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CLIMATE AND ENERGY ECONOMICS DISCUSSION PAPER | DECEMBER 14, 2012

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* We gratefully acknowledge assistance from the Alex C. Walker Foundation and the Center for Climate and Energy Solutions. We thank Danny Cohen and Daniel Hanson for their excellent research assistance. The views expressed in the paper are those of the authors and should not be interpreted as reflecting the views of any of the above organizations or of the institutions with which the authors are affiliated.

EXECUTIVE SUMMARY

This paper analyzes the distributional implications of an illustrative $15 carbon tax imposed in 2010 on carbon in fossil fuels. We analyze its incidence across income classes and regions, both in isolation and when combined with measures that apply the carbon tax revenue to lowering other distortionary taxes in the economy. The analysis first uses an input-output table approach to estimate the effect of the carbon tax on consumer prices, assuming that the tax is passed through fully to retail prices. Then, using Consumer Expenditure Survey data on consumption patterns, we estimate the burdens across households, assuming no behavioral response to the new prices.

Consistent with earlier findings, we find that a carbon tax is regressive. Taking into account both direct and indirect energy costs, the carbon tax burden would comprise 3.5 percent of the income of the poorest decile of households and only 0.6 percent of the income of the highest decile. In the consumption approach, the carbon tax is substantially less regressive, with the ratio of average taxes paid by the bottom and top deciles equal to about 1.7.

In the tax swap simulations, we subtract the burden of other taxes that the carbon tax revenue could displace, such as the corporate and personal income taxes, and compute the net effect on households. We analyze revenue-neutral tax shifts under three assumptions about how those other taxes lower households' capital and labor income: all borne by labor, all borne by capital, and a 50/50 split. Although all of the tax swaps lower the overall burden of the carbon tax (as a share of household income) on the poorest two deciles, tax swaps also exacerbate the regressivity of the carbon tax on the high end. This means that the benefit to the highest income households of the reduction in other taxes is greater than their share of the burden of the carbon tax.

Results suggest that if policymakers direct about 11 percent of the tax revenue towards the poorest two deciles, for example through greater spending on social safety net programs than would otherwise occur, then on average those households would be no worse off after the carbon tax than they were before.

The degree of variation in the carbon tax incidence across regions (with no offsetting tax decreases) is modest; the maximum difference in the average rate across regions is 0.45 percentage points of income. Of the tax swaps, the labor tax swap results in the least variation in net burdens across regions, with a maximum difference across regions of 0.5 percentage points of income. In contrast, the capital tax swap produces a maximum difference across regions of 1.66 percentage points. This suggests that capital incomes are more unevenly distributed across regions than labor incomes.

1. INTRODUCTION

Greenhouse gas emissions are primarily a result of combustion of fossil fuels containing carbon. Economists have long argued that a carbon tax is an efficient and obvious policy tool to effect long-term reductions in carbon emissions. A carbon tax imposes a cost on carbon emissions, and is therefore a market-based instrument that forces polluters to internalize the cost of the externality. A carbon tax that reflects the marginal social damages from the pollution can improve social welfare.

However, economic challenges to the use of carbon taxes arise. Policymakers care about the distribution of policy effects across different household groups, in particular across different income classes and those in different geographic regions. If a policy burdens lower-income households relatively more than higher-income households as a share of household income, then economists call the policy regressive. In general, lower income households spend a higher percentage of their income on energy and other goods whose relative prices will go up under a carbon tax. That suggests a carbon price will be regressive, although the exact measure of its regressivity depends on how one ranks households by socioeconomic status and how one analyzes the burden of the tax.

Some also fear that areas of the U.S. heavily dependent on coal for electricity, for example, will be hit much worse than other regions. However, prior analysis of the distribution of burdens across the country shows that households in different regions will likely bear similar burdens as a share of income. That is because people in different regions use different mixes of fuels to heat and cool homes, and they also vary in their gasoline consumption. Hassett et al (2009) show that these differences tend to even out the impact of the price on carbon. In other words, areas where electricity prices may go up most may be areas where expenditures on transport fuels are relatively low. In addition, households in most regions consume similar baskets of non-energy goods, resulting in similar patterns of indirect energy consumption. However, the study estimates that a carbon pollution tax could fall a little harder than average on households in Eastern central states because of their higher overall fuel consumption as a share of income.

The final economic incidence of a carbon tax depends heavily on what happens to the revenue. As discussed in Dinan (2012), a number of studies have examined of the distributional effects of a carbon tax under varying assumptions about how the revenues are used. This paper provides new estimates for the net burden on households by income class and region when the revenue is used to reduce other taxes. This approach is of particular appeal because it offers the potential to both cost effectively improve the environment and also provide an efficiency-enhancing tax reform. The most efficient form of revenue recycling would offset the most distortionary taxes, meaning the ones that have the highest marginal deadweight loss.

A number of scholars have examined such "tax swaps."[1] Although the studies use different tools and arrive at different conclusions about how much of the macroeconomic cost of a carbon tax can be mitigated, it is clear that reducing existing tax distortions can be an important way to lower its overall burdens. Analyzing a 15 percent cut in emissions through a cap-and-trade system, the Congressional Budget Office estimated that the downward hit to GDP from a cap-and-trade system (which can be economically similar to a carbon tax) could be reduced by more than half if the government sold allowances and used the revenues to lower corporate income taxes rather than to provide lump-sum rebates to households or to give the allowances away.[2] Metcalf (2007) also suggests that linking a carbon tax to a capital income tax reduction could be efficiency-enhancing. Parry and Bento (2000) find that efficiency gains are particularly large when revenue recycling lowers taxes that favor some kinds of consumption (such as housing or health insurance) over others. Feldstein (2006) argues that the distortions from the tax system are greater than most people realize, resulting in costs of about $0.76 for every dollar the federal government raises. Some recent modeling evidence suggests that carbon tax swaps could improve welfare and/or economic growth, irrespective of the environmental benefits.[3]

However, one complication of pursuing the most efficient revenue recycling could be the distributional results. Some of the most distortionary taxes fall on high personal incomes and corporate income, so lowering those marginal tax rates is regressive, even while it provides the greatest efficiency gains and minimizes the cost of the program. Put another way, the most economically efficient recycling benefits poor households (who pay very little in taxes) proportionately less than rich households (who pay much more in taxes). Thus, there is an intrinsic tradeoff between optimizing the macroeconomic effects of the tax reform and making it distributionally neutral or progressive.[4]

In this paper, we consider the effect of an illustrative carbon tax of $15 per metric ton of carbon dioxide in the year 2010. We analyze how the carbon tax affects households of different income differently and what happens if the carbon tax is accompanied by reductions in taxes that fall on labor and/or capital income. This study, along with Dinan (2012), presents new evidence on the net distributional effects of a carbon tax used to offset other taxes. In the next section, we discuss our methodology and data. Section 3 presents distributional burdens by income class for a carbon tax. Section 4 presents incidence results when we swap a corporate or personal income tax with a carbon tax. Section 5 presents regional distributions, and Section 6 concludes.

