The Incidence of U.S. Climate Policy: Alternative Uses of Revenues from a Cap-and-Trade Auction

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1 Introduction

Federal climate policy in the U.S. is now under serious discussion with several bills introduced in Congress in the past two years. Cap and trade appears to be the policy instrument of choice and discussions now center on several key design features, not the least of which is the allocation of carbon allowances. Whether allowances will be fully auctioned by the government and how the auction revenues will be used, or whether some portion of allowances will be distributed for free and to whom they would be given are issues at the center of discussion. Two criteria to be considered in making these decisions are the impact that the policy will have on households and the distribution of those impacts across income groups and regions of the country. These issues are the focus of this paper.

We analyze five specific policy scenarios in each of 11 regions of the country and for households sorted into annual income deciles. The policy scenarios all include the same emissions target and price but use different schemes for returning the revenues from an allowance auction. These schemes include two lump-sum, or "cap and dividend" options, reductions in income and payroll taxes, and expansion of the Earned Income Tax Credit for lower income households. We assume the policy is enacted in 2009 and assess the impacts corresponding roughly to 2015. We introduce a price on CO_2 emissions of $20.91 per metric ton of CO_2 ($mtCO_2$), which is the predicted 2015 allowance price under the cap in Lieberman-

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Warner (S. 2191).[1] This price is expected to yield total emissions that are 16.5 percent lower than business-as-usual emissions in 2015.

Several studies have looked at the incidence of cap-and-trade and carbon tax policies in recent years (Dinan and Rogers 2002; Parry 2004; Boyce and Riddle 2007; Paltsev et al. 2007; Metcalf 2009; and Shammin and Bullard 2009). These studies have estimated the impacts across households in different income groups, with auction or tax revenues returned in a lump-sum manner or in the form of reductions in income and other taxes. Some studies have also looked at policies that give allowances out for free ("grandfathering"). Our contribution to this literature is three-fold. First, we use a regionally disaggregated model of the electricity sector to more carefully assess the impacts on electricity prices and fuel mixes. The electricity sector is responsible for 40 percent of CO_2 emissions and thereby concentrates much of the burden of carbon pricing on households. In addition, by almost all accounts, the electricity sector will be responsible for the bulk of the emissions reductions in the early decades of the program, thus it is important to carefully assess the changes that take place in that sector. Second, we allow for behavioral responses to carbon pricing – again, most importantly in the electricity sector – and calculate consumer surplus losses rather than expenditures changes. Third, we look at the impacts on households in different income deciles by region of the country. Although others have looked at regional impacts (Hassett et al. 2009), we are the first to assess the impact by income group within regions.

We find that putting a price on CO_2 emissions can distribute costs unevenly across income groups and regions, and that revenue allocation decisions can either temper or exacerbate these distributional effects. The introduction of a price on CO_2 is regressive in that it imposes a greater cost as a share of household income on lower-income households – a point that has been made in many studies and that is due primarily to the larger share of income spent by lower income households on energy. In three policy scenarios we examine—caps with taxable or nontaxable dividends and expansion of the Earned Income Tax Credit—the allocation of revenue reverses this outcome, leading to progressive distributions of incidence. For example, an average household in the lowest income decile incurs a consumer surplus loss that is 4.42 percent of income but a taxable lump-sum return of revenues turns that loss into a net consumer surplus gain of 4.25 percent of income. An average household in the top decile, on the other hand, has a gross consumer surplus loss of 0.91 percent and a net loss of 0.51 percent. Expanding the EITC

[1] This is the price estimated by the Department of Energy's Energy Information Administration (EIA); see the supplementary spreadsheets for EIA 2008a (National Energy Modeling System run S2191.D031708A). All monetary values are in 2006 dollars.

is even more progressive. On the other hand, the assignment of revenues to reduce the income tax or payroll tax would amplify the regressivity of climate policy.

Hassett et al. (2009) conclude that regional differences from CO_2 pricing policies are likely to be relatively small. We find that a CO_2 price of $20.91 implemented with revenues returned to households as taxable dividends yields a loss in consumer surplus for the average household on a national basis of $132, but the loss ranges from $91 up to $285. When expressed as a fraction of income, these differences are quite small, thus our findings are similar in this way to those of Hassett et al. Where we find more substantial differences across regions is for poorer households, especially when consumer surplus is viewed as a percentage of income. Again using cap-and-dividend as an example, average households in the lowest two deciles may enjoy a consumer surplus gain of as much as 3.82 percent of income (in Texas) or of just 1.08 percent of income (in the Northeast).

The costs we report are partial equilibrium measures. A more complete analysis would assess the changes in factor markets including capital formation and labor supply. For example, there are likely to be efficiency impacts associated with reducing preexisting distortionary taxes through expansion of the Earned Income Tax Credit or reduction of the income and payroll taxes. Many public finance economists have argued the merits on efficiency grounds of using "green" taxes or auctioned allowances to reduce other distortionary taxes (Goulder et al. 1999; Parry et al. 1999). Assessing the resulting general equilibrium impacts on households by region and by income decile is beyond our scope in this paper. Our findings indicate, however, that there may be trade-offs between efficiency and equity that should be more fully explored in a general equilibrium setting.

We begin by providing a brief literature review. Section 3 then discusses our data and methodology. Section 4 provides the results of our analysis of the impacts across income groups on a national basis, while Section 5 explores the regional impacts. The final section of the paper provides conclusions and directions for future research.

2 Literature on Distributional Impacts of Climate Policies

Many studies of the incidence of CO_2 taxes and cap-and-trade policies have been published in recent years.[2] Dinan and Rogers (2002) analyze the efficiency and distributional impacts of a cap-and-trade program aimed to reduce emissions by 15 percent. They incorporate

[2] We focus here only on studies that look at CO_2 taxes and cap-and-trade systems. See Parry et al. (2007) for a review of the broader literature on the incidence of environmental policies.

behavioral responses (assumed to be uniform across households) and indexing of transfer payments (e.g., Social Security), and they allocate to households additional burdens from the effect of higher product prices on real factor returns and compounding efficiency costs of preexisting factor tax distortions. They find that distributional effects hinge crucially on whether allowances are grandfathered or auctioned and whether revenues from allowance auctions, or from indirect taxation of allowance rents, are used to cut payroll taxes or corporate taxes or provide lump-sum transfers. For example, they estimate that households in the lowest-income quintile would be worse off by around $500 per year under grandfathered allowances; if instead the allowances were auctioned with revenues returned in equal lump-sum rebates for all households, low-income households would, on net, be better off by around $300.

Dinan and Rogers (2002) also address the trade-offs between efficiency and distributional concerns. They find that programs that auction allowances and reduce corporate income taxes have the greatest potential for efficiency gains, whereas programs that implement lump-sum revenue recycling would realize little to no increase in economic efficiency.

Several studies look at CO_2 taxes and other kinds of energy taxes. Bull et al. (1994) extend the analysis of the price impact on direct energy use through the use of input-output tables to trace through the indirect component of changes in the price of other goods and services. They compare a tax based on energy content (i.e., a Btu tax) with a tax based on carbon content. They assess the incidence of these taxes on the basis of annual income, annual consumption expenditures, and a measure of lifetime income that they construct by using data on age and education. Their results suggest that the direct components of Btu and CO_2 taxes look quite regressive on an annual income basis, but the indirect components are less regressive. On the basis of lifetime income, the direct component remains regressive, but the indirect component becomes mildly progressive; overall, the taxes look much less regressive on a lifetime income basis than on an annual income basis. This finding is consistent with studies of other kinds of taxes (Lyon and Schwab 1995).

Metcalf (1999), using similar data, analyzes a revenue-neutral package of environmental taxes, including a CO_2 tax, an increase in motor fuel taxes, taxes on various stationary source emissions, and a virgin materials tax. Prices of energy—electricity, natural gas, fuel oil, and gasoline—increase substantially under these measures while prices of all other consumer goods increase by less than 5 percent. Although the taxes disproportionately hit low-income groups, Metcalf shows that the overall package can be made distributionally neutral (under a range of different income measures) through careful targeting of income and payroll tax reductions.

Parry (2004) estimates a simple, calibrated, analytical model with household income proxied by consumption to examine the incidence of emissions allowances, among other control instruments, to control power plant emissions of CO_2, sulfur dioxide (SO_2), and nitrogen oxide (NO_x). He finds that using grandfathered emissions allowances to reduce CO_2 emissions by 10 percent and NO_x emissions by 30 percent can be highly regressive; the top income quintile is made better off while the bottom income quintile is made much worse off. The SO_2 cap imposed by the Clean Air Act Amendments of 1990, which has reduced emissions by roughly 45 percent, is also found to be regressive but much less so than the CO_2 and NO_x policies.

A recent study adopts the methodology of Bull et al. (1994) and Metcalf (1999)—that is, the use of input-output tables to calculate the indirect effect of the tax and the construction of a measure of lifetime income based on age and education—to analyze the effects of a CO_2 tax (Hassett et al. 2009). The authors add a regional focus and assess the impacts of the tax if it were enacted in 1987, 1997, and 2003. Similar to the earlier studies, they find that the direct component of the tax is significantly more regressive than the indirect component and that the regressivity is muted when lifetime income is used rather than annual income. The authors find only small differences in the incidence of the tax across regions for the average household; they do not look at the distribution of costs across income deciles within regions.[3]

Metcalf et al. (2008) assess the overall impacts of three recent CO_2 tax bills introduced in the U.S. Congress. As part of their study, the authors calculate the tax expenditures as a fraction of income and report the results by annual income decile, under the assumption that revenues are returned in a lump-sum manner. They look at three scenarios: one in which the burden of the tax is fully passed forward to consumers in the form of higher energy and product prices, and two scenarios in which a share of the burden is borne by producers—that is, shareholders of firms.[4] The tax alone, assuming full forward shifting, is highly regressive, but returning revenues lump sum makes it progressive; households in deciles 1 through 6 are actually better off with the policy, and only the two highest-income deciles experience a net loss. Shifting the burden back to shareholders also reduces the regressivity of the tax, since shareholders are predominantly in the higher-income groups.

