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Kevin A. Hassett
American Enterprise Institute

Aparna Mathur
American Enterprise Institute

and

Gilbert E. Metcalf
Tufts University and NBER

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Kevin A. Hassett
American Enterprise Institute
Aparna Mathur
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Abstract

In discussions over how best to implement mandatory restrictions on carbon, the most commonly discussed option is a cap-and-trade system. One critical economic question surrounding cap-and-trade is how to distribute the permits. The two main competing mechanisms are free allocations to polluters (usually based on past emissions levels, output levels, or carbon intensity) and the auction of permits.

In this paper, we explore the differential economic impact of the two approaches. Our results show that the consumer price effects across regions of auctioning and free allocation are quite different. These differences arise due to the nature of electricity regulation. If permits are auctioned, regulators are likely to allow utilities to pass forward to consumers the electricity price increase due to the cost of permits. However, if permits are freely allocated, this forward shifting may not be allowed to take place.

These results suggest that giving the permits away in a world where state regulators don't allow utilities to pass forward the "cost" of free permits simply punishes consumers in those regions of the country that have moved to deregulation.

We thank Dallas Burtraw for information about regional electricity fuel mixes.

I. Introduction

U.S. greenhouse gas emissions equaled 7,147 million metric tons of CO_2 equivalent ($MMCO_2e$) in 2005, an increase of 17 percent over 1990 levels. Carbon dioxide emissions account for the vast bulk of emissions and equaled 6008.6 $MMCO_2$ in that year. A consensus is emerging in the United States that climate change is a critical issue requiring a reduction in GHG emissions. Several bills have been proposed in the current Congressional legislative session (110th Congress, 2007 – 2008) to control greenhouse gas emissions.[1] On May 2007, President Bush called for the United States along with other major greenhouse gas emitting countries to "set a long-term goal for reducing greenhouse gases" (Stolberg (2007)). The recent releases of reports by Intergovernmental Panel on Climate Change Fourth Assessment Report's Working Groups provide additional evidence to support the role of anthropogenic warming. The key issue in climate policy today is the choice of strategy to accomplish the goal of greenhouse gas reduction.

Two general approaches have been explored in the literature: Cap-and-trade and Carbon Taxes.[2] The former approach has, to date at least, been far more popular among policymakers. One consideration that likely has weighed heavily in favor of the cap-and-trade approach is the ability of policymakers to soften the "pain" of the climate policy by handing out permits to emit carbon. In this paper, we explore the consequences of such an approach.

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[1] Paltsev et al. (2007) describe and conduct an economic analysis of climate mitigation scenarios based on these proposals.

[2] We note that a carbon tax is preferable to a carbon cap-and-trade system, as is currently implemented in Europe. While a carbon charge and a cap-and-trade system could be designed to bring about the same reduction in carbon emissions in a world with no uncertainty over marginal abatement costs, the instruments are not equivalent in a world with uncertainty. Given the uncertainties with respect to the introduction of new technologies to reduce carbon emissions, tax and permit systems can have very different efficiency costs. Because global warming depends on the stock of carbon in the atmosphere rather than on emissions in any one year, the expected efficiency costs of a carbon charge policy are likely to be much lower than the costs of a carbon cap-and-trade system (Newell and Pizer, 2003)

Our analysis focuses on the distributional burden of a cap-and-trade system with allocated permits. One critical economic question surrounding cap-and-trade is how to distribute the permits, which represent a limited right to emit carbon. The two main competing mechanisms are free allocations to polluters (often called “grandfathering”) or the sale of permits (usually through an auction). These represent two ends of a continuum as a mix of auctioning and free allocation is also possible. We focus on these two polar cases since our interest is in the distributional implications of auctioning for electricity produced in states subject to consumer price regulation.