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[1] A review of this literature appears in Parry and Williams (2011). Also see Goulder et al. (1999), Parry et al. (1999), Parry and Oates (2000), Parry and Bento (2000), and CBO(2007).

[2] Elmendorf (2009)

[3] See for example Rausch and Reilly (2012) and McKibbin, Morris, and Wilcoxen (2012).

[4] See Dinan and Rogers (2002).

2. METHODOLOGY

Energy related emissions of CO_2 were 6,821.8 million metric tons in 2010. Given the $15 per metric ton tax rate and ignoring initial reductions in emissions, the carbon tax would be expected to raise $102.3 billion in 2010.[5]

The incidence calculations divide up the $102.3 billion in tax paid across households and regions. 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 fossil energy prices and higher prices of goods and services that had energy as an input somewhere in their supply chain. 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 seven 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), and a summary appears in the Appendix of this paper.

In short, we start with Input-Output matrices from U.S. Bureau of Economic Analysis (BEA) called the Summary Make and Use matrices from 2010. The Make matrix shows how much each industry makes of each commodity, and the Use matrix shows how much each industry uses of each commodity. Using these two matrices, we derive an industry-by-industry transactions matrix that traces the use of inputs by one of 66 industries to all the other industries. Using various adding-up identities and making assumptions about production and trade, we can trace the impact of price changes from the carbon tax in one industry to the products of all other industries in the economy. We translate those price increases into corresponding price increases for these consumer items using the PCE Bridge tables, also from BEA. Then, we use data from the U.S. Bureau of Labor Statistics' Consumer Expenditure Survey (CEX) for 2010 to compute the carbon taxes paid (via those higher prices) by each household in the survey across 33 categories of personal consumption items. These price increases are shown in Appendix Table 1.

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 because participants in the supply chain shift the burden forward and backward as much as supply and demand conditions in their markets allow. The economic incidence of a carbon tax in particular is likely to differ markedly from the statutory incidence. For example, while the statutory incidence of an upstream tax on gasoline may be on the refinery owner, the economic

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[5] 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).

incidence is likely to be on final consumers as fuel refiners and marketers shift the tax forward to consumers in the form of higher prices.

Estimating the incidence of a tax necessarily requires numerous assumptions and methodological choices. First, we must determine a unit of observation, such as an individual or a household. For this study, we use the household as a unit. Second, we must choose the time frame over which to characterize households' incomes. The early tax incidence literature used current income as the basis of burden measures; it compared the tax liability over a short period (such as a year) to income earned over that same period. Following Friedman (1957) and the permanent income hypothesis, a realization emerged that households make consumption decisions a longer time horizon. Hence, in this view analysts should measure income 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 from an annual income perspective when in fact, they may be comfortably well off. In other words, many low-income people are not necessarily poor. Caspersen and Metcalf (1995) report cross tabulations on income 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. Therefore, we also use current consumption as a proxy for lifetime income.

The final assumption in an incidence analysis is the allocation of the tax burden between consumers and producers. 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). Our approach assumes that consumers bear the full burden of the tax. Considerable theoretical work on the incidence of energy taxes in general, and of carbon taxes, in particular supports this approach. A number of large-scale general equilibrium models (CGE models) suggest that in the short to medium run, the burden of a carbon tax will be mostly passed forward into higher consumer prices.[6]

Our analytic approach assumes no consumer behavioral response to the after-tax prices, and we do not account for how price-indexed social safety net programs could buffer the effect on the poor. Consumer substitution away from more carbon-intensive products will indeed contribute to an erosion of the carbon tax base. But given the inelastic demand for energy in the short run, consumers' behavioral response to higher energy prices will reduce the tax burden by less than it reduces tax collections. Firms incur costs to shift away from carbon-intensive inputs, costs that will be passed forward to consumers. Consumers also will engage in welfare-reducing activities as they shift their consumption activities to avoid paying the full

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[6] See, for example, Bovenberg and Goulder (2001) and Metcalf et al. (2008).

carbon tax. Although the burden impacts reported here do not take account of the range of economic responses to the tax, our estimates are a reasonable first approximation of the short run welfare impacts of a carbon tax.

3. DISTRIBUTION OF BURDEN OF THE CARBON TAX BY INCOME AND CONSUMPTION

Table 1 presents our results for incidence using annual income as our measure of socioeconomic status. Figure 1 shows the results graphically. We have sorted households by income into ten equally sized groups, or deciles, from the ten percent of households with the lowest income to the ten percent with the highest income. The entries in the tables show the average carbon tax as a fraction of income for households in each income decile. Confirming earlier findings, the carbon tax is quite regressive when measured relative to current income. The burden in the lowest income decile in 2010 is over five times the burden in the top decile when measured as a fraction of annual income.[7]

Table 1. Distribution of Burden by Annual Household Income

Decile	Direct	Indirect	Total
Bottom	2.38	1.16	3.54
Second	1.83	0.90	2.74
Third	1.27	0.75	2.02
Fourth	1.06	0.61	1.67
Fifth	0.94	0.55	1.49
Sixth	0.78	0.48	1.26
Seventh	0.68	0.44	1.12
Eighth	0.54	0.41	0.95
Ninth	0.48	0.37	0.85
Top	0.31	0.31	0.63

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

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[7] The actual burden on each decile in dollars appears below.

Figure 1.

