The Distributional Impacts of Carbon Mitigation Policies

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I. Introduction

Who will pay for new policies to reduce carbon dioxide (CO_2) and other greenhouse gas emissions in the United States? Over the past several years, considerable strides have been made in understanding the aggregate, economywide costs of policies designed to reduce greenhouse gas emissions. Yet little attention has been paid to the distribution of these costs across households, geographic regions, or industries. Not surprisingly, disagreements on the magnitude of the costs imposed on different groups—urban versus rural households, rich versus poor households, or the electric utility versus coal mining versus steel industries—can stymie efforts to reach consensus on basic greenhouse gas mitigation strategies. Disagreements on the distribution of the burden also can impede the development of policies to offset the economic damages endured by particular groups or industries. Such disagreements over the basic facts compound the already difficult problems associated with reaching consensus on carbon mitigation policies. As Mancur Olson (1965) argued almost four decades ago, the more narrowly focused the adverse impacts of a given policy, the more politically difficult it is to sustain that policy. Claims of high and unfair burdens imposed on selected industries or households are widely seen as having doomed the British thermal unit (Btu) tax advanced by the Clinton Administration in 1993. An ongoing problem for policymakers regarding energy and carbon policies is the dearth of objective and transparent estimates of the impacts of carbon policies; to this day there is still disagreement on the true magnitude of the burdens that would have been imposed by the Btu tax.

This issue brief reports on the results of four papers, each of which examines a different aspect of the question of who will pay for mandatory carbon mitigation policies that might be adopted by the United States. These papers were presented on December 11, 2001, at an RFF workshop titled “The Distributional Impacts of Carbon Mitigation Policies: Various Lenses on the Issue.” One of the papers focuses exclusively on the impacts carbon mitigation policies might have on U.S. households by region, including state and county-level analyses. The other three examine impacts on industry, each through a somewhat different lens. Two types of carbon mitigation policies are considered: an economywide carbon mitigation policy, such as a carbon tax or an upstream emissions trading system; and a downstream policy focused exclusively on the electric power industry, such as the one contained in S.556. An important finding of these analyses is that the burdens of a carbon mitigation policy fall very unevenly across population and industry groups. Another conclusion is that without significant cost to the overall economy, compensatory schemes can be introduced to make the distributional impacts more uniform, avoiding the concentration of costs on a few key industries. This knowledge may enhance the political feasibility of future carbon mitigation policies.

II. Economywide Analysis

The first paper, "Mitigating the Adverse Impacts of CO_2 Abatement Policies on Energy-Intensive Industries," by Larry Goulder, professor of economics at Stanford University and University Fellow at Resources for the Future, uses a numerically solved general equilibrium model to examine the economywide costs of mitigating adverse distributional impacts of CO_2 policies on important fossil fuel industries. Goulder finds that the efficiency cost of avoiding profit losses to fossil fuel industries is relatively modest. Underlying this finding is the recognition that some important CO_2 abatement policies, such as a cap-and-trade system involving carbon permits, tend to restrict the output of carbon-intensive industries. Such output-restricting policies cause carbon-supplying industries to behave like a cartel, potentially leading to economic gains, or rents. If the tradable permits are auctioned, then these potential rents are collected as government revenue. On the other hand, if the permits are freely allocated (or grandfathered), the potential rents are retained by firms and yield increases in profit. To create a level playing field, the government needs to freely allocate only a fraction of the permits. Based on his model simulations, Goulder finds that only about 13% of the permits must be freely distributed to the major affected industries in order to prevent losses of profit. The remainder of the permits can be auctioned, thus generating revenues to finance cuts in pre-existing distortionary taxes—thereby offsetting the adverse effects of the new CO_2 policies.

The analysis conducted by Goulder is an updated version of work he has carried out with Lans Bovenberg of Tilburg University in the Netherlands. It divides U.S. production into 13 industries. A distinguishing feature of the model is its attention to the adjustment costs associated with the installation or reallocation of physical capital. The model links these costs to investment decisions and profits. This contrasts with most computable general equilibrium models, which treat physical capital as perfectly mobile across industries. Attention to adjustment costs is necessary to evaluate the impacts of CO_2 mitigation policies on industry profits. In the revised version, Goulder has retained his original structure but updated the work to include data for the year 2000.[1]

In his paper, Goulder examines a number of carbon tax and permits policies. All the carbon tax scenarios start at $25 per ton of carbon. Several involve an escalating carbon tax that reaches as high as $50 per ton. In the cases without earmarked compensation to particular fossil fuel industries, the revenues are rebated as either lump-sum transfers to households or reductions in marginal rates of the personal income tax. Alternative permit policies include 100% auction, 100% free allocation ("grandfathering"), and partial grandfathering.