Our results show that the consumer price impacts across regions of auctioning and free allocation could differ markedly with our assumption about regulatory behavior. These differences arise due to the nature of electricity regulation. If permits are auctioned and regulators adhere to their standard price setting practices, regulators would allow utilities to pass forward the electricity price increase due to the carbon permit cost to consumers. However, if permits are freely allocated, this forward shifting may not be allowed to take place, even though utilities would, in terms of opportunity costs, face similar higher costs of electricity production as if the permits had been auctioned. Theory or experience can not guide us in predicting how regulators will respond to permit programs. A reasonable assumption that we will posit for this paper is that regulators will allow local electric utilities to pass forward the cost of auctioned permits but that they will not allow firms to pass forward the cost of permits that are freely allocated to them.

Some policymakers argue that an auction would disproportionately harm the central parts of the country that are dependent on coal for electricity. Our results suggest that the regional differences are not that large; and that giving the permits away in a world where state regulators don't allow utilities to pass forward the "cost" of free permits simply changes the regional variation without reducing it. If anything it punishes consumers in those regions of the country that have moved to deregulated utility markets.

In the next section, we briefly compare a cap-and-trade system with a carbon tax, and discuss the circumstances under which one can approximate the distributional burden of a cap-and-trade system via analogy to the analysis of carbon tax. Functionally, a cap-and-trade system is similar to a carbon tax in that it causes production costs to go up for firms, and firms would try to pass on these costs to consumers in the form of higher prices of energy and non-energy goods and services. Section II discusses the choice facing policymakers of either auctioning the permits or freely allocating them. Section III describes our methodology. Section IV presents results under the two cases of grandfathered permits and auctioned permits. Section V concludes.

I.A. Cap-and-Trade and Carbon Taxes

With a cap-and-trade system for carbon dioxide (CO2), policy makers set a limit on the quantity of CO2 that can be emitted in a given period. Emission rights (permits) are created equal in number to the total emissions allowed under this cap. The permits are then allocated in some fashion. At the end of a reporting period, each source must report all emissions and surrender an equivalent number of permits. Since the number of permits is limited, they have financial value. Companies able to reduce their emissions at low cost can sell the permits they don't need to companies for whom the cost of reducing emissions is high. Each company has the flexibility to choose how to meet its emissions target, but market incentives encourage them to develop new, cleaner technologies. Over time, the cap can be lowered to achieve more aggressive emissions-reduction targets.

A key decision facing lawmakers is whether, under a cap-and-trade system, permits should be sold to polluters or given away, or some combination of the two. This decision will not only determine the flow of potentially trillions of dollars through the economy, but also the overall cost of climate policy.

A cap-and-trade system with 100 percent permit auction can be constructed to be identical in impact to a carbon tax in a world with known damage and cost curves. Higher cost of carbon consumption would shift cost curves upward in affected markets, and influence the behavior of both consumers and producers in identical ways under the two policies. The policies differ under uncertainty as has been noted by Newell and Pizer (2003) among others.

If permits are distributed freely rather than auctioned off, the results could be similar to a carbon tax as well (ignoring the use of funds), provided that the relevant markets are competitive. In that case, a firm that uses a permit rather than selling it would consider the opportunity cost of forgone permit revenues as a cost, and that would influence market equilibrium. If, however, the relevant markets are not competitive, then the analogy breaks down. In particular, in regulated markets, regulators might not allow utilities to pass forward the cost of permits if they received them for free.

In this paper, we explore the variation in the burden of a cap and trade system when we only allow states with deregulation to fully pass forward electricity price increases (resulting specifically from carbon pricing) to consumers.[3] We assume a $15 per unit price of carbon permits, where the permit allows the permit holder to emit one metric ton of CO2.