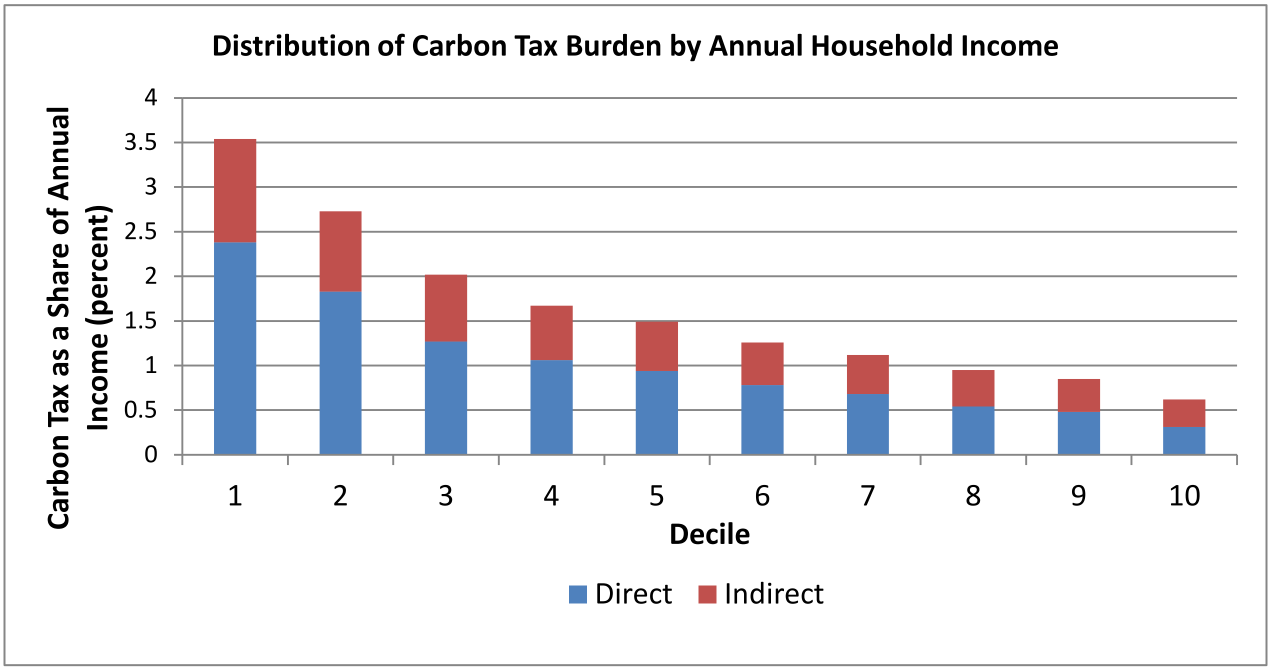


Table 1 and Figure 1 also show the burden of the direct and indirect components of the tax. The direct component of the tax is highly regressive – the average tax burden in the bottom decile is 7.6 times the average tax rate in the highest decile in 2010. The regressivity of the indirect portion of the tax is nearly half of the direct component. The indirect tax burden is 3.7 times higher for the bottom decile relative to the top. The result 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. In summary, had a carbon tax been in effect in 2010, the tax would have looked quite regressive using annual income as a measure of household well being.

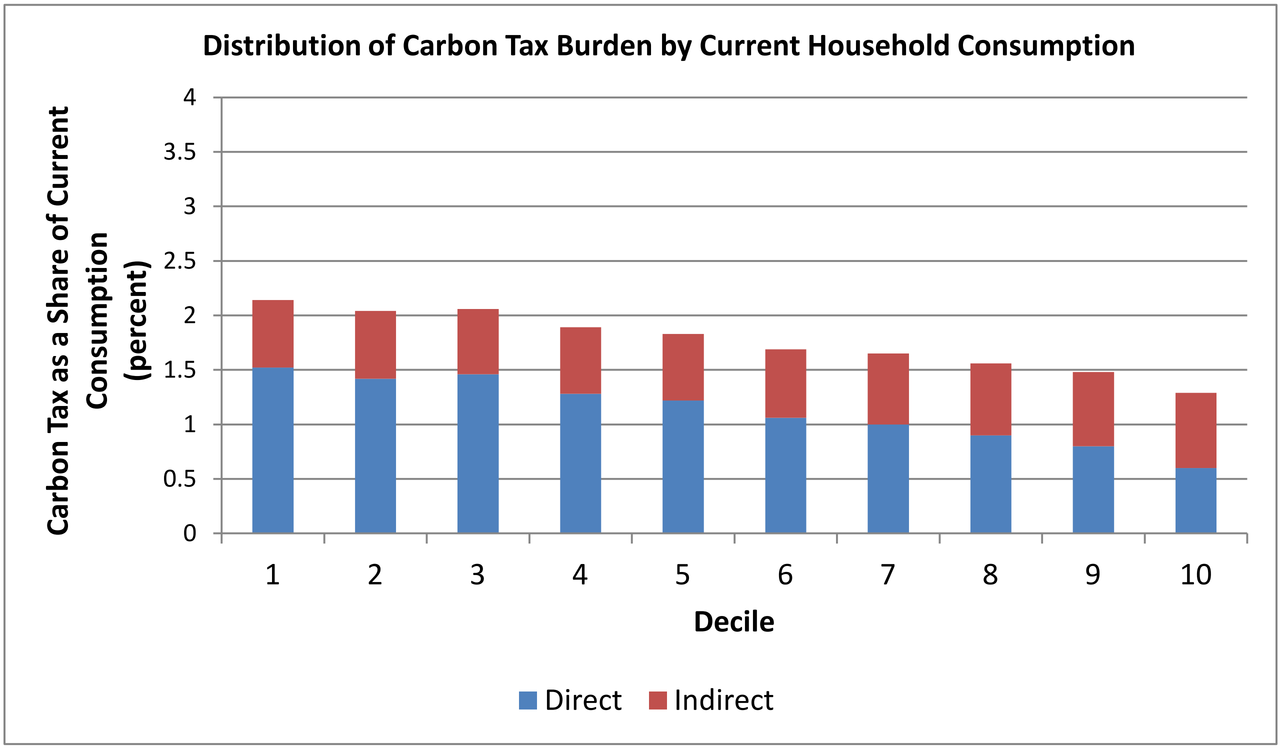
Another way of measuring regressivity uses the tax burden as a share of consumption, not income. Economists use consumption as a proxy for income averaged over an individual's lifetime, rather than annual income. Economists use this measure because income can vary greatly over the course of individuals' lifetimes. For example income tends to be smaller than average both in early and late life. Standards of living, i.e. consumption, fluctuate much less. The results change dramatically. Table 2 shows the distribution of the carbon tax in the three years when households are sorted by current consumption. Figure 2 show the results graphically on the same scale as Figure 1. For these results, the carbon tax burden is expressed as a fraction of overall consumption, rather than income.