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[3] Batz et al. (2007) find differences in the regional impact of climate policy to be an important consideration, but they do not look at income differences. They consider only direct energy use, and they use kernal regression to estimate effects at a local scale, thereby accounting for rural versus urban differences in consumption.

[4] The backward shifting analysis is informed by runs from the MIT Emissions Prediction and Policy Analysis model. See Paltsev et al. (2007) for a description of the model.

Metcalf (2009) assesses the impact of a carbon tax “swap”—a CO_2 tax coupled with a reduction in payroll taxes. Specifically, he gives each worker in a household a tax credit equal to the first $560 of payroll taxes; this would be equivalent to exempting from the payroll tax the first $3,660 of wages per worker. Metcalf finds that this option leads to an outcome that is approximately distributionally neutral. He then analyzes an option that couples this rebate with an adjustment to Social Security payments that benefits the lowest-income households. This makes the CO_2 policy more progressive. Finally, he compares these options with a lump-sum redistribution of the CO_2 tax revenues and finds that this option is the most progressive of all.

In summary, the literature indicates that it is important to look at both the direct effects of climate policies (i.e., the increase in the price of energy consumed by households) and the indirect effects (i.e., the increase in the costs of products and services for which energy is an input). The two effects have different impacts on regressivity. Studies also find that the way in which revenues from a CO_2 tax or auctioned allowances are returned to households is critically important in determining the incidence of the policy. Although one study finds little difference in impacts on the mean household across regions, we provide a more detailed regional analysis that accounts for the income distribution across regions. We also develop a more careful representation of the electricity sector, which has regional implications. We look at five alternative scenarios for redistributing revenues and reducing the impacts of CO_2 pricing.

3 Data and Methodology

The building blocks for our analysis are expenditures at the household level as reported in the Bureau of Labor Statistics’ Consumer Expenditure Survey (CEX) for 2004–2006. We include direct energy expenditures and indirect expenditures through purchase of goods and services. We focus the analysis on 2015, by which time some technological, economic, and demographic changes can be expected even in the absence of climate policy. We account for changes only in the transportation and electricity sectors. Transportation-related changes are expected to result from new corporate average fuel economy (CAFE) standards that will take effect on the basis of recent legislation and proposed regulations.[5] For electricity, we use the Haiku electricity model maintained by Resources for the Future to associate emissions with electricity consumption by region and to predict changes in fuel mix and capital turnover by region, accounting for changes in equilibria in regional electricity markets (Paul et al. 2008).

[5] Specifically incorporated are the requirements in the 2007 Energy Independence and Security Act, which would bring about a fleetwide average fuel economy of 35 miles per gallon by the 2020 model year. In May 2009, President Obama announced an acceleration of this policy, essentially reaching the new by the 2015 model year.

Predictions are made for the 2015 baseline and the climate policy scenarios. Beyond these changes, we assume that baseline consumption patterns in 2015 are the same as in 2004-2006 as reflected by the CEX data. We explain our assumptions for the climate policy scenarios below.

The population sampled in the survey includes 97,519 observations for 39,839 households; an observation equals one household in one quarter.[6] The BLS builds a national sample, and we use their data to construct national after-tax income deciles. The numbers of observations by region and decile are shown in Appendix A.[7] Since we are interested in a finer level of geographic detail, we examine the data with state-level indicators. BLS cannot preserve the confidentiality of its respondents when samples get small, so 15,486 observations (6,605 households) have missing state identifiers. This leaves us with a final sample of 82,033 observations for 33,234 households in 43 states plus the District of Columbia.[8] We aggregate the observations into 11 regions, which are listed in Appendix A. Observations with missing state identifiers are still used in our calculations at the national level. [9]

Household direct energy expenditures include electricity, gasoline, natural gas, and heating oil. Using CEX data, we find that, at the national level, direct expenditure on energy represents 24 percent of annual income among the households in the lowest-income category, which is the greatest percentage of any group. For the highest-income households, it is 3.6 percent. On average across all income groups, the share of expenditure on energy is 6.7 percent of annual income. Regionally, we find some differences. The average expenditure ranges from a

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[6] These numbers exclude observations in Hawaii and Alaska. Although households can remain in the data for up to four quarters, each quarter's sample is designed to be independently representative. Analysis has shown that richer, older, homeowning households are disproportianately likely to complete all four quarters of the survey. For both of these reasons, we treat each individual quarter as an observation, which we annualize, as opposed to only taking observations that contain four quarters' worth of data. All observations are unweighted, and straight averages are calculated at for each region and income decile. Though we have a large number of observations, BLS does not guarantee the statistiscal representativeness of its data at the state level.

[7] We distribute regional observations based on the CEX data into these national income deciles. These income "buckets" do not necessarily accurately represent regional income deciles; rather, they are constructed as deciles at the national level.

[8] BLS refers to observations as "consumer units," which we loosely interpret as households. Compared with the population as a whole, the missing observations are unevenly distributed toward the lower end of the income distribution. Five states—Iowa, New Mexico, North Dakota, Vermont, and Wyoming—fall out of the data entirely due to missing observations.

[9] The data for some expenditure categories appear missing or are reported as zero for a few households. Most problematic are reported zeros for electricity expenditures, because although it is feasible that households do not pay a separate bill, in those cases they inevitably receive services bundled with their housing. Therefore our estimates may underestimate electricity expenditure. On the other hand, zero expenditure for gasoline for personal transportation is plausible but also could reflect errors in data. We interpret the data as a conservative (lower-bound) estimate of energy use and associated CO_2 emissions in these categories.

low of 5.8 percent of annual income in California and the Northwest to a high of 7.5 percent in Texas. In dollars, average annual expenditures range from $3,547 in the Northwest to $4,676 in the Northeast. We find bigger differences across regions for lower income households. Furthermore, the categories of expenditure also vary considerably across regions. For example, in the Northeast and the Mid-Atlantic, home heating contributes importantly to expenditures; electricity expenditures are substantially greater as a percentage of income in the South than for other regions, as are gasoline expenditures. In the West, overall expenditure tends to be lower, but gasoline expenditure is relatively high, especially compared with the Northeast. These variations are amplified when comparing regional differences for the lowest-income groups.

The second category we incorporate is spending on energy embodied indirectly in food, durable goods, and other goods and services. CO_2 emissions resulting from indirect energy consumption are calculated from data in Hassett et al. (2009), who provide information on the emissions intensity of goods aggregated into 38 indirect expenditure categories.[10]

The estimates of direct fuel use and the implied CO_2 emissions based on the CEX data correspond well to data collected by EIA (2007) (Batz et al. 2007). However, the total emissions we calculate fall short of economy-wide EIA estimates, which are 20.2 $mtCO_2$ in 2006.[11] At least some of the missing emissions are from the public sector—that is, from direct and indirect energy consumption by federal, state, and local government agencies. Assuming that government directly accounts for 14 percent of total emissions, we would expect the CEX data to yield per capita emissions of 17.32 $mtCO_2$. Our analysis of the CEX data accounts for per capita emissions of 15.24 $mtCO_2$.[12] Table 2 shows emissions in 2006 by use category using the CEX data.

[10] Hassett et al. update methods developed by Metcalf (1999) that have been the basis for similar calculations elsewhere in the literature (Dinan and Rogers 2002; Boyce and Riddle 2007).

[11] The estimate is based on the U.S. population in 2006.

[12] Batz et al. (2007) mention several potential explanations for discrepancies between CEX data and other sources, including oversampling of urban areas in the CEX data. Another discrepancy is nonfossil fuel sources of CO_2, including cement and limestone, which account for nearly 2 percent in the EIA data. Also, errors in mapping CEX data into expenditure categories and exclusion of exports (and imports) could be other discrepancies. Batz et al. (2007) corrects for oversampling in their demographic model. Dinan and Rogers (2002) scale the CEX data so that they align with expenditures reported in the National Income Product Accounts, which implicitly scale emissions from fossil fuel use at the national level. Boyce and Riddle (2007) do not scale and appear to account for only 13.46 mtCO2 per capita in their data. On the other hand, Hassett et al. (2009) appear to account for emissions of 24.4 mtCO2 per capita, well above the EIA estimate.

Table 2. Per Capita Emissions in 2006 and Elasticities, by Category

	Baseline (mtCO2)	Percent of EIA Total	Elasticity	Source
Direct				
Electricity	2.76	13.7%	-0.32	Haiku*
Natural Gas	1.09	5.4%	-0.20	Dahl (1993)
Gasoline	4.60	22.8%	-0.10	Hughes et al. (2008)
Fuel Oil	0.43	2.1%	-0.20	Dahl (1993)
Indirect				
Food	1.31	6.5%	-0.63	Tellis (1988)
Services	1.49	7.4%	-1.00	Boyce and Riddle (2008)
Air Travel	0.19	0.9%	-0.25	Boyce and Riddle (2008)
Industrial Goods	0.86	4.3%	-1.23	Tellis (1988)
Auto	2.25	11.1%	-1.30	Boyce and Riddle (2008)
Other Transportation	0.04	0.2%	-0.25	Boyce and Riddle (2008)
Total Calculated Emissions	15.03	74.4%		
Government (Implied)	2.83	14.0%	0.00	Assumption
Missing**	2.34	11.6%		
EIA Total	20.2			

* Note: For the electricity sector, this elasticity represents the equilibrium percent change in quantities for a percent change in equilibrium prices