II. Auction or Free Allocation?

[3] The states with deregulated electricity are CA, CT, DE, MA, MD, ME, MT, NH, NJ, NY, RI, TX, and DC. Source: http://www2.whitefence.com/articles/energy/states-deregulation.html

While it is a common understanding that auctioned permits will result in higher energy and other product prices much the same way that an equivalent fee on carbon emissions would, it is often erroneously assumed that free permit allocations will not, i.e., if emitters receive carbon permits for free, there will be no costs to pass on to their consumers. Though intuitive, this reasoning is incorrect. Cap-and-trade systems increase energy and product prices because of the scarcity they introduce. Someone must reduce emissions at some cost. That scarcity is what drives the price increases, not the method of permit distribution. Consider a cap-and-trade system in which emission permits are distributed to polluters for free. To reduce greenhouse gases, fewer permits are distributed than would be necessary to support pre-policy consumption. For a polluting company to maintain production levels, it will need either to undertake abatement or purchase a permit from another polluter. In either case, production costs will go up, and it will pass as much of those costs onto its customers as it can. If it is able to increase prices to cover all of the increased costs, then output can be maintained and the costs will be passed on to consumers. Alternatively, it will choose to reduce emissions by cutting back output. Of course, as supply falls, prices will increase. The end result is that "free" emission permits will indeed cause higher prices, and will increase prices by the same amount as if the permits were auctioned. This scenario has played out in existing cap-and-trade systems and is beyond dispute in the economics profession (Barrett, 2008).

An equally forceful reason that economists favor an auction is that it makes available funds that can be used to achieve other goals. Depending on how these revenues are used, they can help to reduce the social cost of climate policy. For the purposes of minimizing the cost of climate policy on the economy and promoting economic growth, some economists favor dedicating the use of revenue from an auction to the reduction of pre-existing distortions. This so called revenue recycling would have significant efficiency advantages compared to free distribution.[4] Others care about the distributional implications of carbon pricing and want to use the revenue to offset regressivity. Still others would address macroeconomic issues such as the fiscal deficit.

The question of who actually pays for the cost of pollution abatement is similar to the question of tax incidence. In a competitive market, the degree that firms are able to charge customers for any change in cost depends on the relative elasticities of demand and supply, but theory clearly indicates that firms will charge customers to the degree they are able to do so. The use of permits constitutes a change in the cost of production. The important idea is that the ability of firms to pass on a change in costs of production does not hinge on how they received the allowances initially.

This analysis applies to markets that are competitive. A substantial portion of the electricity market is not competitive, but instead operates under cost-of-service regulation. The electricity sector emits about 40 percent of the nation's CO_2 emissions, but it is expected to provide two-thirds to three-quarters of emission reductions in the first decades of a carbon policy (Burtraw, 2007).

If regulators set prices to allow firms to recover their costs and costs are calculated on an original cost basis, then if allowances are received for free by regulated electricity generators, then the addition to the cost basis for the purpose of cost recovery is zero. This is one case where

[4] Bovenberg, A.L., & Goulder, L.H. (1996). Optimal Environmental Taxation in the Presence of Other Taxes: General Equilibrium Analyses. American Economic Review, 86, 985–1000. Bovenberg, A. & de Mooij, R. (1994). Environmental Levies and Distortionary Taxation. American Economic Review, 84, 1085-9. Goulder, L.H., Parry, I.W.H., Williams III, R.C., and Burtraw, D. (1999). The Cost-Effectiveness of Alternative Instruments for Environmental Protection in a Second-Best Setting. Journal of Public Economics, 72(3), 329–360.; Parry, I.W.H., Williams, R.C., & Goulder, L.H. (1999). When Can Carbon Abatement Policies Increase Welfare? The Fundamental Role of Distorted Factor Markets. Journal of Environmental Economics and Management, 37(1), 52–84.; Smith, A.E., Ross, M.T., & Montgomery, W.D. (2002). Implications of Trading Implementation Design for Equity-Efficiency Trade-offs in Carbon Permit Allocations. Washington, DC: Charles River Associates.

the benefit of free allocation to emitters or producers can be expected to be passed on to consumers.

In the next section, we discuss the method we will use to identify the incidence effects of different permit approaches.

III. Methodology

Our methodology is based on the approach we employed in Hassett, Mathur and Metcalf (forthcoming, 2009). Our basic approach is to estimate the price response that is likely if prices are allowed to adjust, and then explore the regional variation in the extent to which perfect price adjustment is a reasonable estimate of the impact of a cap-and-trade policy.