Table 2. Distribution of Burden by Current Household Consumption

Decile	Direct	Indirect	Total
Bottom	1.52	0.62	2.14
Second	1.42	0.62	2.03
Third	1.46	0.60	2.06
Fourth	1.28	0.61	1.89
Fifth	1.22	0.61	1.82
Sixth	1.06	0.63	1.70
Seventh	1.00	0.65	1.66
Eighth	0.90	0.66	1.56
Ninth	0.80	0.68	1.48
Top	0.60	0.69	1.29

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

Figure 2.



In this measurement approach, the carbon tax is substantially less regressive, with the ratio of average taxes paid by the bottom and the top at about 1.7. The primary force driving this difference is the tendency for consumption to be more evenly distributed than income, especially in the lower brackets.[8] We also see that for the lowest deciles, the tax is a smaller

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[8] This relationship is well known in the literature. Krueger and Perri (2002) for example, document this fact.

share of total consumption than income, whereas for higher income deciles the tax is a larger share of consumption than income. The reason for this is that the distribution of consumption is a lot more even than the distribution of income. Consumption expenditures at the bottom are approximately 11 percent of those at the top. However, incomes at the bottom are only 4.5 percent of those at the top. Further, households in the bottom decile show average consumption expenditures that are higher than their average incomes. In other words, they tend to reduce saving and consume more than the income data would suggest. Therefore, carbon taxes are a smaller fraction of consumption than income for this decile. The opposite is true for higher income households. Average consumption expenditures are lower than average incomes, since these households tend to save out of income. As a result, carbon taxes are a larger fraction of consumption than income.

The direct and indirect burdens shown in Table 2 and Figure 2 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.

This result was similarly reported in Bull, Hassett, and Metcalf (1994) who found that the lifetime calculation changed the results because the proportion of energy in total consumption (or ratio of energy consumption to income) varied significantly over a person's life, with the elderly low income individuals in particular having relatively large current energy consumption. The ratio of direct taxes paid by the bottom is about 3 times that in the top deciles. This is less than half the ratio when we used current income as the welfare measure. The indirect burden is in fact, slightly progressive in 2010. Clearly, direct consumption has the characteristics usually associated with necessary consumption, while indirect consumption has a more varied distribution.

4. DISTRIBUTION OF BURDEN WITH TAX SWAPS

We now turn to the question of the regressivity of a carbon tax if the revenue is used to reduce other tax burdens. In the results in Tables 1 and 2, we implicitly assumed the carbon tax revenue leaves the economy; essentially nobody gets it. More realistic would be an assumption that the money goes somewhere; the government could spend it, rebate it, reduce the budget deficit, or reduce other taxes. As noted above, economists widely favor using the carbon revenue for pro-growth tax reforms or deficit reduction. Here we don't capture any effects of the potential macroeconomic benefits of such revenue recycling. Rather, we estimate what would happen distributionally in the short run if other tax burdens fall.

What share of other taxes could a carbon tax replace? In 2010, the U.S. corporate income tax raised $191.4 billion, while the personal income tax brought in $898.5 billion.[9] Therefore, our carbon tax of $15 per metric ton generating revenues of $102.3 billion would replace slightly more than half of the corporate income tax or 11.4 percent of personal income tax revenues. In practice, those shares would evolve over time as carbon tax revenue and other revenues evolve at different rates.

To model the change in overall tax burden that would come with a carbon tax swap, we start with the carbon tax burdens we computed above. We now subtract the burden of other taxes that revenue could displace, such as the corporate and personal income taxes, and compute the net effect on households of the revenue-neutral shift in tax instruments. To do this, we need to make an assumption about how those other taxes lower households' capital and labor income. This is not as straightforward as it sounds because the statutory incidence is not the same as the economic incidence. For example, the employer's share of a worker's payroll tax could result in either lower profits for the employer or lower wages for the worker. It depends on how the labor market works.

Therefore, we have to assume how the tax reduction will benefit workers in the form of higher wages, shareholders in the form of higher returns to capital, or a combination of both. To span the possible outcomes of a carbon tax swap, we compute the burden shift in three ways. First, we assume all of the taxes the carbon tax revenue offsets fall on households in proportion to their share of labor income. Then we assume the burden of the offset taxes are split 50-50 across labor and capital income, and third we assume all of the burden falls on households in proportion to their share of capital income. The burden of the tax swap is the ratio of higher consumer goods prices minus the benefits of higher returns to wage and salary income divided by household annual income.

In the CEX data, we use wage and salary income to define the returns to labor, and we use rents, dividends and interest to define the returns to capital. For the share of the swap that benefits labor, we assume that households receive higher wages based on their respective shares of labor income in the total population. Similarly, for the share of the swap that benefits capital, households receive higher capital income based on their respective shares of capital income in the population.

These scenarios are idealized, but they broadly correspond to what could happen in an actual tax reform situation. Economists generally find that that lowering payroll taxes and labor income taxes (the share of the personal income tax that falls on wages and other compensation) would benefit workers in the form of higher after-tax wage income. On the