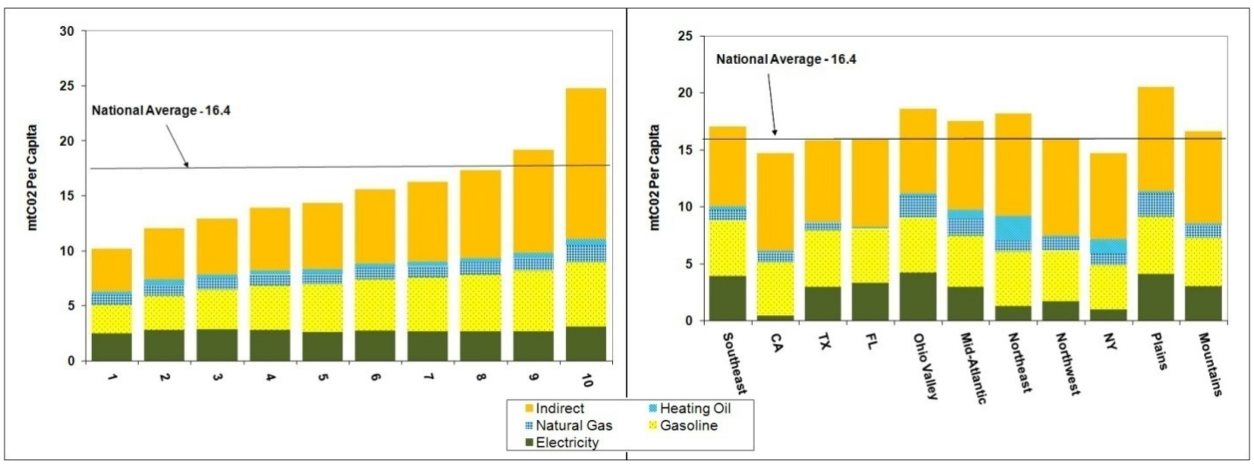
** Missing emissions are the difference between the EIA total and Calculated emissions total. Discrepency is due to the use of Haiku emissions intensity to calculate emisisons in electricity from expenditure data

To understand how household expenditures would be affected by climate policy, we use the estimate of the embodied CO_2 content of expenditures and the incremental change in expenditures that would result from a price on CO_2 emissions. For natural gas, fuel oil, and gasoline, the carbon content and resulting CO_2 emissions are fixed numbers. For electricity, the effect of climate policy is more complicated. The CO_2 content of electricity depends on the fuel used for generation, which varies over seasonal and diurnal periods in different regions. Changes in electricity price also depend on the way that price is determined in electricity markets, which varies across regions. The Haiku model solves for electricity market equilibria accounting for price-sensitive demand, electricity transmission between regions and changes in electricity supply, including changes in capacity investment and retirement over a 25-year horizon and system operation for three seasons of the year (spring and fall are combined) and four times of day. The model solves for 21 regions of the country, which are mapped into the 11 regions in this analysis. The model indicates that changes in electricity prices and expenditures differ significantly by region (see Appendix H).[13]

Figure 3 displays the CO_2 emissions per capita for direct and indirect fuel purchases for our baseline 2015 scenario. Panel A shows the average household in each income group at the national level and Panel B shows the average household for each region. The emissions indicated as missing in Table 2 are attributed proportionally to all uses of energy except electricity (where we rely on our Haiku estimates). Note that the average per capita emissions of 15.02mtCO_2, shown by the line in the graph in each panel exclude government emissions and incorporate implementation of the new vehicle CAFE standard and some changes in electricity markets captured by the Haiku model expected to occur in the baseline by 2015. Thus the figure does not match the 2006 number in Table 2.

Figure 3. Emissions (mtCO_2) per Capita, by Alternative Measure

Panel A. Income Decile **Panel B. Region**

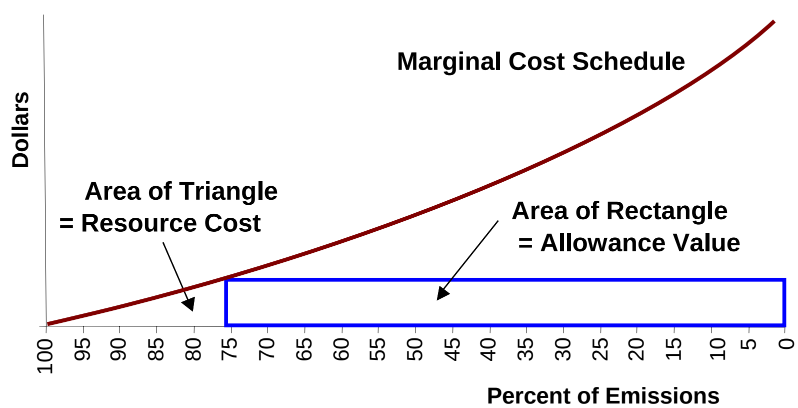


Note: Figures exclude government emissions, reflect adjustments for CAFE and the use of Haiku for the electricity sector. Prior to these adjustments, emissions are 20.2 mtCO_2 per capita.

The expenditures for direct fuel purchases are distributed fairly evenly across income groups. The big difference emerges in the indirect expenditure category, where high-income households spend significantly more than low-income households. We assume the emissions intensity per dollar of expenditure for indirect consumption of fuels is uniform throughout the country; consequently, actual emissions vary directly with expenditure. However, panel B shows significant differences across regions in the types of direct expenditures for fuels. The variation in emissions from the electricity sector is particularly noteworthy. The figure indicates emissions associated with *production* in each region, with California being dramatically lower than other regions; Florida and the Mountain region have the highest electricity sector emissions. In our subsequent calculations, we use the electricity model to calculate the effect on prices associated with *consumption* by region, accounting for power transmission between regions and other issues. The change in prices is the important metric for assessing the effect on households.

Figure 4 illustrates the mechanism of placing a price on CO_2 emissions through the introduction of a cap-and-trade policy. The horizontal axis in the graph is the reduction in emissions (moving to the right implies lower emissions), and the upward-sloping curve is the incremental resource cost of a schedule of measures to reduce emissions; thus, it sketches out the marginal abatement cost curve. The triangular area under the marginal cost curve up to the equilibrium emissions is the resource cost and the rectangle is the allowance value. EIA's analysis of S.2191 provides an estimate of the aggregate cost, i.e., these two areas shown on the graph, along with a breakdown of costs among sectors. Although we treat the electricity sector separately, using the Haiku model to obtain changes in emissions due to the CO_2 price (see Appendix H), all other sectors' reductions and costs are assumed to match EIA.

Figure 4. Resource Cost and Allowance Value in CO_2 Cap-and-Trade Program



The CO_2 price leads to demand reduction and a consumer surplus loss estimated under linear demand curves with own-price elasticities reported in Table 2. Using baseline emissions intensity estimates, the emission reductions associated with the reduction in demand underestimates the true emissions reductions and overestimates the cost that would result if process changes and other substitution possibilities were modeled as they presumably are in EIA's analysis. Thus to match EIA's cost estimate outside the electricity sector, we scale the consumer surplus losses to the sum of the resource cost and the allowance value, which is the total cost of the policy, across all non-electricity goods.[14]

This approach implicitly assumes that all changes in costs are fully passed through to consumers in every industry. In the long run, production technology is usually characterized as constant returns to scale, which implies that consumers bear the cost of policy. The electricity sector is special because of the long-lived nature of capital in the sector. Nonetheless, even in this sector consumers are expected to bear eight times the cost borne by producers (Burtraw and Palmer 2008). The degree to which the burden of any tax is shared between consumers and producers has been the focus of previous studies but is outside our scope here. As mentioned above, Metcalf et al. (2008) assess the distributional impacts of a carbon tax under alternative assumptions about the share of burden borne by consumers and producers.

One way to represent the distribution of costs in a quantitative manner is the Suits Index, which is the tax analog to the better-known Gini coefficient that serves as an index measuring income inequality. A typical Suits Index is calculated by plotting the relationship between cumulative tax paid and cumulative income earned.[15] The area under this curve is then compared with the area under a proportional line to calculate the Suits Index. If all tax collections are nonnegative, the index is bounded by –1 and 1, with values less than zero connoting regressivity, and values greater than zero, progressivity; a proportional tax has a Suits Index of zero (Suits 1977). We modify the standard interpretation to measure the incidence on households according to their loss in consumer surplus rather than taxes paid. At the national level, not accounting for the revenue that may be collected or the allocation of emissions allowances, our Suits Index for the CO_2 price of $20.91 is –0.20, which indicates that the cost burden is regressive. We also calculate a Suits Index for the rebate of revenue raised from cap-and-trade. In this case, the analysis is the same, but the sign interpretation is reversed, with negative values indicating progressivity. Although both numbers are informative individually, they are not additive. We discuss the rebate indexes in the individual scenarios below.

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[14] This exercise does not materially affect our distributional findings. It does, however, provide for cost numbers that have meaning in the policy debate and can be compared to estimates by others of the costs to households of cap and trade policy.

[15] This curve is similar to a Lorenz curve, which graphically represents the cumulative distribution of income relative to the cumulative distribution of the population.

3 Results for Alternative Policy Scenarios

We group our revenue scenarios into two categories, cap-and-dividend options and changes to preexisting taxes. In the first group, we consider two cap-and-dividend options—one in which the dividend is subject to income taxes and one in which it is not. In the second group, we consider a reduction in income taxes, a reduction in payroll taxes, and an expansion of the Earned Income Tax Credit. In each of the options, the revenues generated from the allowances used to cover all nongovernment emissions are returned to households according to the individual policy prescription. The one exception is the Earned Income Tax Credit; in this option, we assume the credit is increased by 50 percent above its current level, which leads to "leftover" revenue that is returned in a lump-sum manner as in the (taxable) cap-and-dividend case.

Table 3 shows consumer surplus loss as a percent of income for the average household in each income decile before and after the redistribution of revenues for each of the five policies. Negative numbers in the table refer to a consumer surplus gain and positive numbers are a loss. It is clear from the table that the alternative mechanisms for rebating have very different distributional effects. We discuss each in turn in the following sections, along with the results by region.