Goulder's central results are shown in Table 1 (page 15), which displays ten policy scenarios. The first three scenarios involve imposition of a carbon tax with alternative revenue-recycling schemes but no compensation earmarked to specific industries. The next three scenarios involve imposition of a tradable permits policy with alternative policies for distributing the permits. The final four scenarios introduce corporate tax credits designed to achieve profit neutrality in the hardest-hit industries.

Column A1 represents the case of a $25 per ton carbon tax imposed in 2002 and remaining constant in real terms thereafter, with revenues rebated as a lump-sum transfer to households. In the absence of specific compensation policies, the industries experiencing the largest percentage reductions in 2002 after-tax profits are (in descending order) coal mining, petroleum refining, electric utilities, oil and gas, and metals and machinery (rows 1–5). In the coal mining industry, for example, after-tax profits initially decline by more than one-third in 2002; by 2025, after-tax profits are down slightly more than one-quarter. The average decline in after-tax profits for all other industries is shown in row 6. Rows 7 and 8 display the efficiency

[1] The 2000 data indicate that the carbon intensity of some fossil fuel industries has increased somewhat compared

impact of the $25 per ton carbon tax, using the equivalent variation measure.[2] The $25 per ton carbon tax implies a gross efficiency loss of approximately $104 per ton of emissions reduced, which is equivalent to 56 cents per dollar of discounted gross tax revenue. Row 9 displays the percentage change in carbon emissions compared with the baseline.

Perusal of the alternative tax and permit policies examined by Goulder (columns A1–3 and B1–3) reveals several interesting results. For example, consistent with other analyses, Goulder finds that rebating the revenues via reductions in distortionary taxes, such as marginal personal income tax rates, significantly reduces the total economic cost compared with the case of lump-sum rebates. Columns B2 and B3 illustrate the implications of grandfathering some or all of the permits. Column B3 shows that grandfathering 100% of the permits leads to substantial gains for the coal mining and oil and gas industries. This policy enables firms to retain all the rents associated with the policy-induced restriction in fossil fuel output. Column B2 gives results from grandfathering about 13% of the permits—just enough to prevent losses of profits in the coal and oil and gas industries. This policy is considerably less costly to the overall economy than 100% grandfathering. Although 100% grandfathering raises efficiency costs by 90% relative to the cost under the policy of 100% auctioning (column B1), the policy of partial grandfathering in column B2 raises costs by only 7%. The partial grandfathering policy is less costly because it yields more government revenue and thus reduces the government's need to raise revenue from other taxes.

Goulder also considers the use of targeted corporate tax credits designed to achieve profit neutrality in the hardest-hit industries. The efficiency cost of compensating the coal mining industry is $87.2 per ton of carbon reduction (column C1), 1.5% more than the efficiency cost of not compensating that industry.[3] Insulating other major industries from losses in after-tax profits involves only small additional losses in terms of economic efficiency. As shown in column C4,

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with the previous decade.

[2] This is a gross measure because the numerical model does not account for the benefits associated with the environmental improvement from reduced emissions. The negative of the equivalent variation is the gross efficiency cost, or loss.

[3] This efficiency cost reflects the fact that the tax credits absorb government revenue; hence the government must rely more heavily on distortionary taxes than in the absence of the targeted corporate tax credits.

insulating the electric utility, petroleum refining, and metals and machinery industries increases the efficiency cost by only an additional 0.3%.

Overall, Goulder argues, the cost of avoiding losses of profit to the hardest-hit (fossil fuel) industries is relatively modest—less than 2% of the costs of not compensating them. When other (smaller) industries are included in a safety net, as well as other groups outside the industrial sector—for example, labor—the needed compensation will certainly rise. How much it will rise is a matter requiring further research.

III. Manufacturing: Short-Term, Disaggregate Approach

A key strength of Goulder's analysis is his effort to consider corporate profits as opposed to only revenues. Much of his focus is on impacts five or more years from the time a new policy is introduced. In the short term (the zero- to five-year horizon), however, firms cannot easily remold their factories and machines in response to higher energy and other input costs. For a variety of reasons, including competition from imports, firms may not be able to take immediate advantage of the favorable market conditions caused by the carbon policy, and in fact, they may not even be able to pass along all cost increases to their customers.