For purposes of our analysis, we consider the effect of a carbon price set at a rate of $15 per permit where a permit allows the permit holder to emit one metric ton of carbon dioxide in 2003.[5] We deflate the permit price to keep it constant in year 2005 dollars. Using the CPI deflator, the price we consider is $14.13 in 2003. The incidence calculations require two types of data. First, to assess the impact of the permit price on industry prices and subsequently on prices of consumer goods, we use the Input-Output matrices provided by the U.S. Bureau of Economic Analysis. Second, once we have the predicted price increases for the consumer goods, we need to assess incidence at the household level. For this, we use data from the U.S. Bureau of Labor Statistics Consumer Expenditure Survey for various years. In this section, we explain briefly our use of these two different data sets.

[5] The effect of a different carbon price on consumer goods prices can be approximated by appropriately grossing up (or down) Table 1.

We note at the outset that the policy we consider is economically significant. Energy related emissions of CO_2 were 5,800 million tons in 2003. Given the per unit price of a permit of $15 and ignoring initial reductions in emissions, the policy would raise $82.0 billion in 2003.[6]

We assume that the higher price of carbon applies to coal at the mine mouth, natural gas at the well head, and petroleum products at the refinery. Imported fossil fuels are also subject to the higher carbon price. To begin with, we assume in all cases that the cost of the permit is passed forward to consumers in the form of higher energy prices. Based on work in Metcalf (2007), we estimate that a carbon price of $15 per metric ton of CO_2 applied to average fuel prices in 2005 would nearly double the price of coal, assuming the permit price is fully passed forward. Petroleum products would increase in price by nearly 13 percent and natural gas by just under 7 percent. The permit price is also passed on indirectly to other industries that use these energy sources as inputs. We use the methodology discussed in Fullerton (1995) and Metcalf (1999) to evaluate the effect of such a policy as the cost of carbon emissions is passed through the economy.

We provide a summary of the methodology in the Appendix. The starting point for the analysis is the use of Input-Output matrices available from the Bureau of Economic Analysis. In particular, we use the Summary Make and Use matrices from the I-O tables for 2003. The Make matrix shows how much each industry makes of each commodity and the Use matrix shows how much of each commodity is used by each industry. Using these two matrices for each year, we derive an industry-by-industry transactions matrix which enables us to trace the use of inputs by one industry by all other industries. Various adding-up identities along with assumptions about

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

production and trade allow the accounts to be manipulated to trace through the impact of price changes in one industry on the products of all other industries in the economy.

For each year, we cluster the industry groups provided in the I-O tables into 60 categories. For 2003, we separate out aggregate mining into two separate groups, mining and coal mining using the split provided in the 2002 benchmark I-O files. We do a similar split to break out electricity and natural gas from other utilities.

Once we obtain the effect of the permit cost on prices of consumer goods, we use data from the Consumer Expenditure Survey (CEX) to compute energy prices paid by each household in the survey. The CEX contains data on household income and expenditures for numerous consumption goods. We combine commodities to work with 42 categories of personal consumption items. Having computed the average price increase for each industry using the Input-Output tables from the Bureau of Economic Analysis, we translate those price increases into corresponding price increases for these consumer items. This is also discussed in detail in the Appendix, and we provide a table (Table 1) showing the recorded price increases for each consumer item as a result of the policy.

While for most industries, the use of national input output tables to compute the average price increase is not problematic, this is not true of the electricity sector, where regional variation in fossil fuel usage for electricity generation may lead to very different price impacts across regions. To account for this, we used a separate methodology to compute the regional electricity price increases which is discussed in the Appendix. The computed electricity price increases are shown in Table 3.