Table 3. Consumer Surplus Loss as Percent of Income, by Decile

	Decile										
	1	2	3	4	5	6	7	8	9	10	Avg
Initial CS Loss of CO_2 Pricing	4.42	2.82	2.32	2.05	1.82	1.65	1.51	1.35	1.23	0.91	1.42
Cap-and-Dividend (Taxable)	-4.25	-1.13	-0.44	-0.10	0.01	0.17	0.27	0.38	0.46	0.51	0.23
Cap-and-Dividend (Non-Taxable)	-1.64	-0.44	-0.18	0.00	0.06	0.18	0.23	0.28	0.35	0.41	0.23
Reduce Income Tax	4.15	2.55	1.71	1.44	0.98	0.80	0.46	0.30	-0.18	-0.74	0.23
Reduce Payroll Tax	3.89	2.21	1.37	0.96	0.62	0.38	0.18	-0.04	-0.16	-0.14	0.23
Expansion of EITC	-4.56	-2.14	-1.44	-0.53	0.04	0.33	0.43	0.53	0.58	0.57	0.23

Note: Negative numbers in the table reflect gains in welfare.

3.1 Cap-and-Dividend (Lump-Sum Transfers)

One straightforward remedy to alleviate the regressivity of the CO_2 policy would be to return the CO_2 revenue to households on a per capita basis. This approach recently has been referred to as cap-and-dividend (Boyce and Riddle 2007) and previously was known as “sky trust” (Kopp et al. 1999; Barnes 2001). In principle, the government would auction the emissions allowances and return the auction revenues in a lump-sum manner to each person. The revenues are equal to the price of emissions allowances multiplied by the quantity. Using information from the CEX, we identify the number of persons per household in each income group in each region and calculate a per capita dividend payment to redistribute to each household. In our first scenario, people are assumed to pay personal income taxes on the dividends; in the next scenario, we consider a dividend that is not taxed. [16]

3.1.1. Taxed Dividends

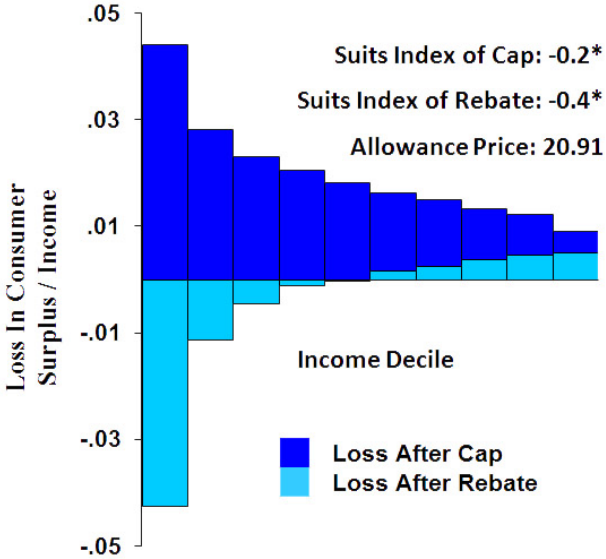
The net effect of the cap-and-taxable dividend policy is shown in the second row of Table 3 above and in Figure 5. The left-hand-side of Figure 5 graphs the results shown in Table 3, i.e., it illustrates the incidence of the policy, in consumer surplus loss as a fraction of annual income, on the average household in each income group. The Suits Indexes and the CO_2 allowance price are also listed. The bars with darker shading represent the loss in consumer surplus as a share of after-tax income, without accounting for the revenues. The bars with the lighter shading represent the incidence of the policy after distributing the value of allowances as a per capita dividend. The graph clearly shows that households in the lowest deciles see a dramatic improvement in their well-being as a result of the lump-sum dividend of allowance revenues. The average household in decile 1 incurs a consumer surplus loss of 4.42 percent of income without the dividend but gets a consumer surplus gain equal to 4.25 percent with the dividend. The figure also shows that households in all deciles benefit from the lump-sum return of revenues. Although households in the higher income deciles do not experience a net gain, on average, they do incur a much smaller loss as a result of the rebate. The Suits Index from the tax is –0.20, indicating that the CO_2 price is regressive; however, the Suits Index from the rebate is –0.40, which is strongly progressive. On net, the graph makes it clear that the cap-and-dividend option is a progressive policy.

The table portion of the figure shows the regional results. Positive numbers in the table indicate a loss and negative numbers indicate a gain, consistent with the graph. The important take-away messages from the table are the relatively small variation in impacts across regions for average households and the larger differences for households in deciles 1 and 2. The average

[16] Since our results are derived in a partial equilibrium setting, we do not consider any effects that this lump-sum payment would have on household expenditures. However, recent evidence from the behavioral economics literature suggests that consumers are unlikely to factor the expectation of such payments into their short-run energy consumption decisions (Sunstein and Thaler 2008).

household in California and the Northwest has a consumer surplus loss equal to 0.15 percent of income ($106 in California and $91 in the Northwest), while in the Plains, an average household has a consumer surplus loss of 0.43 percent ($273). By contrast, an average household in the bottom two deciles in Texas experiences a consumer surplus gain of $361, or 3.82 percent of income, on average, whereas households in this same income group in the Northeast gain $87, or 1.08 percent of income.

Figure 5. Cap-and-Dividend (Taxable)



	Average Welfare Loss for Households in the Bottom Two Deciles Nationally		Average Welfare Loss for All Households	
	$	%	$	%
Southeast	-$234	-2.58%	$92	0.16%
CA	-$341	-3.54%	$106	0.15%
TX	-$361	-3.82%	$118	0.20%
FL	-$164	-1.79%	$96	0.18%
Ohio Valley	-$126	-1.47%	$252	0.42%
Mid-Atlantic	-$151	-1.67%	$222	0.34%
Northeast	-$87	-1.08%	$285	0.41%
Northwest	-$253	-2.83%	$91	0.15%
NY	-$193	-2.30%	$165	0.25%
Plains	-$180	-2.12%	$273	0.43%
Mountains	-$253	-2.85%	$143	0.25%
National	-$236	-2.69%	$132	0.23%

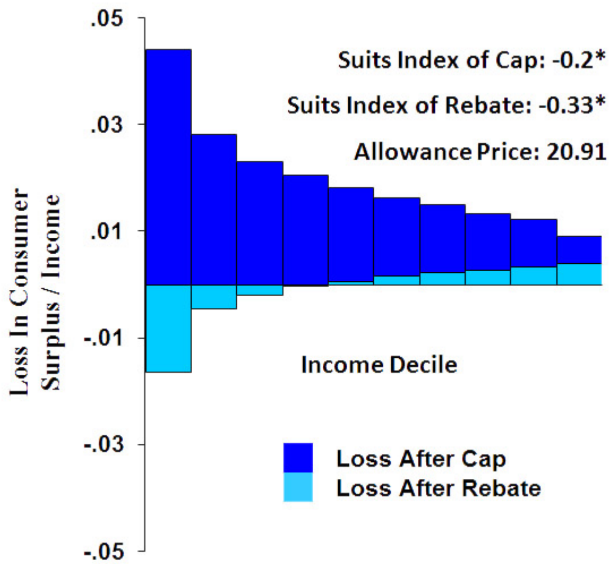
Note: Negative numbers in the table reflect gains in welfare. The bottom two deciles nationally consist of households earning less than $19,208 in annual income after taxes and transfers.
*A negative Suits Index number represents regressive taxation and progressive rebates.

3.1.2. Nontaxable Dividends

It is not clear whether CO_2 allowance dividends in a new cap-and-trade program would be treated as taxable or nontaxable income. In this scenario, we treat the dividends as untaxed, similar to the 2008 federal tax rebates, which were also untaxed.

The third row of Table 3 and Figure 7 show the distributional impacts of the policy. Similar to the previously analyzed cap-and-dividend policy, Table 3 and the bar graph in Figure 7 show that while households in all income groups are better off as a result of the dividend, this policy benefits lower-income households relatively more. The average household in the lowest income decile experiences a net gain in consumer surplus equal to 1.64 percent of income after the lump-sum return of revenue, compared with a loss of 4.42 percent of income before the return of revenue.

Figure 7. Cap-and-Dividend (Nontaxable)



	Average Welfare Loss for Households in the Bottom Two Deciles Nationally		Average Welfare Loss for All Households	
	$	%	$	%
Southeast	-$83	-0.90%	$99	0.17%
CA	-$176	-1.76%	$84	0.12%
TX	-$173	-1.78%	$124	0.21%
FL	-$28	-0.35%	$101	0.19%
Ohio Valley	$12	0.04%	$242	0.40%
Mid-Atlantic	-$12	-0.17%	$205	0.31%
Northeast	$38	0.33%	$259	0.37%
Northwest	-$108	-1.16%	$80	0.13%
NY	-$52	-0.67%	$151	0.23%
Plains	-$46	-0.59%	$257	0.41%
Mountains	-$91	-1.00%	$141	0.24%
National	-$91	-1.04%	$132	0.23%

Note: Negative numbers in the table reflect gains in welfare. The bottom two deciles nationally consist of households earning less than $19,208 in annual income after taxes and transfers.
*A negative Suits Index number represents regressive taxation and progressive rebates.

In comparison with the first scenario, in which dividends are taxed, the nontaxable dividend option tends to lead to a slightly more equal distribution of the net burden across income groups. The lower-income households do not experience quite as large a gain, and the higher-income households do not incur quite as large a loss. This happens because of the differences in the marginal tax rates across income groups. When the dividend is taxed, the relative gain to the lower deciles is greater because of their lower marginal tax rates. In this scenario, where the dividends are untaxed, these tax rate differences do not play a role. The difference shows up in the Suits Index for the rebate, which at –0.33 is less negative than in our first policy scenario. Both cap-and-dividend options are progressive, but the taxable dividend option is more progressive.

Regional results are quite similar to the first scenario – although there is some variation across regions, it is not great for average households. However, some more substantial regional differences show up for low income households.

3.2 Reducing Preexisting Taxes

A prominent suggestion from the public finance literature is to direct revenues collected under federal climate policy to reduce preexisting taxes that distort behavior away from economic efficiency (Bovenberg and de Mooij 1994; Bovenberg and Goulder 1996; Goulder et al. 1999; Parry et al. 1999). Studies show that such an option improves the overall efficiency of the policy because it removes the distortions those preexisting taxes cause in factor markets. In fact, failure to reduce those taxes can impose a hidden cost of climate policy.[17] If climate policy is more expensive than it otherwise needs to be, then this inevitably affects households in all income groups. Therefore, designing policy to be as cost-effective as possible can be thought of as an important component of addressing the impact on low-income households.