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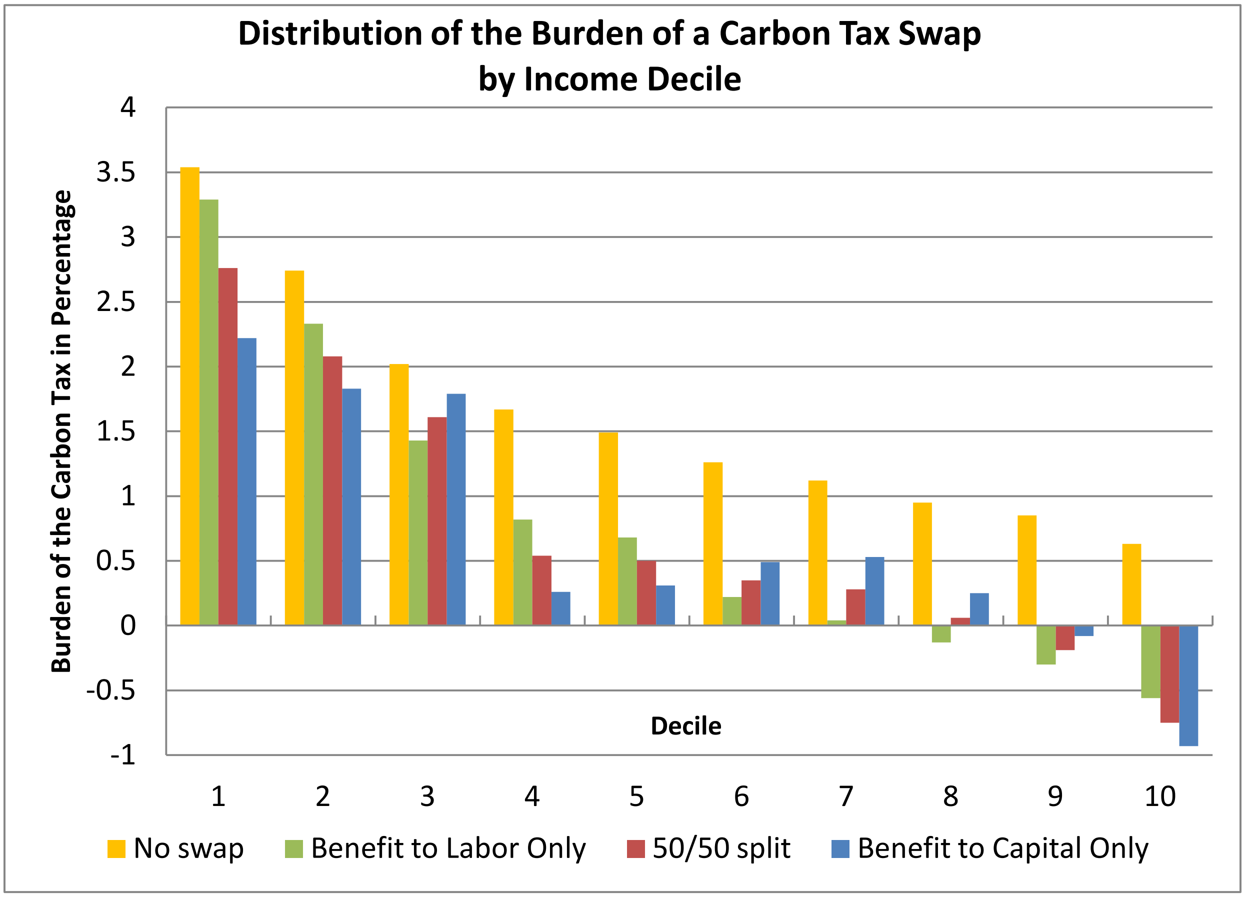
[9] White House Office of Management and Budget Historical Tables, Table 2.1, Receipts by Source 1934-2017. Downloaded from http://www.whitehouse.gov/omb/budget/Historicals.

other hand, lowering taxes on corporate income, dividends, and capital gains is far more likely to increase after-tax income for shareholders.

Figure 3 graphs the results for the scenario with no tax swap (i.e. the carbon tax alone as shown in Figure 1), along with the three tax swap scenarios. Tables 3, 4, and 5 report the numerical results for the tax swap scenarios. Figure 3 shows that although all of the tax swaps lower the overall burden of the carbon tax (as a share of household income) on the poorest two deciles, tax swaps also exacerbate the regressivity of the carbon tax on the high end. This means that the benefit to the highest income households of the reduction in other taxes is greater than their share of the burden of the carbon tax. Of course, all households are better off than in the scenario in Table 1, in which we assume the carbon tax revenue leaves the economy entirely.

Figure 3.



One might wonder why the colored bars in Figure 3 do not appear to sum to zero in the tax swap scenarios since the same amount of money is being taken away with the carbon tax and being returned through lowering other taxes. Each decile represents 10 percent of households, not 10 percent of all income, and therefore the bars would not sum to zero. For example, the blue bar showing the positive net benefits to the highest income households from a capital tax swap represents a lot more money than the blue bar showing about a 2.2 percent net burden as a share of income to the lowest decile.

Table 3 shows that the burden of the tax swap is marginally lower for bottom income deciles and significantly lower for top income deciles under Scenario 1, relative to Table 1. Note that for the tables involving tax swaps, the direct and indirect burden do not sum up to the total burden since we have subtracted the benefits derived from the tax swap from both the direct burden as well as the indirect burden. In practice, the benefit will apply only once to the total.

Table 3. Distribution of Burden: Tax Swap, Full Benefit to Labor

Decile	Direct	Indirect	Total
Bottom	2.13	0.91	3.29
Second	1.43	0.50	2.33
Third	0.68	0.16	1.43
Fourth	0.20	-0.24	0.82
Fifth	0.13	-0.26	0.68
Sixth	-0.27	-0.56	0.22
Seventh	-0.40	-0.64	0.04
Eighth	-0.54	-0.67	-0.13
Ninth	-0.67	-0.79	-0.30
Top	-0.87	-0.87	-0.56

Source: Author's Calculations. The table reports the within-decile average ratio of carbon tax burdens to income when the full benefit of the reduced corporate tax is on labor wages.

The average tax burden on the bottom decile is 3.3 percent of income, and for the top decile, the burden is negative since the price increases are less than the returns to wage income from the reduction in the personal or corporate income tax. The ratio of the bottom to the top is (negative) 5.9. Much of this is driven by the direct tax burden which is significantly higher for the bottom deciles relative to the top. The indirect burden is also relatively unequally distributed. Thus, while this tax swap leads to lower absolute burdens in all deciles of the population, it seems to worsen the relative ratios since it helps the higher income groups much more than the lower income deciles.

Table 4 shows the results for the 50 percent labor/50 percent capital split. This reduces the average tax rate for all households relative to the 100 percent labor scenario, since not only are they getting higher "returns" on their wage income but also on their capital income. The bottom decile household now pays only 2.76 percent of the carbon tax on their income. The top decile again experiences a negative tax rate of -0.75 percent of income.

Table 4. Distribution of Burden: Tax Swap, Labor/Capital Split

Decile	Direct	Indirect	Total
Bottom	1.60	0.37	2.76
Second	1.18	0.25	2.08
Third	0.86	0.34	1.61
Fourth	-0.08	-0.52	0.54
Fifth	-0.06	-0.44	0.50
Sixth	-0.13	-0.43	0.35
Seventh	-0.15	-0.40	0.28
Eighth	-0.36	-0.48	0.06
Ninth	-0.56	-0.68	-0.19
Top	-1.06	-1.06	-0.75

Source: Author's Calculations. The table reports the within-decile average ratio of carbon tax burdens to income when the benefit of the reduced corporate tax is passed on equally to labor wages and capital.