IV. Results

To measure the geographic burden of the cost of carbon permits, we group households by region and measure their average cost of carbon usage under a system of carbon permits using weighted averages of the carbon permit cost burdens. Results are shown in Tables 4 (A and B) and 5.[7] Table 4A depicts the case of a cap-and-trade system with auctioned permits. Since firms have to pay for the permits at the auction determined price, there is no difference between the regulated and unregulated electricity regions. For both, the entire cost of the permits is assumed to be fully passed forward to consumers. Variation in the average burden is quite modest in 2003. The maximum difference in the average burden across regions is just under one-half of a percentage point in 2003. It is quite remarkable how small the differences are across the regions given the variation in weather conditions and driving patterns across the regions.

The bulk of the variation across regions in energy costs arises from the direct portion of the carbon burden. A closer look at the data reveals that the high regional burden for the Mountain region for instance is due to the relatively higher consumption of gasoline per household in that region, relative to others. By itself, this would have lead to much larger burdens of the energy costs on consumers in this region. However, the other direct energy consumption items such as natural gas, electricity and home heating oil even out the variation in the burden across regions to some extent. For instance, gas consumption is highest in East North Central, electricity in West South Central and home heating oil in New England. The distribution of these burdens (as a fraction of income) is shown in Table 4B.

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

The indirect results suggest that consumers in different regions of the country buy similar mixes of non-energy commodities. There is little variation across regions, with the highest burden on households in the Mountain region, perhaps driven by greater expenditures on cars and other means of transportation. This region also spends more than the average on car services and airfares. Auto expenditures are also relatively high in the East North Central and West North Central regions. Expenditures on doctors and health care services tend to be high in the Mid-Atlantic, East North and West North Central regions. These have low carbon intensities (see Table 1).

Table 5 reports the total burden assuming permits are freely allocated to energy providers. It assumes that the permit costs are passed forward into higher electricity prices only in states with deregulated electricity. Those states are CA, CT, DE, MA, MD, ME, MT, NH, NJ, NY, RI, TX, and DC. In all other states, the assumption is that state electricity regulators do not allow utilities to pass forward the cost of using freely allocated permits to residential consumers.

The coefficient of variation (ratio of standard deviation to mean across regions) is essentially unchanged. The impact of freely allocated permits and regulators who don't pass forward the price of permits is to shift the regional burden from coal-intensive states to those states that have moved ahead with electricity deregulation. We can see this by looking at the difference in the total burden with and without free allocation. The burden falls by much more in regions such as the South Atlantic, East North Central, East South Central and West North Central regions and much less in the Mid-Atlantic and Pacific Regions.

We also estimate that the consumer burden from the price impacts falls from $82 billion (2003 analysis) to $69 billion. Since the permits are freely allocated, there is no impact on revenues. But the lower burden means that we will obtain fewer reductions in emissions than would occur if permits were auctioned (or if regulators allow the cost of using a freely allocated permit to be passed forward into higher electricity prices).

About 20 percent of electricity related carbon emissions come from states that have deregulated electricity prices. If goods are traded around the country in a uniform way then the impact would be to reduce the indirect burden of the policy by 80 percent of electricity's share of costs in producing non-energy goods and services.

To the extent that goods tend to be consumed more in regions in which they are produced, then the indirect burden will fall more in regions with a larger share of regulated electricity. This increases the regional burden on those states that have moved to deregulation.

To capture this effect, we first had to account for the electricity component of different non-energy goods and services. The methodology for this computation is detailed in Appendix 3. We then applied the national electricity price increase to each consumption item to calculate the indirect burden of the electricity component of the carbon permits. We used the national electricity price increase since the consumed goods need not necessarily have been produced in the region where they are consumed. Therefore it would not be entirely accurate to apply the regional electricity price increase to these consumer items. The distribution of the aggregate indirect burden, under grandfathered permits, is also shown in Table 5. The burden for each region is lower by 4 percent (relative to Table 4) to reflect the lower cost of producing goods and services with regulated electricity.

Hence with regulated electricity markets, the indirect burden of the carbon permits is somewhat lower than under auctioned permits. The differential arises mainly because of the nature of regulation, rather than the nature of permit allocation.