Measuring the effect of interactions with other regulations and taxes and the benefits of revenue recycling requires a general equilibrium framework or linked partial equilibrium models that include labor or capital supply decisions. Dinan and Rogers (2002) include a reduced-form representation of the benefits of revenue recycling using estimates of the welfare loss in factor markets from Parry et al. (1999). We do not include the effects in factor markets in this analysis, in part because the exact way in which those effects are distributed among households in different regions has not been studied previously. However, we do model the direct effect on household finances of using CO_2 revenue to reduce the income tax, reduce the payroll tax, and augment the Earned Income Tax Credit, ignoring the welfare issues associated with changes in the supply of labor.

3.2.1 Reducing Income Tax

A reduction in the income tax could be implemented in many ways. In this scenario, we assume an overall reduction in tax collections in proportion to the amount paid by households in each income bracket. This is effectively like an equal reduction in average tax rates across all households. It disproportionately benefits the highest-income groups because they have the highest average and marginal rate, and the rate is applied to the most income. Nonetheless, this approach follows from the underlying theory that changes in labor supply affect economic growth most significantly if they involve those individuals with the highest value of marginal product, such as the highest wage. Thus this scenario is useful to analyze.

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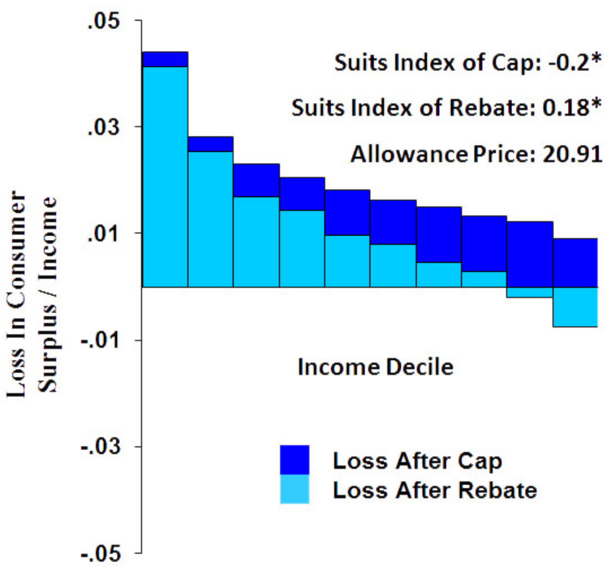
[17] Theory suggests that any tax or regulatory cost causes a difference between the value of marginal product and opportunity cost in the affected factor markets. By raising costs, a new regulation, such as climate policy, acts like a virtual tax by lowering the real wage, which causes a reduction in the supply of relevant factors, such as labor or capital. Moreover, a new regulatory cost exacerbates the inefficiency that arises from preexisting regulations and taxes, raising costs at an increasing rate. If revenue is used to reduce preexisting taxes, then this effect can be offset to a considerable degree.

The Congressional Budget Office (2005) reports the average tax burden of U.S. households by income decile. We multiply this percentage by the amount of income earned by each decile to get a share of total income tax burden by decile. Finally, we distribute CO_2 revenue proportional to each household's estimated share of the total income tax burden.

The fourth row of Table 3 and Figure 8 show the incidence of the policy. Lowest-income groups receive very little benefit from this approach to reducing taxes. Most of the benefit accrues to the highest-income deciles, and the average family in the top decile ends up with a net gain of $1,322 per year, or 0.74 percent of annual income. By contrast, the average family in the lowest-income decile incurs a net cost of $292, or 4.15 percent of income. The figure makes clear that the return of revenues to households has increasing importance as we move up the income distribution: the gap between the dark blue and light blue bars—that is, between the gross and net impacts on consumer surplus—increases as we move up the deciles. The average household in decile 8 would be almost indifferent between this option and the taxable cap-and-dividend scenario; its net consumer surplus loss as a percent of income is 0.38 in the cap and dividend case and 0.30 in the income tax case. Households in higher-income deciles would prefer this approach; those in lower deciles would, on average, be better off with cap-and-dividend. The Suits Index for this rebate is 0.18, indicating that the option is strongly regressive.

Figure 8. Reducing the Income Tax



	Average Welfare Loss for Households in the Bottom Two Deciles Nationally		Average Welfare Loss for All Households	
	$	%	$	%
Southeast	$372	3.63%	$127	0.22%
CA	$322	3.06%	-$2	0.00%
TX	$388	3.73%	$189	0.32%
FL	$368	3.47%	$143	0.26%
Ohio Valley	$421	4.07%	$213	0.35%
Mid-Atlantic	$391	3.77%	$68	0.10%
Northeast	$415	4.09%	$59	0.08%
Northwest	$324	3.25%	$58	0.09%
NY	$366	3.62%	$48	0.07%
Plains	$340	3.40%	$163	0.26%
Mountains	$395	3.95%	$159	0.27%
National	$342	3.35%	$132	0.23%

Note: Negative numbers in the table reflect gains in welfare. The bottom two deciles nationally consist of households earning less than $19,208 in annual income after taxes and transfers.
*A negative Suits Index number represents regressive taxation and progressive rebates.

The table in Figure 8 shows that, as in our first two policy options, the regional variation for an average household is quite small. In addition, the regional variation for poor households is not as pronounced as it was in the previous two policies. The national average loss for households in the bottom two deciles is $342 per year, or 3.35 percent of income. The highest average loss for this group occurs in the Ohio Valley, at $421, or 4.07 percent of income, and the lowest is in California, at $322, or 3.06 percent. This is a dollar range of only $99, compared with a range of $273 for the taxable cap-and-dividend scenario. This is mainly a result of the smaller amount of money going back to these lower income households in this scenario and some regional differences in income and income taxes paid.

3.2.2 Reducing Payroll Tax

Using CO_2 allowance revenues to reduce payroll taxes such as Social Security is another option for “greening” the tax system that some experts have suggested. In addition to income taxes, employers are required to withhold one-half of each employee’s Social Security and Medicare tax requirements (equal to 12.4 percent and 2.8 percent, respectively). The employer then pays the other half; however, it is common to assume that this expense is passed on to employees in the form of lower wages. Together, these two taxes, also called Federal Insurance Contributions Act (FICA) taxes, are applied to the first $90,000 in wages for each employee.[18] For this policy case we modeled a 12.4 percent reduction in payroll taxes. Unfortunately, it is not easy to distinguish which member of the household earned what fraction of wage income in the BLS data.[19] To represent households with multiple wage earners, we cap eligible wages at $135,000.

Like the income tax reduction scenario we analyzed above, the payroll tax deduction makes for a net regressive CO_2 policy. The distribution of net consumer surplus losses across the deciles is shown in the fifth row of Table 3 and in Figure 9. The bar graph illustrates that although the burden is reduced from rebating the revenues through reductions in this preexisting tax—that is, the light blue bars all lie below the dark blue ones—the distribution of the impacts across deciles remains virtually the same. Poor households are still disproportionately harmed by the policy. Households in the top three income deciles end up benefiting from this policy option:

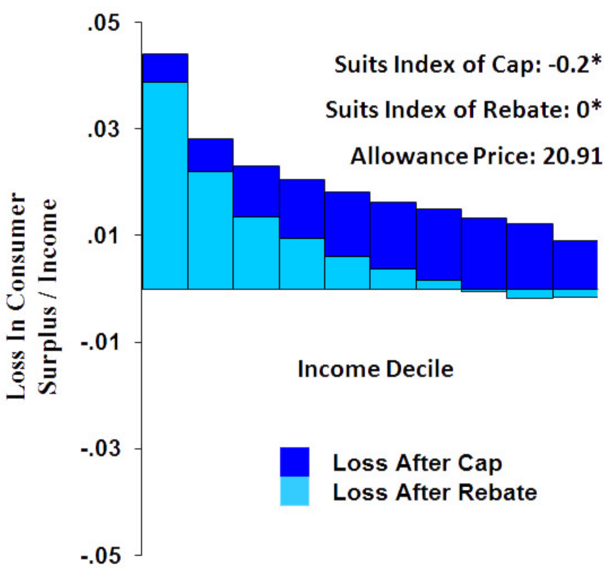
[18] The $90,000 cap was in effect in 2005, the middle of our sample period, and we use that figure in our analysis here. A slightly higher cap was in effect in 2006 in these deciles.

[19] Note the distinction between wages and income.

with the payroll tax deduction, the CO_2 policy actually yields a net consumer surplus gain for average households in those deciles. Although the magnitude of the effects is different, directionally the results are quite similar to the income tax scenario in the preceding section. The Suits Index associated with the reduction in the payroll tax is essentially 0, indicating that this rebate is income neutral. However, given that the CO_2 policy itself is regressive, the net effect of this program is also regressive.

Regional results are similar to those for the income tax scenario – i.e., while there are some differences across regions, they are smaller than for the two cap and dividend scenarios. This holds true for the average household overall and the average household in the bottom two deciles.