Finally, Table 5 shows a situation where 100 percent of the benefits are transferred to capital owners, and none to labor. This has the effect of further lowering average tax rates on the bottom and top deciles. Note that the distribution in this scenario looks relatively more even than in the earlier two cases since capital incomes in the CEX are not well measured at the top. Therefore, capital incomes are more evenly distributed and tax burdens go down by less at the top than at the bottom income deciles. Note that we may be overstating the tax rates in this table since capital incomes are poorly measured in the CEX, particularly for the higher income households.

Table 5. Distribution of Burden: Tax Swap, Full Benefit to Capital

Decile	Direct	Indirect	Total
Bottom	1.06	-0.16	2.22
Second	0.92	0.00	1.83
Third	1.04	0.53	1.79
Fourth	-0.36	-0.80	0.26
Fifth	-0.25	-0.63	0.31
Sixth	0.00	-0.29	0.49
Seventh	0.09	-0.15	0.53
Eighth	-0.17	-0.29	0.25
Ninth	-0.45	-0.56	-0.08
Top	-1.25	-1.25	-0.93

Source: Author's Calculations. The table reports the within-decile average ratio of carbon tax burdens to income when the full benefit of the reduced corporate tax is on capital income.

Share of Revenue Needed to Hold Poor Households Harmless

Figure 3 shows that even if all the tax revenue is returned to households through lower taxes, the poorest households are still worse off under a carbon tax. Since hose households make little money, they pay a small share of federal taxes on labor and capital, and consequently a tax cut simply does not help them much.

This section examines how much of the revenue policymakers would have target to those households so that they are no worse off, leaving the remainder for a tax swap. Table 6 shows how much of the $102.3 billion in carbon tax revenue is paid by each group of households. It shows that the poorest 20 percent of households pay about 11 percent of the tax, and the richest twenty percent of households pay about 34 percent of the tax. The table suggests that if policymakers direct about 11 percent of the tax towards the poorest two deciles, for example through greater spending on social safety net programs than would otherwise occur, then those households would on average be no worse off after the carbon tax than they were before. Of course, individual households within those groups might be better or worse off depending on their individual energy consumption patterns and participation in federal spending programs.

Table 6. Share of the Burden by Income Decile

Decile	Burden ($ billions)	Cumulative burden ($ billions)	Percent of total burden (%)	Cumulative % of burden
Bottom	5.0	5.0	5	5
Second	6.5	11.5	6	11
Third	7.0	18.5	7	18
Fourth	8.2	26.7	8	26
Fifth	9.3	36.0	9	35
Sixth	10.0	46.0	10	45
Seventh	11.2	57.2	11	56
Eighth	12.1	69.3	12	68
Ninth	13.9	83.2	14	81
Top	19.1	102.3	19	100

Source: Authors' Calculations. The table reports the total carbon tax burdens to each household income decile, before any tax swaps or other redistribution of proceeds.

5. DISTRIBUTION OF BURDEN BY U.S. REGION

We next turn to a regional analysis of the incidence of the tax. Policymakers may be concerned that a carbon tax might burden some regions or parts of the country more than others. For example, regions that are more dependent on coal-fired electricity will likely see higher burdens than areas that derive electricity predominantly from renewables or nuclear power. Coal-dependent regions may start with electricity prices that are low relative to other areas, but a carbon tax would impose a relatively higher burden those regions at the same time it evens out electricity prices across the country.

To measure the geographic burden of the tax (had it been imposed in 2010), we group households by region and measure their average tax rate using weighted averages of the tax burdens.[10] First, we assume, as we did in the earlier section, that the revenue simply leaves the U.S. economy. Results appear in Table 7.[11] The tax burden as a share of household income varies around 1.5 percent, and the degree of variation across regions is modest. The maximum difference in the average rate across regions is just 0.45 percentage points. This is remarkable considering the variation in weather conditions, driving patterns, and other factors across the regions.

Table 7. Regional Distribution of Burden: Annual Income

Region	Direct	Indirect	Total
New England	0.90	0.59	1.49
Mid Atlantic	0.96	0.53	1.49
South Atlantic	0.83	0.54	1.37
East South Central	0.99	0.55	1.53
East North Central	1.15	0.58	1.73
West North Central	1.06	0.52	1.58
West South Central	0.85	0.56	1.41
Mountain	0.94	0.66	1.60
Pacific	0.69	0.58	1.27

Source: Author's Calculations. The table reports the within region average ratio of carbon tax burdens to income.

The bulk of the variation across regions in carbon tax payments arises from the direct portion of the tax. The underlying data reveals that the relatively high regional burden for the East South and East North Central region is due to the higher consumption of gasoline per household in that region relative to others. By itself, this would have lead to much larger burdens of the carbon tax on consumers in this region. However, consumption of other direct energy goods such as natural gas, electricity and home heating oil are relatively low in that region. Such differences substantially even out the burden across regions. For instance, gas

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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.

[11] The states in each region are as follows: New England: Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island; Mid Atlantic: New Jersey, New York, Pennsylvania; South Atlantic: West Virginia, Virginia, North Carolina, South Carolina, Georgia, Florida, District of Columbia, Maryland, Delaware; East South Central: Kentucky, Tennessee, Missouri, Alabama, Mississippi; East North Central: Wisconsin, Illinois, Michigan, Indiana, Ohio; West North Central: North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa; West South Central: Texas, Oklahoma, Arkansas, Louisiana; Mountain: Montana, Idaho, Wyoming, Nevada, Utah, Colorado, Arizona, New Mexico; Pacific: California, Oregon, Washington, Alaska, Hawaii.

consumption is highest in the East North Central region, electricity is highest in the West South Central region, and home heating oil is highest in New England. There is little variation in the indirect burden across regions. This suggests that consumers in different regions of the country buy similar mixes of non-energy commodities.

Figure 4 graphs both the results in Table 7 and the regional results for the three different tax swap incidence scenarios that appear in Tables 8, 9, and 10. The results suggest that a tax swap is likely to increase the variation in burden across regions. The incidence of a tax swap can vary significantly across regions, and the regional incidence depends importantly on whether the swap reduces labor or capital taxes. Of the tax swaps, the labor tax approach results in the least variation in net burdens across regions. In the case when full benefits are passed to labor, the maximum difference across regions is 0.5 percentage points, whereas in the capital tax swap the maximum difference across regions is 1.66 percentage points. This suggests that capital incomes are more unevenly distributed across regions than labor incomes. Figure 4 indicates where that capital income may be going; New England, the South Atlantic, and the Pacific region fare best with a tax swap favoring capital income, but the other regions fare best with lower labor income taxes.