Figure 1 shows graphically the distribution of the burden across regions in a regime with auctioning versus a regime with free allocation.

Our results suggest that free allocation of permits in a market where electricity is regulated in some states and deregulated in others leads to a shifting of the regional burden from the regulated to the deregulated states. In fact, it punishes consumers in those regions of the country that have moved to deregulation. This simply aggravates an existing situation where deregulated states have been facing larger price hikes than regulated states making their consumers worse off. A recent report on the electricity price increases in the deregulated states shows that between 2002 and 2006, Connecticut consumers saw a 53.2% increase in prices, Delaware 33.6%, DC 23.8%, Massachusetts 55.6%, Texas 57.7% etc.[8] Therefore, it is important to take into account the regulation in the electricity market when deciding between free allocation or auctioning of permits.

V. Conclusion

Our results show that the consumer price impacts across regions of auctioning and free allocation are quite different. These differences arise due to the nature of electricity regulation. If permits are auctioned, regulators would allow utilities to pass forward the electricity price increase due to a carbon permit to consumers. However, if permits are freely allocated, this forward shifting will not be allowed to take place, even though utilities would face similar higher costs of electricity production as if the permits had been auctioned.

These results also suggest that the regional differences are not that large; and giving the permits away in a world where state regulators don't allow utilities to pass forward the "cost" of

[8] http://www.usatoday.com/money/industries/energy/2007-08-09-power-prices_N.htm

free permits simply changes the regional variation without reducing it. If anything it punishes consumers in those regions of the country that have moved to deregulation.

References

Armington, Paul S. (1969). "A Theory of Demand for Products Distinguished by Place of Production." International Monetary Fund, Staff Paper # 16:159-176.

Barrett, James. "Arguments for Auctioning Carbon Permits." Redefining Progress. Available at: http://www.e3network.org/Barrett_11.pdf; Accessed XX/XX/2008.

Barrett, James. "The True Cost of Free Pollution Permits: A Redefining Progress Issue Brief." Redefining Progress. February, 2008. www.rprogress.org/publications/2008/True%20Cost%20Issue%20Brief%2002-08.pdf.

Bowles, Ian. Testimony before the Select Committee on Energy Independence and Global Warming. *Cap, Auction, and Trade: Auctions and Revenue Recycling Under Carbon Cap-and-trade*, January 23, 2008. Available at: http://globalwarming.house.gov/tools/assets/files/0323.pdf; Accessed XX/XX/2008

Bovenberg, A.L., & Goulder, L.H. (1996). Optimal Environmental Taxation in the Presence of Other Taxes: General Equilibrium Analyses. American Economic Review, 86, 985–1000.

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

Bovenberg, A. & de Mooij, R. (1994). Environmental Levies and Distortionary Taxation. American Economic Review, 84, 1085-9.

Burtraw, Dallas. Testimony before the U.S. House of Representatives Select Committee on Energy Independence and Global Warming. *Cap, Auction, and Trade: Auctions and Revenue Recycling Under Carbon Cap-and-trade*, January 23, 2008. Available at: http://globalwarming.house.gov/tools/assets/files/0326.pdf; Accessed: XX/XX/2008.

Burtraw, Dallas, Alan Krupnick, Karen Palmer, Anthony Paul, Michael Toman, and Cary Bloyd (YEAR). " Ancillary Benefits of Reduced Air Pollution in the U.S. from Moderate Greenhouse Gas Mitigation policies in the Electricity Sector." *Journal of Environmental Economics and Management* 45(3)650-673.

Energy Information Administration (2006). "Emissions of Greenhouse Gases in the United States 2005." Accessed at.<URL>.

Energy Information Administration (2006). "Energy Market Impacts of Alternative Greenhouse Gas Intensity Reduction Goals." Accessed at <URL>.

Fullerton, Don (1995). "Why Have Separate Environmental Taxes?." NBER, Working paper # 5380.