The second paper, "Near-Term Impacts of Carbon Mitigation Policies on Manufacturing Industries," by RFF's Richard Morgenstern, Mun Ho, Jhih-Shyang Shih, and Xuehua Zhang, concentrates on the cost impacts of CO_2 policies in the short term. In this time interval, the costs to a firm will roughly equal the per ton tax (or permit charge) multiplied by the current level of carbon usage. For example, the cost of a $25 per ton carbon tax (or permit) to a firm that uses 100 tons of carbon is $2,500. Morgenstern et al. adopt a number of simplifications: they ignore the effects of the carbon tax (or permit charge) on the quantity or type of capital and labor inputs used, the effects of competition from imports, and any changes to tax laws and public spending patterns that might be implemented in light of the new revenue from the carbon taxes (or auctioned permits). Though lacking the elegance of the computable general equilibrium model, the short-term analysis by Morgenstern et al. has the attraction of presenting information on the distribution of costs at a large number of industries. Whereas Goulder is able to estimate the effects of a carbon policy on the after-tax profits of 13 sectors, including 5 manufacturing industries, Morgenstern et al. consider the increased costs borne by firms (not corporate profits) across 361 separate manufacturing industries.[4] Since capital and other factor inputs are frozen at current levels, the Morgenstern et al. approach yields upper-bound estimates of total costs. Thus, the results are best viewed as descriptive of the relative burdens within the manufacturing sector, rather than as a measure of absolute costs.

Morgenstern et al. analyze two different policies: an economywide carbon mitigation policy, such as a carbon tax or an upstream emissions trading system, and a downstream policy focused exclusively on the electric utility industry. Two distinct steps are involved in the analysis. First, a detailed picture of direct carbon (fuel) use by the 361 individual manufacturing industries is developed. Second, interindustry accounts are constructed, including the final demands for a detailed list of commodities. The latter step reveals indirect carbon use, such as carbon embodied in nonfuel inputs. Using input-output analysis, it is possible to calculate the total impacts on both consumer goods and on manufacturing industries of a carbon tax or tradable permit system placed on primary fossil fuels (coal, crude oil, and natural gas). Since the underlying model is linear, the results are reported as increases in overall production costs per dollar of carbon tax imposed. The cost of a $25 per ton carbon tax is 25 times the cost of a $1 tax.

Figure 1 (page 19) displays the distribution of the percentage cost increases per dollar of output across the 361 manufacturing industries associated with an economywide carbon policy. This highly skewed picture reflects the basic conclusion of the Morgenstern et al. analysis: the burden of an economywide carbon policy impacts the manufacturing sector quite unevenly. The eight hardest-hit industries bear more than 50% of the total burden, measured as the cumulative percentage of total costs. Among the entire list of 361 manufacturing industries, cost increases vary by two orders of magnitude.

Table 2 (page 16) displays the 25 hardest-hit manufacturing industries by the sources of the additional cost burdens. Particularly interesting is the variation in the sources of the burdens

[4] Interestingly, Morgenstern et al. demonstrate a remarkable consistency between the results of their input-output analysis and the computable general equilibrium models. They aggregate their results to the 21 manufacturing categories examined by Ho and Jorgenson (1998) in their general equilibrium model of the U.S. economy. Nine of their top 10 industries rank in Ho and Jorgenson's top 10. The simple correlation coefficient between the two is 0.96, suggesting a high degree of consistency between the two approaches.

across different industries: direct combustion of fossil fuels, purchased electricity, and nonenergy intermediate inputs. For example, in the case of petroleum refining, almost all of the increase in total costs comes from increases in the cost of nonfuel intermediate inputs, mostly crude oil used as a feedstock. Relatively minor contributions arise from increases in direct fuel costs or from purchased electricity. In contrast, the cement (hydraulic) industry, direct combustion of fossil fuels, and purchased electricity contribute more to total costs than nonenergy intermediate inputs.

Table 3 (page17) compares the impacts on manufacturing industries when an economywide policy versus an electricity-only policy is imposed. The per ton charge on carbon inputs is equal for the two policies. However, the former policy affects all carbon inputs, direct and indirect, used in the manufacturing sector. The latter affects only carbon used in the production of electricity, including the impact of the corresponding rise in electricity prices on nonenergy intermediate inputs, such as the higher cost of aluminum car parts purchased by the auto industry.

The left half of Table 3 displays the top 10 industries hardest hit by the economywide policy and their corresponding ranking (among the 361 manufacturing industries) for the electricity-only policy. Petroleum refining is hardest hit by the economywide policy, for example, but ranks 145 under the electricity-only policy. Eight of the 10 industries hardest hit by the economywide policy rank lower (or the same) for the electricity-only policy—in most cases considerably lower.

The right half of Table 3 displays the 10 industries hardest hit by the electricity-only policy along with their corresponding ranking for the economywide policy. The hardest hit—aluminum—ranks number 13 for the economywide policy. All of the top 10 hardest hit under the electricity-only policy rank lower or the same under the economywide policy—in many cases substantially lower. The key conclusion of this exercise is clear: manufacturing industries are affected very differently by these two policies. Many of those industries hardest hit by one policy tend not to be so adversely affected by the other, and vice versa. Thus, opposition to these two policies is likely to come from very different manufacturing industries.