Figure 4

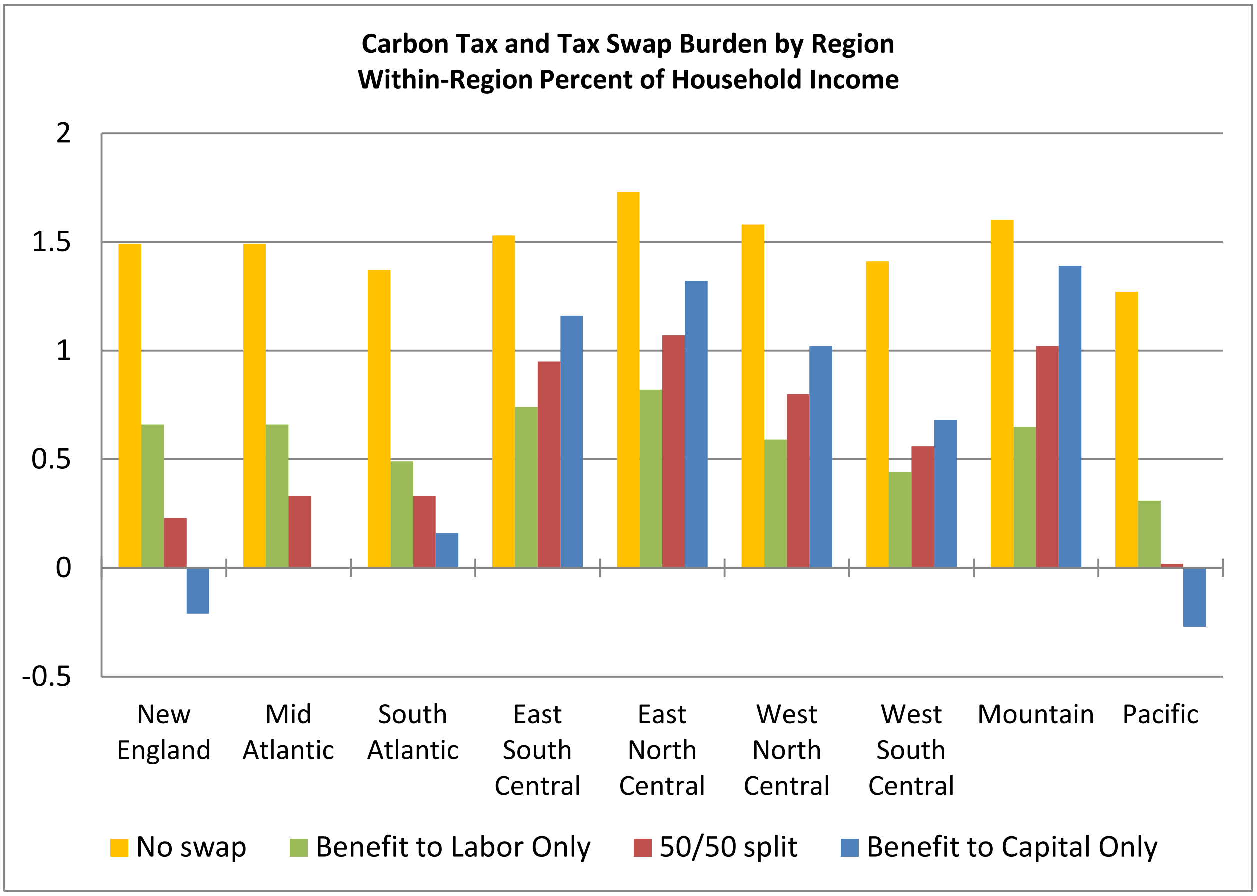

Table 8. Regional Distribution of Burden: Tax Swap, Full Benefit to Labor

Region	Direct	Indirect	Total
New England	0.08	-0.24	0.66
Mid Atlantic	0.13	-0.30	0.66
South Atlantic	-0.05	-0.34	0.49
East South Central	0.20	-0.25	0.74
East North Central	0.24	-0.32	0.82
West North Central	0.07	-0.47	0.59
West South Central	-0.12	-0.41	0.44
Mountain	-0.01	-0.29	0.65
Pacific	-0.27	-0.38	0.31

Source: Author's Calculations. The table reports the within region average ratio of carbon tax burdens to income when the full benefit of the reduced corporate tax is on labor income. Regions are defined elsewhere.

Table 9. Regional Distribution of Burden: Labor/Capital Split Burden

Region	Direct	Indirect	Total
New England	-0.36	-0.67	0.23
Mid Atlantic	-0.20	-0.63	0.33
South Atlantic	-0.21	-0.50	0.33
East South Central	0.40	-0.04	0.95
East North Central	0.49	-0.08	1.07
West North Central	0.29	-0.26	0.80
West South Central	0.01	-0.29	0.56
Mountain	0.36	0.08	1.02
Pacific	-0.56	-0.67	0.02

Source: Author's Calculations. The table reports the within region average ratio of carbon tax burdens to income when the benefit of the reduced corporate tax is passed equally to labor and capital income. Regions are defined elsewhere.

Table 10. Regional Distribution of Burden: Full Benefit to Capital

Region	Direct	Indirect	Total
New England	-0.80	-1.11	-0.21
Mid Atlantic	-0.53	-0.96	0.00
South Atlantic	-0.38	-0.67	0.16
East South Central	0.61	0.17	1.16
East North Central	0.73	0.17	1.32
West North Central	0.50	-0.05	1.02
West South Central	0.13	-0.17	0.68
Mountain	0.73	0.45	1.39
Pacific	-0.85	-0.97	-0.27

Source: Author's Calculations. The table reports the within region average ratio of carbon tax burdens to income when the full benefit of the reduced corporate tax is on capital income. Regions are defined elsewhere.

6. CONCLUSION

This paper measures the incidence of carbon taxes using both annual income and consumption as a basis for the household burden of the tax. We analyze a $15 per metric ton tax on CO_2 in the year 2010. We first use economy-wide Input-Output tables from the Bureau of Economic Analysis to assess how the $15 tax would affect the industrial sector generally and particularly 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 increases in 33 categories of consumer goods, we calculate the burden of the tax on households using consumption data from the Consumer Expenditure Survey.

Our results suggest that a carbon tax is regressive when using annual incomes as the base for the incidence measure, but less regressive when using consumption. Our analysis suggests that if policymakers direct about 11 percent of the tax towards the poorest two deciles, for example through greater spending on social safety net programs than would otherwise occur, then those households would on average be no worse off after the carbon tax than they were before. Of course, individual households within those groups might be better or worse off depending on their individual energy consumption patterns and participation in federal spending programs.