Figure 9. Reducing the Payroll Tax



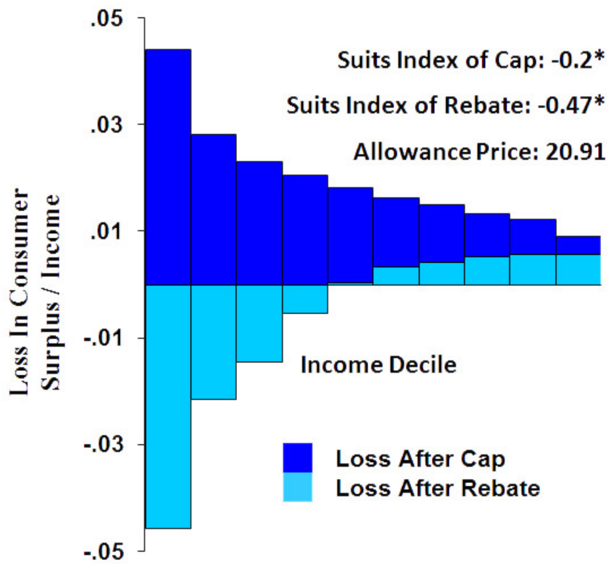
	Average Welfare Loss for Households in the Bottom Two Deciles Nationally		Average Welfare Loss for All Households	
	$	%	$	%
Southeast	$331	3.30%	$98	0.17%
CA	$284	2.75%	$66	0.09%
TX	$338	3.32%	$165	0.28%
FL	$345	3.29%	$144	0.26%
Ohio Valley	$390	3.81%	$211	0.35%
Mid-Atlantic	$371	3.61%	$91	0.14%
Northeast	$398	3.94%	$83	0.12%
Northwest	$268	2.72%	$67	0.11%
NY	$326	3.28%	$89	0.13%
Plains	$297	3.06%	$131	0.21%
Mountains	$354	3.59%	$146	0.25%
National	$307	3.05%	$132	0.23%

Note: Negative numbers in the table reflect gains in welfare. The bottom two deciles nationally consist of households earning less than $19,208 in annual income after taxes and transfers.
*A negative Suits Index number represents regressive taxation and progressive rebates.

3.2.3 Expanding Earned Income Tax Credit

Greenstein et al. (2008) have suggested that revenues generated under a cap-and-trade program or a CO_2 tax should be used to expand the Earned Income Tax Credit. The tax credit is available to families earning wages below a particular threshold.[20] The amount of the credit falls as income rises, is higher for families with children, and is adjusted each year. For example, in 2007, the credit for a family with two or more children was equal to 40 percent of the first $11,790 of earned income; for earnings beyond $15,399, the credit drops to 21 percent, and it falls to zero when earnings pass $37,782. In our policy scenario, we first estimate the current credit for each observation based on the 2006 parameters. We then take half of this estimate and redistribute it to each household, which is analogous to increasing the program by 50 percent. This fairly substantial expansion accounted for just 14 percent of total revenue raised by the CO_2 policy, leaving 86 percent to be distributed as per capita dividends.

Figure 10. Expanding the EITC



	Average Welfare Loss for Households in the Bottom Two Deciles Nationally		Average Welfare Loss for All Households	
	$	%	$	%
Southeast	-$357	-3.49%	$74	0.13%
CA	-$453	-4.41%	$109	0.16%
TX	-$607	-5.86%	$52	0.09%
FL	-$219	-2.21%	$109	0.20%
Ohio Valley	-$206	-2.03%	$267	0.44%
Mid-Atlantic	-$231	-2.25%	$246	0.37%
Northeast	-$108	-1.18%	$321	0.46%
Northwest	-$362	-3.73%	$104	0.17%
NY	-$272	-2.89%	$183	0.27%
Plains	-$263	-2.71%	$278	0.44%
Mountains	-$410	-4.19%	$136	0.23%
National	-$324	-3.35%	$132	0.23%

Note: Negative numbers in the table reflect gains in welfare. The bottom two deciles nationally consist of households earning less than $19,208 in annual income after taxes and transfers.
*A negative Suits Index number represents regressive taxation and progressive rebates.

[20] Here, note that we are distinguishing between wages and income. Although the tax credit does phase out at a given wage level, it is possible for a family's total income to exceed that. For this reason, we see some families receiving the tax credit in every decile.

The distributional results for our Earned Income Tax Credit expansion policy are shown in the sixth row of Table 3 above and in Figure 10. As expected, households in the lower-income deciles benefit the most from this policy. The average household in the first decile experiences a net consumer surplus gain of 4.56 percent of income. By contrast, the average household in the highest income decile earns a net consumer surplus loss of 0.57 percent of income, which is very close to the loss before redistribution of revenue, 0.91 percent of income. Comparing the dark and light blue bars in the graph indicates that the redistribution of revenues through the program dramatically changes the regressivity of the policy. The Suits Index is –0.47, making this policy the most progressive of the options we have analyzed here.

There is substantial variation in the regional impacts for poor households. As the table shows, the average consumer surplus gain for these households nationwide is $324, or 3.35 percent of income, but the gain varies from $607 in Texas (5.86 percent of income) to only $108 in the Northeast (1.18 percent of income). As with the other policy options, the impact for average households across regions shows less variability.

3.4 Results Using Consumption Expenditures

As we explained in Section 2, it has long been argued by economists that some measure of lifetime, or permanent, income is a better measure of ability to pay than is annual income. Since information on lifetime income is difficult to come by, however, many studies have used consumption as a proxy. Consumption has its own problems, but we show our results using consumption for purposes of comparison with our results based on annual income. Both results are in Figure 11, which shows the gross and net effect on consumer surplus as a percent of income (top panel) and as a percent of consumption (bottom panel).

Clearly, all of the policy scenarios using annual consumption expenditures look much less regressive, both before and after return of the revenues, than they do using annual income. Pricing CO_2 appears to have about an equal impact, in terms of consumer surplus loss as a percentage of consumption, across income deciles. Thus, the policy looks approximately proportional. Returning the revenues makes the policy appear progressive in most cases—that is, the graph shows that the lighter blue bars get larger as income increases. The only scenarios in which this does not hold are, as expected, the scenarios in which income or payroll taxes are reduced. These findings are consistent with those of others who have found that the regressivity of many taxes is muted when consumption is used in place of income.

4 Concluding Remarks

Climate policy may impose important costs on the economy. For a cap-and-trade policy, the primary determinant of how these costs are distributed across the population is the allocation of CO_2 allowances and dispensation of any auctioned CO_2 revenue. The magnitude of the revenues generated from a full auction far outweighs the size of the resource costs and thus can go a long way to alleviating the burden imposed by higher energy and product prices. This paper has calculated the distributional effects of five alternative ways of distributing this revenue across two demographic dimensions, income and geography.

We find the simplest approach to have merit on distributional grounds: returning revenues in a lump-sum manner in a so-called cap-and-dividend approach makes for an overall progressive policy. If the dividend, or rebate, is taxed, this option is slightly more progressive than if it is untaxed. Not surprisingly, expanding the Earned Income Tax Credit is even more progressive. Reducing income or payroll taxes, however, is regressive. These two options benefit those households who pay a relatively higher share of these taxes and those households tend to be in the higher income categories.

Regional differences among the options are more pronounced for lower income households than for average households. The average net consumer surplus loss, across all regions of the country, is 0.23 percent of income (for all of the policies) and only varies by region from about 0 percent to 0.4 percent. The average loss for the bottom two deciles shows a greater range across regions and varies by policy scenario. For example, the net consumer surplus gain for the bottom two deciles for the cap and (taxable) dividend scenario ranges from 1 percent of income to 3.8 percent of income. Nonetheless, the difference across regions for a given income grouping – even the bottom two deciles, where the difference is greatest – is less pronounced that the difference across policy scenarios. In other words, it matters less where a household lives than whether that household receives a lump-sum dividend or a reduction in its income tax.

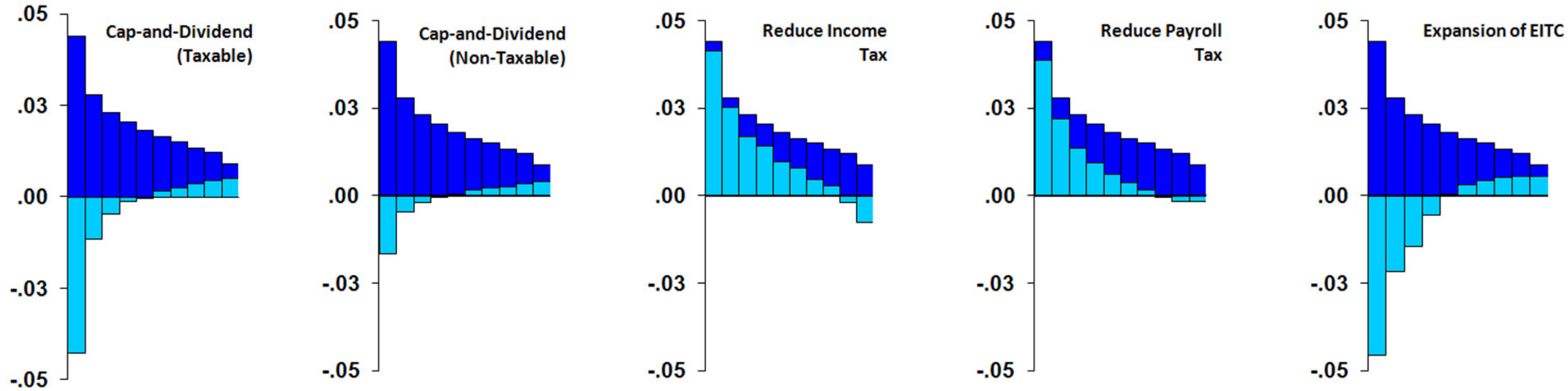
Our findings are specific to the policies we examine and it is important to emphasize exactly what those policies are, especially for our tax change scenarios. We reduced the income tax and the payroll tax proportionally across households; for the EITC, we expanded the program by 50 percent, which increased the credit received for those households who are currently eligible. There are obviously many other alternatives that can be examined and those alternatives could have different impacts. For example, the income tax could be reduced more for households below a particular income level and less for those above that level or the EITC income cut-off could be raised. In addition, combinations of options, such as a partial lump-sum payment combined with a payroll tax reduction, might generate some interesting results. This was beyond our scope here.

In addition, there are some other important issues that should be considered but that were outside our scope. First, we reiterate the need for a more general equilibrium analysis. Expansion of the model to account for the important role played by labor and capital markets would be instructive. Second, even within our partial equilibrium framework, sensitivity analysis of some of our parameters, in particular, the elasticities used to calculate consumer surplus losses, would be helpful. Third, we would welcome further evidence about the relationship between lifetime income and annual income (or consumption) as a measure of ability to pay. And finally, it would be useful for policy makers to see impacts by other demographic and regional measures. For example, state-level impacts would be interesting; also, incidence by family size and age are two possible ways to delve deeper into the incidence of climate policy.