IV. The Electricity Sector

The third paper, "The Effect of Allowance Allocation on the Cost of Carbon Emissions Trading," by RFF's Dallas Burtraw, Karen Palmer, Ranjit Bharvirkar, and Anthony Paul, focuses exclusively on the impacts of electricity-only carbon policies on the electricity sector. Burtraw et al. consider the cost-effectiveness and distributional impacts of three alternative approaches for distributing carbon emissions allowances within the electricity sector: 100% auctioning, 100% free allocation or grandfathering, and a so-called generation performance standard (GPS), a form of grandfathering that would update allowance allocations based on shares of current electricity generation. The GPS standard is embodied in some current U.S. legislative proposals, such as S. 556, as well as in the nitrogen oxide (NO_x) policy in place in Sweden. Interestingly, although the electricity sector is responsible for just over one-third of U.S. carbon emissions, Burtraw et al. report that based on various studies in the literature, the industry would be responsible for two-thirds to three-quarters of the emissions reductions under a cost-effective economywide policy.

Burtraw et al. solve a detailed national electricity market model, known as Haiku, and measure the economic cost and distributional effects on consumers and producers of each of the three alternative approaches for distributing emissions allowances. The model includes algorithms for investment and retirement of generation capacity and selection of NO_x emissions control technologies. It simulates electricity demand, electricity prices, the composition of electricity supply, and emissions of major pollutants, including carbon. Generator dispatch in the model is based on minimization of short-run variable costs of generation. Adjustments to capacity are based on net revenues accounting for all costs, including new capital investments.

Two important components of the Haiku model are the intraregional electricity market component and the interregional power-trading component. The intraregional electricity market component solves for a market equilibrium identified by the intersection of price-sensitive electricity demand for three customer classes (residential, industrial, and commercial) and supply curves for four time periods (peak, shoulder, middle, and base load hours) in three seasons within the 13 National Electricity Reliability Council (NERC) regions and subregions. Parameters for each regional supply curve are established using cost estimates and capacity information for up to 45 aggregate "model" plants. The interregional power-trading component solves for the level of trading necessary to achieve equilibrium in regional electricity prices. These interregional transactions are constrained by the assumed level of available interregional transmission capability as reported by NERC.

Burtraw et al.'s main finding is that the auction is dramatically more cost-effective than the other approaches—approximately one-half the societal cost of grandfathering or the GPS. These differences, they argue, arise from the effect of each permit allocation approach on electricity prices. The GPS provides an incentive for generators to increase electricity production in the form of a grant of additional emissions allowances. These additional allowances constitute an output subsidy.[5] Although the GPS mitigates electricity price increases, it raises economic costs, since it tends to amplify existing economic distortions in electricity markets resulting from economic regulation and other inefficiencies in electricity pricing. In contrast, the auction approach increases electricity prices the most, but the efficiency cost of the price changes is less than under the other approaches.[6]

Table 4 (page 18) displays the changes in economic surplus and cost-effectiveness of the three alternative approaches for distributing carbon emissions allowances examined by Burtraw et al. (price changes are virtually proportional to changes in economic surplus). Under the auction approach, consumers face the highest electricity prices but the lowest natural gas prices. The GPS yields the opposite results: the lowest electricity prices and the highest natural gas prices. Grandfathering falls in between with respect to both electricity and natural gas prices.

Producers can expect to do the best under grandfathering because it represents a substantial transfer of wealth to producers from consumers. Consistent with Goulder's results, Burtraw et al. find that producer profits and asset values increase substantially compared with the baseline, making producers better off with a carbon policy than without one but leaving consumers substantially worse off. Even though grandfathering is the intermediate approach with respect to its effect on electricity and natural gas prices, it is the most extreme approach with

[5] Simulations by Burtraw et al. indicate that much of this subsidy persists even when utilities are able to receive credit for energy conservation programs.

[6] Under the auction policy examined by Burtraw et al., the revenues from the auction are returned to households as lump-sum transfers. The authors point out that alternative revenue-recycling methods—for example, returning revenues via cuts in marginal income tax rates (as in some of the experiments performed by Goulder)—could further reduce the costs of the auction policy.

respect to transfers of wealth. In fact, the compensation implicit in the allowance allocation is substantially greater than the cost of compliance activities for industry—that is, grandfathering actually overcompensates industry for its costs. The auction and GPS approaches have much more moderate distributional effects. In effect, under an auction, industry could be fully compensated for all of the change in the value of the existing assets with a free allocation of less than 10% of the total allowances, and the remaining 90% could be auctioned.

Producers can expect to do at least as well in the aggregate under an auction as they would under a GPS, but owners of existing assets can expect to do substantially better under an auction. This finding raises an interesting paradox: producers do better paying for emissions allowances (through the auction) than receiving them for free (under the GPS). The reason for this, according to Burtraw et al., is that the GPS yields the lowest electricity price, which erodes the value of existing assets. The auction yields the highest electricity price, which preserves or enhances the value of many assets.[7]

The auction approach also has institutional features that make it more readily expandable to an economywide scheme for regulating carbon emissions. Apart from its lower societal cost, the auction provides policymakers with flexibility through the collection of revenues that can be used to meet distributional or other needs. Further, because it is so cost- effective, it will have less effect on economic growth than would the alternative approaches when used to achieve the same environmental goals. This, in itself, is an important distributional benefit.

