25] However, a Congressional Budget Office study (CBO, 2006) argues that the overall social security system is progressive once benefits are factored in. On the other hand, Coronado, Fullerton, and Glass (2000) show that the progressivity of social security depends critically on the methodology of calculation. When incorporating mortality probabilities that differ by potential lifetime income, they find that social security, overall, is no longer progressive; for a discount rate of 4%, it is even regressive.

substantial government revenues, and careful recycling of these revenues could offset the regressive nature of a national GHG emissions policy.

IV. Conclusions

We use the Consumer Expenditure Survey and an augmented input-output model of the US economy to illustrate the regressive nature of a carbon tax in the United States. We find that the costs of a greenhouse gas policy in the United States are regressive, but there are a few caveats that deserve some attention. First, the preceding analysis was a *partial equilibrium* approach. Producers were assumed not to change production choices, costs were assumed to be fully passed through to consumers, and consumers are assumed to be unresponsive to increased product prices. Other researchers have found that low-income consumers are more responsive to price increases of polluting goods such as gasoline (West and Williams, 2004). Depending on the price elasticity of demand for other energy-intensive products, this could reduce the regressivity of a carbon tax. Second, some of the costs may be borne by factors of production. Environmental regulations may change real wages and returns to capital, which would change the optimal production inputs (and hence emissions) for various sectors, and the distribution of these costs across income groups affects the overall incidence of a carbon tax. Third, while we consider a broad carbon tax that takes into account all emissions, a cap-and-trade program for GHG emissions may have exemptions for emissions from some industries due to political considerations or high monitoring costs. Finally, we do not consider the distribution of the benefits of a greenhouse gas policy. If low income groups have more to gain from a cap-and-trade program or a carbon tax, the 'net' incidence of the policy may actually be progressive; alternatively, if wealthier households have more to gain, the 'net' incidence may be even more regressive.

A carbon tax (or an emissions trading program) is by nature regressive because polluting goods are mostly energy-intensive and take up a large percentage of a low-income person's budget. The regressive nature of a carbon tax could be alleviated (or eliminated) by recycling revenues wisely. This could be done by targeted transfers, financing cuts in regressive payroll or excise taxes, targeting income tax cuts at lower income groups, or by increasing spending on government programs targeted at lower income groups.

References

Burtraw, Dallas, Rich Sweeney, and Margaret Walls. 2008. "The Incidence of U.S. Climate Policy: Where You Stand Depends on Where You Sit." *RFF Discussion Paper 08-28.*

Carnegie Mellon University Green Design Institute. 2008. Economic Input-Output Life Cycle Assessment (EIO-LCA) model [Internet], Available from: http://www.eiolca.net/> [Accessed 19 Jul, 2008].

Caspersen, Erik, and Gilbert E. Metcalf (1994), "Is a value added tax regressive? Annual versus lifetime incidence measures", *National Tax Journal* 47:731−746.

Consumer Expenditure Survey, 2006. "Table 2. Income Before Taxes: Average Annual Expenditures and Characteristics." Available http://www.bls.gov/cex/2007/Standard/income.pdf. Accessed Dec 1, 2008.

Consumer Expenditure Survey, 2006. "Table 45. Quintiles of income before taxes: Shares of average annual expenditures and sources of income." Available http://www.bls.gov/cex/2006/share/quintile.pdf. Accessed Dec 1, 2008.

Consumer Expenditure Survey, 2006. "Table 2301. Quintiles of Income Before Taxes: Shares of Average Annual Expenditures and Sources of Income." Available http://www.bls.gov/cex/2007/Standard/higherincome.pdf. Accessed Dec 1, 2008.

Coronado, Julia Lynn; Don Fullerton; and Thomas Glass. 2000. "The Progressivity of Social Security" NBER Working Paper 7520.

Fullerton, Don. Distributional Effects of Environmental and Energy Policy: An Introduction, Distributional Effects of Environmental and Energy Policy (forthcoming) (2009)

Fullerton, Don, and Gilbert E. Metcalf. "Tax Incidence" *Handbook of Public Economics*. Ed. A.J. Auerbach and M. Feldstein. Amsterdam: Elsvier Science B.V., 2002. 1788-1839.

Goulder, Lawrence H., Ian W.H. Parry, and Dallas Burtraw. 1997. "Revenue-Raising Versus Other Approaches to Environmental Protection: The Critical Significance of Preexisting Tax Distortions." *Rand Journal of Economics* 28: 708-731.

Hendrickson, Chris T., Lester B. Lave, and H. Scott Matthews. *Environmental Life Cycle Assessment of Goods and Services: An Input-Output Approach.* (Resources for the Future Press, Washington, DC, 2006).

Leontief, Wassily., 1970. "Environmental Repercussions and the Economic Structure: An Input-Output Approach." *The Review of Economics and Statistics* 52(3): 262-271.

Leontief, Wassily. *Input-Output Economics*. 2nd ed., New York: Oxford University Press, 1986.

Metcalf, Gilbert E., 1999. "A Distributional Analysis of Green Tax Reforms." *National Tax Journal* 52: 665-681.

Metcalf, Gilbert E., 2008. "A Proposal for a U.S. Carbon Tax Swap: An Equitable Tax Reform to Address Global Climate Change." Forthcoming, *Review of Environmental Economics and Policy.*

Metcalf, Gilbert E., Sergey Paltsev, John M. Reilly, Henry D. Jacoby and Jennifer Holak. 2008. "Analysis of U.S. Greenhouse Gas Tax Proposals." *MIT Joint Program on the Science and Policy of Global Change Report 160.*

Paltsev, S., J. Reilly, H. Jacoby, A. Gurgel, G. Metcalf, A. Sokolov, and J. Holak. 2007. Assessment of U.S. Cap-and-Trade Proposals. MIT CEEPR paper 07-005.

Parry, Ian W.H., 2004. "Are Emissions Permits Regressive?" *Journal of Environmental Economics and Management* 47: 364-387.

Poterba, James M., 1989. "Lifetime Incidence and the Distributional Burden of Excise Taxes." *American Economic Review* 79: 325-330.

US EPA, 2007. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005." Available http://www.epa.gov/climatechange/emissions/downloads06/07ES.pdf.

West, Sarah E., and Roberton C. Williams III, 2004. "Estimates from a Consumer Demand System: Implications for the Incidence of Environmental Taxes." *Journal of Environmental Economics and Management* 47: 535-558.

Wier, Mette, Katja Birr-Pedersen, Henrik Klinge Jacobsen, and Jacob Klok, 2005. "Are CO2 Taxes Regressive? Evidence from the Danish experience" *Ecological Economics* 52: 239-251.

U.S. Census Bureau, Current Population Survey, 2007 Annual Social and Economic Supplement. Table HINC-06. Revised August 28, 2007. Available http://pubdb3.census.gov/macro/032007/hhinc/new06_000.htm.