Although climate change is a long-run problem, climate policy has an important short-run political dynamic. Therefore, delivering compensation or finding ways to alleviate disproportional burdens of the policy seems especially important in the early years of climate policy. Our main message is that allocation of the value of the CO_2 permits or the revenues from a CO_2 auction is critical in determining who loses and who gains from climate policy and the magnitude of those impacts.

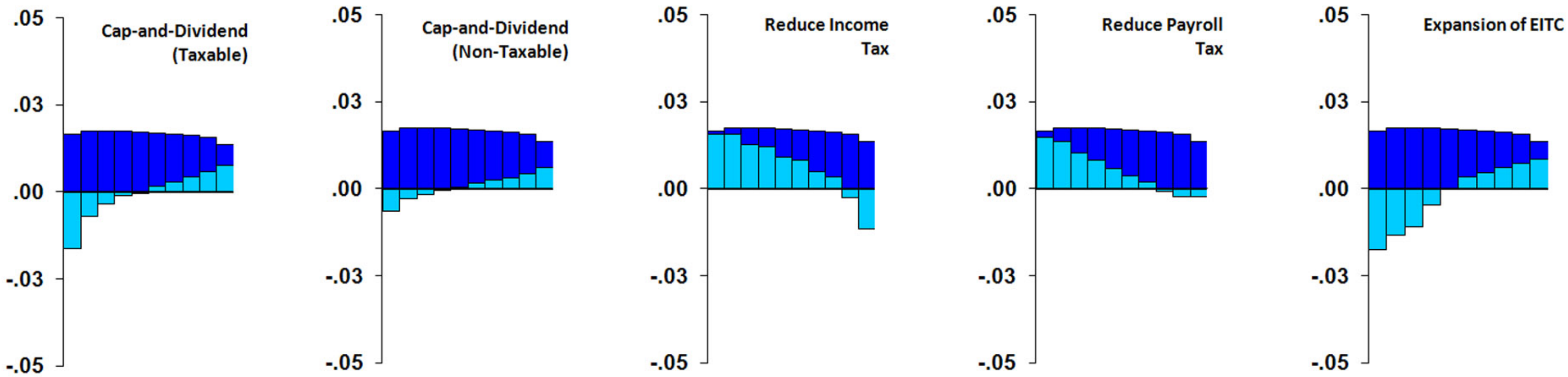
Figure 11. Incidence of Policies across Income Deciles as Fraction of Income

(Net Consumer Surplus Loss as Fraction of Annual Household Income)



Incidence of Policies across Income Deciles as Fraction of Consumption

(Net Consumer Surplus Loss as Fraction of Annual Household Consumption)



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Appendix A: Observations by Region and After-Tax Income Decile

		Decile										
Region	**States**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Southeast	AL, AR, DC, GA, LA, MS, NC, SC, TN, VA	1327	1423	1434	1354	1371	1189	1230	1156	1315	1189	12988
CA	CA	577	792	796	905	904	1001	962	1002	1196	1457	9592
TX	TX	462	501	602	617	631	624	541	608	520	594	5700
FL	FL	438	578	571	611	536	634	546	568	469	401	5352
Ohio Valley	IL, IN, KY, MI, MO, OH, WV, WI	1247	1476	1764	1716	1567	1722	1754	1805	1814	1644	16509
Mid-Atlantic	DE, MD, NJ, PA	593	840	961	966	926	889	1069	1061	1052	1268	9625
Northeast	CT, ME, MA, NH, RI	261	312	387	314	350	464	389	476	579	579	4111
Northwest	ID, MT, OR, UT, WA	454	443	469	534	587	584	697	591	573	590	5522
NY	NY	405	443	345	391	444	407	456	465	531	599	4486
Plains	KS, MN, NE, OK, SD	218	254	304	346	319	398	401	439	327	368	3374
Mountains	AZ, CO, NV	350	434	485	509	574	486	495	503	481	457	4774
National		9751	9752	9752	9752	9752	9752	9752	9752	9752	9752	97519

Appendix B.

Household Electricity (KWh) Consumption by Decile and Region

		Decile										
Region	**States**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Mean**
Southeast	AL, AR, DC, GA, LA, MS, NC, SC, TN, VA	13,177	14,788	16,406	18,045	18,454	18,833	19,703	20,749	22,109	24,666	18,540
CA	CA	4,818	5,567	5,809	6,309	6,874	7,224	7,931	9,021	10,680	14,106	8,441
TX	TX	9,814	10,788	13,080	13,957	15,306	16,804	17,731	18,777	22,419	27,251	16,741
FL	FL	11,000	12,443	14,187	15,134	14,501	16,791	17,438	18,946	22,098	26,070	16,606
Ohio Valley	IL, IN, KY, MI, MO, OH, WV, WI	9,386	11,079	12,275	12,918	13,364	14,781	15,150	16,535	17,440	21,735	14,662
Mid-Atlantic	DE, MD, NJ, PA	8,256	9,280	10,632	11,409	12,550	13,190	15,284	16,283	16,792	21,634	14,129
Northeast	CT, ME, MA, NH, RI	4,666	6,819	6,752	6,856	7,425	7,789	8,830	10,063	11,722	14,569	9,188
Northwest	ID, MT, OR, UT, WA	6,933	11,228	11,185	12,677	14,037	13,936	14,819	16,412	18,029	19,659	14,211
NY	NY	5,139	6,126	5,995	7,710	8,921	8,263	9,327	10,170	11,936	14,635	9,204
Plains	KS, MN, NE, OK, SD	6,749	7,759	9,311	10,446	10,926	13,234	14,498	14,686	14,572	22,878	13,066
Mountains	AZ, CO, NV	8,990	10,557	10,053	12,010	12,821	13,838	15,194	15,932	17,139	20,939	13,856
National		7,313	9,828	11,138	12,305	12,859	13,656	14,572	15,585	16,899	20,298	13,445

Appendix C

Household Gasoline (Gallons) Consumption by Decile and Region

Region	States	Decile 1	2	3	4	5	6	7	8	9	10	Mean
Southeast	AL, AR, DC, GA, LA, MS, NC, SC, TN, VA	424	585	778	952	1,026	1,206	1,341	1,387	1,692	1,631	1,082
CA	CA	356	598	758	885	987	1,136	1,304	1,410	1,680	1,857	1,198
TX	TX	543	679	832	1,082	1,216	1,275	1,431	1,533	1,715	1,887	1,235
FL	FL	494	521	662	860	976	1,064	1,150	1,373	1,614	1,536	1,009
Ohio Valley	IL, IN, KY, MI, MO, OH, WV, WI	373	464	658	822	930	1,062	1,305	1,397	1,644	1,743	1,070
Mid-Atlantic	DE, MD, NJ, PA	403	366	537	752	815	985	1,119	1,268	1,339	1,562	971
Northeast	CT, ME, MA, NH, RI	379	481	634	711	841	934	1,114	1,309	1,454	1,654	1,046
Northwest	ID, MT, OR, UT, WA	513	458	670	820	981	1,062	1,160	1,298	1,403	1,555	1,029
NY	NY	332	345	432	625	806	926	954	1,246	1,336	1,457	894
Plains	KS, MN, NE, OK, SD	420	513	678	748	945	1,004	1,280	1,363	1,444	1,806	1,078
Mountains	AZ, CO, NV	395	496	644	744	846	971	1,210	1,266	1,408	1,662	979
National		360	492	672	829	962	1,089	1,244	1,361	1,564	1,682	1,025

Appendix D

Household Natural Gas (tcf) Consumption by Decile and Region

		Decile										
Region	**States**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Mean**
Southeast	AL, AR, DC, GA, LA, MS, NC, SC, TN, VA	30	34	30	31	30	41	33	46	60	74	40
CA	CA	25	25	28	32	34	37	39	45	53	67	41
TX	TX	20	21	22	25	27	28	28	32	37	58	30
FL	FL	2	2	2	4	2	3	4	2	3	6	3
Ohio Valley	IL, IN, KY, MI, MO, OH, WV, WI	49	59	64	64	75	80	80	89	97	131	80
Mid-Atlantic	DE, MD, NJ, PA	35	44	43	51	58	53	57	59	77	101	60
Northeast	CT, ME, MA, NH, RI	23	38	39	40	32	49	34	39	40	54	40
Northwest	ID, MT, OR, UT, WA	15	27	31	35	40	47	63	64	70	84	50
NY	NY	22	34	26	31	36	46	45	51	63	67	44
Plains	KS, MN, NE, OK, SD	36	40	52	62	81	81	90	98	110	137	82
Mountains	AZ, CO, NV	28	35	37	40	40	46	52	65	64	92	50
National		22	31	35	38	41	47	48	55	63	82	46

Appendix E

Household Fuel Oil (Gallons) Consumption by Decile and Region

Region	States	Decile 1	2	3	4	5	6	7	8	9	10	Mean
Southeast	AL, AR, DC, GA, LA, MS, NC, SC, TN, VA	43	40	52	42	53	55	38	52	67	83	52
CA	CA	8	12	16	15	12	27	34	53	30	42	27
TX	TX	10	16	15	10	16	27	23	26	18	18	18
FL	FL	9	14	5	9	13	8	16	15	30	28	14
Ohio Valley	IL, IN, KY, MI, MO, OH, WV, WI	23	34	34	50	54	44	54	40	86	64	49
Mid-Atlantic	DE, MD, NJ, PA	130	168	146	130	110	131	162	156	128	207	149
Northeast	CT, ME, MA, NH, RI	175	353	242	374	395	233	381	400	505	667	397
Northwest	ID, MT, OR, UT, WA	20	25	22	47	39	62	38	66	58	58	45
NY	NY	49	229	95	163	212	154	280	266	305	514	244
Plains	KS, MN, NE, OK, SD	9	22	45	8	11	26	34	18	50	67	30
Mountains	AZ, CO, NV	22	18	19	30	16	11	20	38	7	14	20
National		38	71	59	70	77	73	91	93	114	148	83