V. Regional Impacts

The fourth paper, “Regional Patterns of Household Energy Use and Carbon Emissions,” by RFF’s William Pizer, James Sanchirico, and Michael Batz, reports preliminary results examining the regional patterns of household energy use and carbon emissions, and the corresponding impacts of new carbon policies on the energy costs of different households across

[7] Although consumer expenditures increase under the auction approach, substantial revenues are raised, which can be used to compensate consumers. A portion of the revenues could also be used to compensate producers, or they could be directed to support energy conservation or other benefit programs.

the United States. Despite its obvious importance, this issue has not been studied in great depth, largely because the data needed to conduct such an analysis are sparse.

Pizer et al. use information from the Consumer Expenditure Survey over the period 1984–2000 as their starting point. Although the survey contains a sample of more than 90,000 households for this time period, the sampling technique only includes households from 666 of the 3,140 U.S. counties. Thus, the key challenge for Pizer et al. is to model broad-scale and regional patterns of energy and carbon use with such gaping holes in their data. In addition to the counties with no data at all, they also want to allow for the fact that some of the sampled counties have more observations than others and thus represent a more accurate measure of the energy use in those counties. Pizer et al. address this challenge by employing the statistical technique of nonparametric, kernel regression. This technique creates an estimate of the energy use at a particular geographic point based on energy use at nearby, sampled points.[8]

Overall, Pizer et al. find considerable variation in the type of fuel used and the average level of use across regions, across states within each region, and across counties within each state. They note, based on data from the Energy Information Administration, that the typical U.S. household spends about $2,500 per year on electricity, fuel oil, natural gas, and gasoline and emits 4.4 tons of carbon per year. In general, the patterns they find conform to what one would expect: electricity use is higher in the South, fuel oil is used almost exclusively in the Northeast, and natural gas is more prevalent in the Midwest. Gasoline usage fluctuates modestly across regions. What is surprising is the amount of heterogeneity both within states and within census regions. For example, in Massachusetts, there is an approximately 70% difference in fuel oil use between the highest- and lowest-consuming counties where the median county reports household use around 300 gallons per year. In the South, the census region that has the highest levels of average electricity use, the county averages vary by a factor of two.

Policies designed to reduce U.S. carbon emissions may (inadvertently) place heavier burdens on regions where geography or history has led to higher carbon use per household. Preliminary estimates of average household carbon emissions by county range from six tons per

[8] Work in progress will incorporate information involving household characteristics that might influence energy use.

household in the Midwest to fewer than three tons per household in the Northwest. The principal reason for this variance in emissions lies in the use of electricity and the ways in which it is generated. Much of the Pacific Northwest's power comes from hydroelectric plants. Similarly, carbon emissions in the Northeast and in the South are lower because of their reliance on nuclear power. Although there is less use of air conditioning in the Midwest than in the South, its carbon emissions per household are higher than in other regions because such a large portion of its electricity is generated by burning coal.

Given these preliminary findings on patterns of energy use and carbon emissions, Pizer et al. find that adoption of a broad-based carbon policy—equivalent to a carbon tax or a tradable permit system—would impose significantly different burdens on households in different regions of the country. For example, households in the Northwest would pay about half as much as those in the Midwest and Texas, where household emissions are almost double (see Figure 2, page20).

VI. Conclusions

The four papers presented at the December 2001 RFF Workshop address the critical questions of who will pay for policies designed to reduce CO_2 and other greenhouse gas emissions in the United States. Key issues for discussion involve the magnitude of compensation that might be justified for different sectors or groups, the form of such compensation, and the institutions that may be involved. Although the four papers differ markedly in scope and approach, a number of conclusions can be drawn from the analyses:

- The cost burden of potential carbon mitigation policies is very unevenly distributed across U.S. industries. Absent new compensation schemes, a small number of industries would bear most of the costs. Not surprisingly, a different (small) set of industries is affected by electricity-only compared with economywide policies.
- Through the free provision (or grandfathering) of carbon permits, or through explicit compensation schemes, the distribution of the cost burden of carbon mitigation policies can be made more even. Avoiding uneven cost impacts does not add significantly to the overall economic costs of carbon mitigation. According to one paper, the free allocation (or grandfathering) of 13% of carbon permits would prevent losses of profit in the fossil-fuel supplying industries. Such a policy would involve economywide costs about 8% higher than the standard policies. Another paper finds that earmarking less than 10% of the revenues derived from a carbon tax or auctioned

permit policy that targeted just the electricity sector would be sufficient to fully compensate firms in that sector.