In the tax swap simulations, we subtract the burden of other taxes that the carbon tax revenue could displace, such as the corporate and personal income taxes, and compute the net effect on households. We analyze revenue-neutral tax shifts under three assumptions about how those other taxes lower households' capital and labor income: all borne by labor, all borne by capital, and a 50/50 split. Although all of the tax swaps lower the overall burden of the carbon tax (as a share of household income) on the poorest two deciles, tax swaps also exacerbate the regressivity of the carbon tax on the high end. This means that the benefit to the highest income households of the reduction in other taxes is greater than their share of the burden of the carbon tax.

The degree of variation in the carbon tax incidence across regions (with no offsetting tax decreases) is modest; the maximum difference in the average rate across regions is 0.45 percentage points of income. However, a tax swap is likely to increase the variation in burden across regions. The incidence of a tax swap can vary significantly across regions, and the regional incidence depends importantly on whether the swap reduces labor or capital taxes. This is driven primarily by the uneven distribution of capital incomes across regions.

Of the tax swaps, the labor tax swap results in the least variation in net burdens across regions, with a maximum difference across regions of 0.5 percentage points of income. In contrast, the capital tax swap produces a maximum difference across regions of 1.66 percentage points. This suggests that capital incomes are more unevenly distributed across regions than labor incomes.

We stress that these results reflect short run distributional outcomes, and do not account for dynamic effects such as reductions in emissions, increases over time in the carbon tax rate, macroeconomic feedbacks, and efficiency gains from revenue recycling. Taxes of all kinds can produce important macroeconomic effects through the incentives or disincentives they create and the knock-on effects of how they change prices, wages, and other economic outcomes. We do not account for those effects here.

Nonetheless, these results illustrate the likely initial impacts of a modest carbon tax on households across the income spectrum and across different regions of the country. We present the burdens of the carbon tax in isolation, and how those burdens would change once the tax revenue is recycled by lowering other tax burdens.

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APPENDIX

1. Using the BEA Input-Output Accounts[12]

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 per 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:

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

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

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[12] This section is based on based on Fullerton (1995), and Metcalf (1999).

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:

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

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

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

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 *i*th 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:

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

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

$$P_I=(I-B')^{-1}V \qquad [6]$$

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

We regrouped industries in the Input-Output Accounts into 66 industry groupings. Three separate industries for coal mining, metal ores mining and nonmetallic mineral ores mining and quarrying were created out of the industry group mining. This was done using the split in the 2002 benchmark Input-Output accounts. Tax rates are computed as the ratio of the required tax revenue from the industry divided by the value of output from that industry. For the carbon tax, the tax rate on coal equals

$$t_{4.}=\frac{\alpha_C R}{\sum_{j=1}^{N}x_{4j}} \qquad [7]$$

where *R* is the total revenue from the carbon tax and α_C the share of the tax collected from the coal industry (industry 4). Based on carbon emissions in 2003, the share of the tax falling on the coal industry is 0.361. The taxes for oil and natural gas 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 Personal Consumption Expenditures (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* $(i=1,....,N)$. The columns of *Z* sum to 1.. 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; they appear in Appendix Table 1 for all three years.

2. Consumer Expenditure Survey Data

The Consumer Expenditure Survey (CEX) data is collected by the Bureau of Labor Statistics. The CEX provides a continuous and comprehensive flow of data on the buying habits of American consumers. The data are based on two components, the Diary Survey and the Interview Survey. The Diary Survey interviews households for two consecutive weeks and is designed to obtain detailed expenditures data on small and frequently purchased items, such as food items. The Interview sample follows survey households for a maximum of five quarters. The database covers about 95 percent of all expenditures. In addition, the CEX collects information on a variety of socio-demographic variables and income. For this paper, we have used the Interview Survey data collected over the year 2010. As mentioned, the Interview Survey collects household level data where each household is followed for a period of four quarters. It is a rotating sample in which some households drop out of the survey at the end of the four quarters, and are then replaced by a new sample of households. Overall, the 2010 sample has five quarters of data.

For purposes of this study, it is important to note that we made the following changes to the sample. First, for all households, we have only included expenditures that occurred in 2010. The sample contains information for the last quarter of 2009 for the households that were interviewed in January and February of 2010. It also contains information for January and February of 2011 for households interviewed in March of 2011. However, these expenditures are excluded from the analysis since they are not relevant for the year of study. Moreover, we have only included those households for whom we have information on all four quarters, that is those who were present in the sample throughout 2010. Further, we have only included households with income data. Using these criteria, our sample size is only about 2320 households. Since the sample size drops a lot, it is important to reweight the sample so that the remaining households are representative of the population. For reweighting the data, we simply scaled up the weights for the attritioned sample so that they would add up to the original weights.

All of these adjustments resulted in aggregate household consumption that is about 70 percent of the actual consumption expenditures in the National Income and Product Accounts. This fits in fairly well with the average ratio of CEX expenditures to NIPA expenditures.[13]

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[13] http://www.bls.gov/cex/cecomparison.htm.

Appendix Table 1: Price Increases for Consumer Goods

	CEX Categories	**2010**
1	Food At Home	0.83%
2	Food at Restaurants	0.47%
3	Food at Work	1.05%
4	Tobacco	0.64%
5	Alcohol	0.72%
6	Clothes	0.34%
7	Clothing Services/Tailors	0.22%
8	Toiletry/Miscellaneous	0.39%
9	Health and Beauty	0.55%
10	Tenant-Occupied Non-Farm Dwellings	0.17%
11	Other Dwelling Rentals	0.19%
12	Furnishings	0.74%
13	Household Supplies	0.83%
14	Electricity	5.21%
15	Natural Gas	18.92%
16	Water	0.46%
17	Home Heating Oil	6.10%
18	Telephone	0.27%
19	Health	0.32%
20	Business Services	0.24%
21	Life Insurance	0.06%
22	Automobile and Parts Purchases	1.04%
23	Other Car services	0.25%
24	Gasoline	4.72%
25	Automobile Insurance	0.06%
26	Mass Transit	0.75%
27	Other Transit	1.54%
28	Air Transportation	2.01%
29	Books/Magazines	0.35%
30	Recreation and Sports Equipment	0.63%
31	Other Recreation Services	0.31%
32	Education	0.44%
33	Charity	0.25%

Note: These price increases are calculated using a tax of $15 per metric ton of carbon dioxide.

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