Appendix F

Tax and Stock Ownership Inputs

Decile	Marginal Tax Rate	Average Tax Rate	Stock Ownership
1	-15%	4%	0.80%
2	3%	4%	0.50%
3	11%	10%	0.90%
4	16%	10%	1.70%
5	17%	14%	2.40%
6	19%	14%	4.20%
7	22%	17%	5.70%
8	27%	17%	7.00%
9	30%	23%	12.10%
10	36%	27%	64.70%

Sources: Supporting analysis for Cogressional Budget Office (2005); Department of Treasury (2007)

Appendix G

National Highway Traffic Safety Administration
Proposed CAFE Standards

Model year	Cars, mpg	Trucks, mpg
2011	31.2	25.0
2012	32.8	26.4
2013	34.0	27.8
2014	34.8	28.2
2015	35.7	28.6

Appendix H

Haiku Modeling Results

Region	States	Baseline CO2 Emissions Per MWh of Generation	Post-Cap CO2 Emissions Per MWh of Generation	Price Change	Change in Consumption
Southeast	AL, AR, DC, GA, LA, MS, NC, SC, TN, VA	0.583	0.464	13%	-5%
California	CA	0.170	0.166	7%	-2%
Texas	TX	0.549	0.549	15%	-5%
Florida	FL	0.538	0.448	15%	-4%
Ohio Valley	IL, IN, KY, MI, MO, OH, WV, WI	0.794	0.654	27%	-8%
Mid-Atlantic	DE, MD, NJ, PA	0.573	0.512	18%	-3%
Northeast	CT, ME, MA, NH, RI	0.372	0.317	12%	-4%
Northwest	ID, MT, OR, UT, WA	0.344	0.195	8%	-3%
New York	NY	0.308	0.288	16%	-1%
Plains	KS, MN, NE, OK, SD	0.835	0.749	20%	-9%
Mountains	AZ, CO, NV	0.627	0.471	18%	-7%
National		0.596	0.492	16%	-5%

Appendix I

Consumer Surplus Loss After Carbon Policy

Region	Decile	Avg Income	Gasoline	Electricity	Natural Gas	Fuel Oil	Indirect	Total Loss
Southeast	1	1.6	97	90	36	11	109	343
Southeast	2	1.9	134	101	40	11	175	460
Southeast	3	2.2	178	112	36	14	206	544
Southeast	4	2.3	217	123	37	11	244	632
Southeast	5	2.6	234	125	36	14	287	697
Southeast	6	2.7	275	127	49	14	338	805
Southeast	7	2.8	306	134	39	10	406	896
Southeast	8	2.9	317	141	56	14	466	993
Southeast	9	3.1	387	150	71	17	586	1,212
Southeast	10	3.3	373	168	88	22	820	1,470
Southeast	Avg	2.5	247	126	48	14	354	789
California	1	1.8	81	28	30	2	164	305
California	2	2.1	137	32	29	3	198	400
California	3	2.5	173	33	33	4	243	487
California	4	2.7	202	36	38	4	323	604
California	5	2.9	226	40	41	3	331	640
California	6	3.1	260	42	44	7	408	760
California	7	2.9	298	46	46	9	487	886
California	8	3.1	322	52	54	14	570	1,012
California	9	3.5	384	62	63	8	708	1,224
California	10	3.4	424	82	80	11	1,020	1,616
California	Avg	2.9	274	49	49	7	502	881
Texas	1	2.1	124	98	24	3	128	377
Texas	2	2.2	155	108	26	4	166	459
Texas	3	2.6	190	130	27	4	224	575
Texas	4	2.8	247	141	30	3	274	696
Texas	5	2.8	278	154	33	4	343	812
Texas	6	2.7	291	166	34	7	375	873
Texas	7	3.1	327	179	33	6	454	999
Texas	8	3.2	350	190	38	7	480	1,065
Texas	9	3.3	392	225	45	5	694	1,360
Texas	10	3.1	431	270	69	5	875	1,650
Texas	Avg	2.8	282	168	36	5	406	897
Florida	1	1.5	113	102	2	2	145	365
Florida	2	1.6	119	116	3	4	190	431
Florida	3	2.1	151	133	3	1	236	524
Florida	4	2.3	197	141	5	2	282	627
Florida	5	2.5	223	136	3	4	306	671
Florida	6	2.7	243	157	3	2	360	765
Florida	7	2.8	263	162	5	4	414	847
Florida	8	2.9	314	177	3	4	497	995
Florida	9	2.9	369	206	4	8	585	1,172
Florida	10	3.0	351	243	8	7	860	1,468
Florida	Avg	2.4	230	155	4	4	374	766
Ohio Valley	1	1.5	85	130	58	6	125	405
Ohio Valley	2	1.7	106	154	70	9	158	497
Ohio Valley	3	1.9	150	169	76	9	190	594
Ohio Valley	4	2.2	188	178	77	13	253	709
Ohio Valley	5	2.4	213	186	89	14	295	798
Ohio Valley	6	2.6	243	204	96	12	339	893
Ohio Valley	7	2.8	298	210	95	14	409	1,026
Ohio Valley	8	3.1	310	231	107	11	474	1,141
Ohio Valley	9	3.2	375	244	116	22	578	1,336
Ohio Valley	10	3.4	398	303	157	17	866	1,740
Ohio Valley	Avg	2.5	244	204	95	13	378	935
Mid-Atlantic	1	1.6	92	93	42	34	139	401
Mid-Atlantic	2	1.6	84	105	53	44	155	441
Mid-Atlantic	3	1.8	123	120	51	38	205	537
Mid-Atlantic	4	2.0	172	130	60	34	251	647
Mid-Atlantic	5	2.3	186	141	70	29	285	710
Mid-Atlantic	6	2.4	225	150	63	34	345	817
Mid-Atlantic	7	2.9	256	170	68	42	377	914
Mid-Atlantic	8	2.8	290	183	71	41	454	1,039
Mid-Atlantic	9	3.2	306	190	92	34	531	1,152
Mid-Atlantic	10	3.2	357	250	121	54	840	1,623
Mid-Atlantic	Avg	2.5	222	160	72	39	388	881

Note: Deciles constructed at the national level. All positive welfare losses reflect decreases in consumer surplus.

Consumer Surplus Loss After Carbon Policy								
Region	Decile	Avg Income	Gasoline	Electricity	Natural Gas	Fuel Oil	Indirect	Total Loss
Northeast	1	1.299	87	51	28	46	167	377
Northeast	2	1.673	110	71	45	93	194	513
Northeast	3	1.897	145	72	47	64	223	550
Northeast	4	2.010	165	75	48	98	261	645
Northeast	5	2.234	192	78	38	104	304	717
Northeast	6	2.317	213	84	58	61	350	767
Northeast	7	2.697	255	94	41	100	444	933
Northeast	8	2.935	299	106	46	105	491	1,048
Northeast	9	3.064	332	123	48	133	623	1,260
Northeast	10	3.200	378	156	65	175	917	1,691
Northeast	Avg	2.470	239	98	48	104	448	937
Northwest	1	1.573	117	24	18	5	147	312
Northwest	2	1.799	105	38	32	7	215	397
Northwest	3	1.921	153	38	37	6	269	503
Northwest	4	2.311	187	44	42	12	266	551
Northwest	5	2.557	224	48	47	10	384	714
Northwest	6	2.682	243	48	56	16	390	753
Northwest	7	3.001	265	51	75	10	480	881
Northwest	8	3.212	296	56	77	17	526	972
Northwest	9	3.368	321	61	83	15	631	1,111
Northwest	10	3.263	355	67	101	15	991	1,530
Northwest	Avg	2.636	235	49	59	12	448	803
New York	1	1.521	76	83	26	13	137	335
New York	2	1.752	79	99	40	60	178	457
New York	3	2.171	99	97	32	25	212	465
New York	4	2.396	143	125	37	43	261	609
New York	5	2.500	184	145	43	56	308	736
New York	6	2.432	212	135	55	40	352	794
New York	7	2.860	218	151	53	73	398	894
New York	8	3.084	285	164	61	70	454	1,033
New York	9	3.292	305	194	75	80	533	1,187
New York	10	3.349	333	238	80	135	834	1,620
New York	Avg	2.601	204	149	52	64	393	864
Plains	1	1.532	96	61	43	2	139	342
Plains	2	1.508	117	73	48	6	155	399
Plains	3	1.845	155	87	62	12	208	525
Plains	4	2.029	171	96	74	2	236	578
Plains	5	2.135	216	102	96	3	343	760
Plains	6	2.226	229	124	96	7	384	841
Plains	7	2.868	292	136	107	9	472	1,016
Plains	8	3.030	311	139	116	5	476	1,047
Plains	9	2.951	330	139	131	13	582	1,194
Plains	10	3.250	413	218	163	18	1,201	2,012
Plains	Avg	2.427	246	123	98	8	447	922
Mountains	1	1.771	90	91	33	6	157	377
Mountains	2	1.998	113	108	42	5	205	474
Mountains	3	2.132	147	103	44	5	253	552
Mountains	4	2.338	170	123	48	8	295	644
Mountains	5	2.490	193	132	48	4	344	722
Mountains	6	2.726	222	142	55	3	403	825
Mountains	7	2.909	276	158	63	5	484	986
Mountains	8	3.091	289	165	78	10	504	1,046
Mountains	9	3.231	322	176	76	2	677	1,253
Mountains	10	3.278	380	217	110	4	903	1,613
Mountains	Avg	2.621	224	143	60	5	428	859
National	1	1.555	82	70	26	10	122	311
National	2	1.827	112	95	37	19	171	433
National	3	2.104	153	108	42	15	216	535
National	4	2.330	189	119	45	18	265	638
National	5	2.546	220	124	49	20	308	721
National	6	2.652	249	133	56	19	360	817
National	7	2.885	284	142	58	24	424	932
National	8	3.023	311	154	66	25	486	1,042
National	9	3.229	357	166	75	30	607	1,235
National	10	3.267	384	201	98	39	899	1,621
National	Avg	2.542	234	131	55	22	386	829

Note. Deciles constructed at the national level. All positive welfare losses reflect decreases in consumer surplus.