- Regarding electricity-only control policies, the formula for allocating permits within the electricity-only sector has major implications for both total costs and the distributions of the burdens. Interestingly, auctioned permits cost substantially less than gratis forms of allocation, such as grandfathering or the generation performance standard. Auctioned permits also have the potential for more favorable impacts on consumers and on the electricity sector itself.
- Regional patterns of household energy use and carbon emissions vary significantly across the United States. Based on a new, highly disaggregated analysis of the Consumer Expenditure Survey, it appears that households in some sections of the country, notably the Midwest and Texas, would face heavier burdens than those in other regions, dramatically so when compared with those in the Pacific Northwest.

The policy debates of the past decade make it abundantly clear that the development of mandatory policies to reduce U.S. emissions of CO_2 and other greenhouse gases is no simple matter. To avoid the hyperbole of exaggerated claims of damage to one sector or another, detailed analyses of who will pay is critical. The results reported in this paper are designed to contribute to that research effort and, more broadly, to the evolving policy process.

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Table 1: Impacts of CO2 Abatement Policies

(Percentage changes from reference case)

	Policies with no distributional adjustments			*Permits policies*			*Carbon taxes combined with corporate tax credits*			
	Constant carbon tax, lump-sum repl	Carbon tax growing at 7%, lump-sum repl.	Carbon tax growing at 7%, personal tax repl.	100% auctioning	Partial free allocation (equity-value neutrality)	100% free allocation	Credits to coal and to oil and gas	Add credits to electric utilities	Add credits to petroleum refining	Add credits to metals and machinery
	A1	A2	A3	B1	B2	B3	C1	C2	C3	C4
After-tax profits (2002, 2025)										
Coal mining	-35.6, -26.6	-38.6, -40.5	-38.0, -40.0	-38.0, -40.0	-23.0, -19.9	154.9, 217.6	-38.0, -40.0	-38.0, -40.0	-38.0, -40.0	-38.0, -40.0
Oil and gas	-4.8, -1.9	-6.4, -5.5	-6.5, -5.5	-6.5, -5.5	-2.8, -1.5	19.9, 22.3	-6.5, -5.5	-6.5, -5.5	-6.5, -5.5	-6.5, -5.5
Petroleum refining	-8.3, -5.0	-9.2, -9.8	-8.4, -9.1	-8.4, -9.1	-8.4, -9.1	-8.7, -9.3	-8.5, -9.1	-8.4, -9.1	-8.5, -9.1	-8.5, -9.1
Electric utilities	-6.2, -3.7	-6.8, -6.9	-5.4, -6.2	-5.4, -6.2	-5.5, -6.3	-6.0, -6.5	-5.5, -6.2	-5.5, -6.2	-5.5, -6.2	-5.5, -6.2
Metal and machinery	-2.7, -2.6	-2.8, -4.5	-1.4, -3.5	-1.4, -3.5	-1.3, -3.4	-1.0, -2.3	-1.5, -3.5	-1.5, -3.5	-1.5, -3.5	-1.5, -3.5
Average for other industries	-1.0, -1.3	0.0, -2.5	-0.1, -1.8	-0.1, -1.8	-0.2, -1.8	-0.6, -2.2	-0.2, -1.8	-0.2, -1.8	-0.2, -1.8	-0.2, -1.8
Efficiency cost										
Absolute	1190.0	2228.0	1478.0	1478.0	1591.0	2810.0	1501.4	1504.8	1506.0	1506.2
Per ton of CO2 reduction	104.2	126.7	85.9	85.9	92.3	160.5	87.2	87.4	87.5	87.5
Emissions										
Percentage change	-14.84	-22.85	-22.35	-22.36	-22.39	-22.74	-22.38	-22.38	-22.38	-22.38

Source: Goulder (2001).

Table 2: Estimated Percentage Increase in Manufacturing Costs, Top 25 Industries, per Dollar of Carbon Charge

Industry	*Percentage change in total cost*	*Rank*	*Cumulative percentage*	*Percentage change in fuel cost*	*Rank*	*Percentage change in cost of purchased electricity*	*Rank*	*Percent Change in Indirect Cost*	*Rank*
Petroleum refining	0.718	1	0.485	0.050	5	0.005	76	0.663	1
Products of petroleum and coal	0.358	2	0.486	0.005	53	0.006	50	0.347	2
Lubricating oils and greases	0.259	3	0.492	0.070	3	0.001	315	0.189	5
Carbon black	0.254	4	0.493	0.023	12	0.020	7	0.211	4
Asphalt paving mixtures and blocks	0.220	5	0.498	0.004	69	0.004	95	0.212	3
Lime	0.196	6	0.499	0.090	1	0.025	5	0.082	10
Nitrogenous and phosphatic fertilizers	0.186	7	0.505	0.046	7	0.013	21	0.127	7
Asphalt felts and coatings	0.134	8	0.508	0.002	147	0.003	145	0.129	6
Cement, hydraulic	0.129	9	0.511	0.048	6	0.042	4	0.039	53
Blast furnaces and steel mills	0.123	10	0.537	0.089	2	0.020	6	0.014	320
Industrial inorganic and organic chemicals	0.120	11	0.591	0.009	36	0.019	8	0.092	9
Gypsum products	0.104	12	0.592	0.035	9	0.011	24	0.058	19
Primary aluminum	0.103	13	0.595	0.011	29	0.045	3	0.047	30
Brick and structural clay tile	0.102	14	0.596	0.043	8	0.016	14	0.044	34
Gum and wood chemicals	0.102	15	0.596	0.057	4	0.005	81	0.040	50
Fertilizers, mixing only	0.101	16	0.597	0.005	54	0.003	156	0.094	8
Structural clay products	0.101	17	0.597	0.034	10	0.006	51	0.061	18
Electrometallurgical products, except steel	0.101	18	0.598	0.032	11	0.070	2	-0.002	360
Synthetic rubber	0.092	19	0.600	0.007	45	0.010	28	0.075	11
Plastics materials and resins	0.088	20	0.614	0.004	75	0.011	23	0.073	12
Printing ink	0.085	21	0.615	0.014	21	0.002	282	0.070	14
Cellulosic manmade fibers	0.082	22	0.616	0.009	35	0.004	90	0.069	16
Adhesives and sealants	0.076	23	0.618	0.001	189	0.002	204	0.073	13
Surface active agents	0.076	24	0.619	0.003	84	0.003	143	0.070	15
Clay refractories	0.070	25	0.619	0.017	18	0.005	64	0.047	29

Source: Morgenstern et al. (2001).

Table 3: Comparison of Economywide and Electricity-Only Policies

Ranked by economywide policy					*Ranked by electricity-only policy*				
Industry	*Economywide carbon charge*	*Rank*	*Electricity-only carbon charge*	*Rank*	*Industry*	*Economywide carbon charge*	*Rank*	*Electricity-only carbon charge*	*Rank*
Petroleum refining	0.718	1	0.007	145	Primary aluminum	0.103	13	0.064	1
Products of petroleum and coal	0.358	2	0.006	191	Electrometallurgical products, except steel	0.101	18	0.032	2
Lubricating oils and greases	0.259	3	0.007	154	Cement, hydraulic	0.129	9	0.027	3
Carbon black	0.254	4	0.011	36	Aluminum rolling and drawing	0.054	49	0.021	4
Asphalt paving mixtures and blocks	0.220	5	0.009	76	Primary smelting and refining of copper	0.052	52	0.019	5
Lime	0.196	6	0.017	6	Lime	0.196	6	0.017	6
Nitrogenous and phosphatic fertilizers	0.186	7	0.011	25	Primary nonferrous metals	0.048	64	0.017	7
Asphalt felts and coatings	0.134	8	0.006	196	Blast furnaces and steel mills	0.123	10	0.016	8
Cement, hydraulic	0.129	9	0.027	3	Metal cans	0.054	48	0.016	9
Blast furnaces and steel mills	0.123	10	0.016	8	Aluminum castings	0.039	95	0.015	10

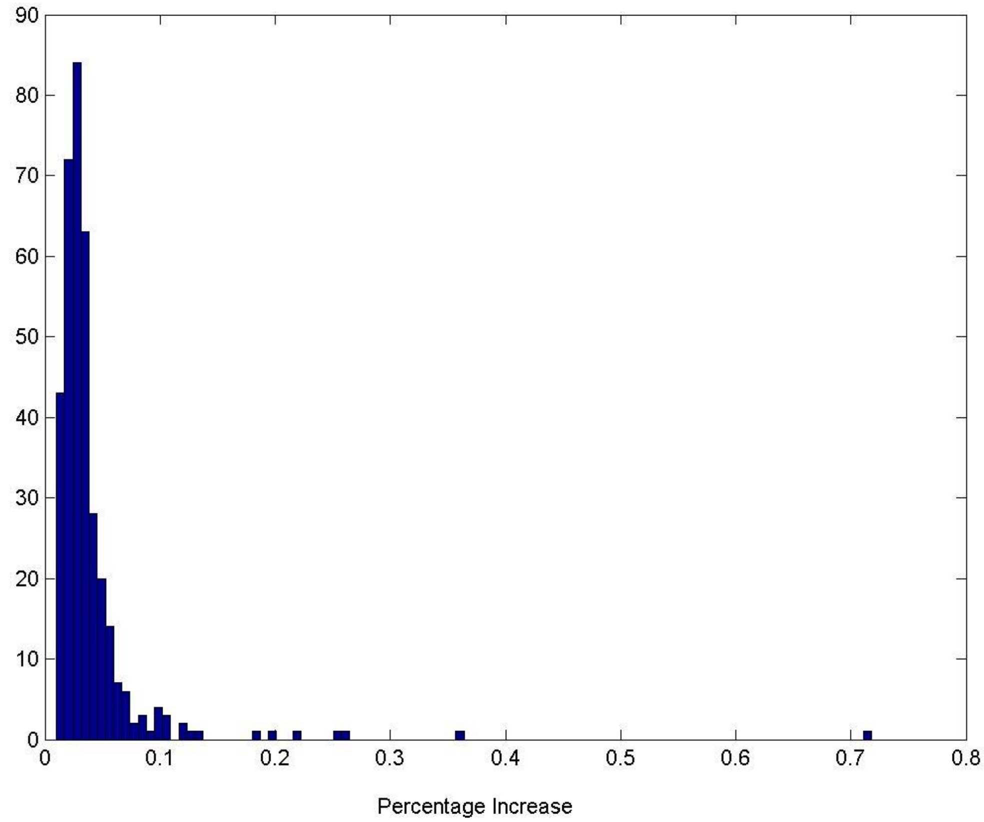
Source: Morgenstern et al. (2001).

Table 4: Change in Economic Surplus and Cost-Effectiveness of Policies in 2012 (billion 1997$; 35 million mtC reduction)

	Auction	Grandfathering	GPS
Consumer Surplus	-13.9	-8.0	-1.4
Producer Surplus	-1.7	4.9	-1.6
Sum	*-15.6*	*-3.1*	*-3.0*
Revenue to Government	14.8	0.0	0.0
Net Direct Surplus	-0.9	-3.1	-3.0
Cost-Effectiveness ($/ton of Carbon)	26.5	88.7	87.2

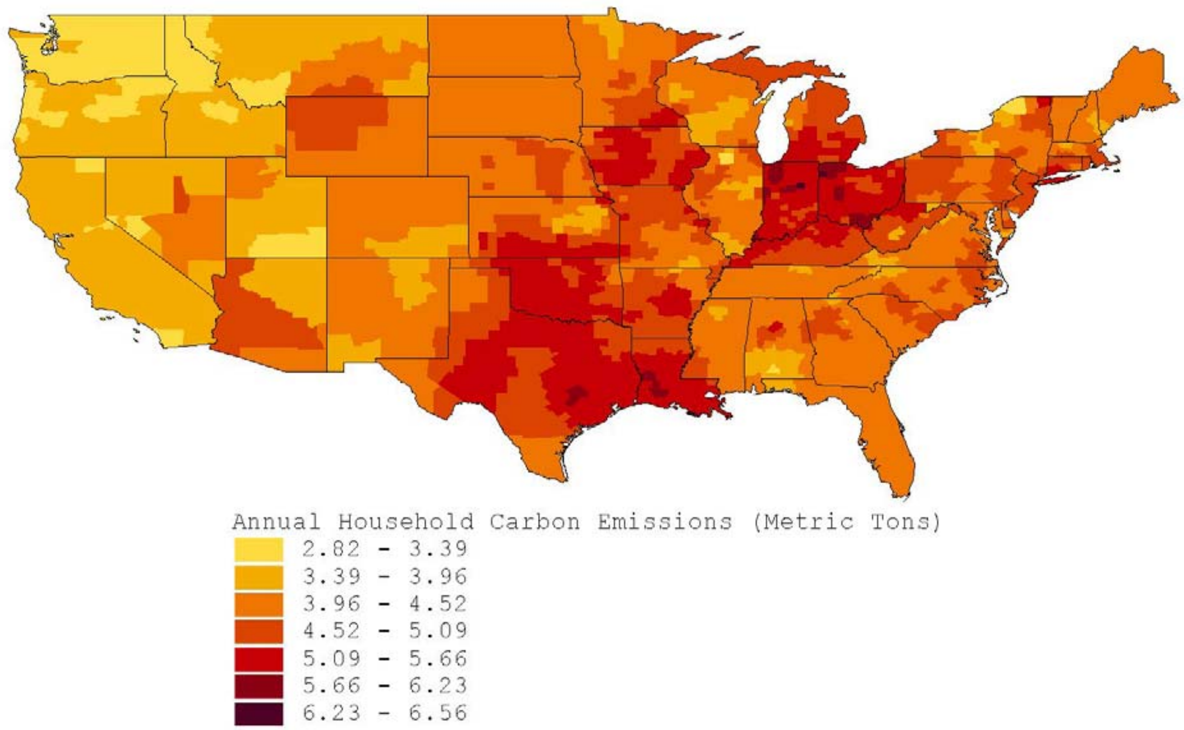
Source: Burtraw et al. (2001).

Figure 1: Distribution of Percentage Cost Increase per Dollar of Carbon Charge



Source: Morgenstern et al. (2001).

Figure 2: Estimated Carbon Emissions (All Fuels)



Source: Pizer et al. (2001).