Goulder, L.H. (1992). "Carbon Tax Design and U.S. Industry Performance." *Tax Policy and the Economy* 6(ISSUE):59-104.

Goulder, L.H., Parry, I.W.H., Williams III, R.C., and Burtraw, D. (1999). The Cost-Effectiveness of Alternative Instruments for Environmental Protection in a Second-Best Setting. Journal of Public Economics, 72(3), 329–360.

Hassett, Kevin A., Aparna Mathur and Gilbert E. Metcalf. "The Incidence of a U.S. Carbon Tax: A Lifetime and Regional Analysis" Energy Journal, Forthcoming 2009.

Hepburn, C., Grubb, M., Neuhoff, K., Matthes, F., and Tse, M., (2006a). Auctioning of EU ETS Phase II Allowances: How and Why? Climate Policy 6(1), 137-160.)
Intergovernmental Panel on Climate Change (2007). "Contribution of Working Group I to the Fourth Assessment Report." Geneva Switzerland: IPCC.
Leontief, W. (1986). *Input-Output Economics*, 2nd Edition. New York: Oxford University Press. pp.XX-XX.
Metcalf, Gilbert E. (1999). "A Distributional Analysis of Green Tax Reforms," *National Tax Journal* 52(4): 655-682.
Metcalf, Gilbert E. (2007). "A Proposal for a U.S. Carbon Tax Swap: An Equitable Tax Reform to Address Global Climate Change," *The Hamilton Project*, *Brookings Institution*. October.
Newell, Richard G. and William A. Pizer. 2003. "Regulating Stock Externalities Under Uncertainty." *Journal of Environmental Economics and Management*, 45, pp. 416-32.
Parry, I.W.H., Williams, R.C., & Goulder, L.H. (1999). When Can Carbon Abatement Policies Increase Welfare? The Fundamental Role of Distorted Factor Markets. Journal of Environmental Economics and Management, 37(1), 52–84.;
Smith, A.E., Ross, M.T., & Montgomery, W.D. (2002). Implications of Trading Implementation Design for Equity-Efficiency Trade-offs in Carbon Permit Allocations. Washington, DC: Charles River Associates.
Stolberg, Sheryl Gay (2007). "Bush Proposes Goal to Reduce Greenhouse Gas Emissions." *New York Times*, June 1, 2007.
"Voters Guide to the Climate Crisis Election." The Sierra Club Canada. September, 2008. Available at: http://www.sierraclub.ca/national/vote-canada/2008/voters-guide-climate-crisis-election.pdf. Accessed XX/XX/2008.

Appendix

1. Using the Input-Output Accounts[9]

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

Tracing price changes through the economy on the basis of Input-Output accounts dates back to work by Leontief (1986). The model makes a number of important assumptions, the most important of which are (1) goods are produced and sold in a perfectly competitive environment such that all factor price increases are passed forward to consumers, (2) domestic and foreign goods are sufficiently different so that the price of domestic goods can adjust following changes in factor prices (Armington, 1969) and (3) input coefficients (the amount of industry *i* used in the production of industry *j*) are constant. Thus, input substitution is not allowed as factor prices

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

change. This last assumption means that price responses are only approximate as they don't allow for product mix changes as relative prices change. In effect, the Input-Output accounts can be used to trace first-order price effects through the economy.

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

$$
\begin{aligned}
&x_{11}p_1 + x_{12}p_1 + ... + x_{1N}p_1 + d_1p_1 = x_1p_1 \\
&x_{21}p_2 + x_{22}p_2 + ... + x_{2N}p_2 + d_2p_2 = x_2p_2 \\
&. \\
&. \\
&. \\
&x_{N1}p_N + x_{N2}p_N + ... + x_{NN}p_N + d_Np_N = x_Np_N
\end{aligned}
\qquad [1]
$$

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

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

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

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

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

These equations can be expressed in matrix notation as

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

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

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

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

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

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

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

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

We regrouped industries in the Input-Output Accounts into 60 industry groupings. For 2003 , a separate industry for coal mining was created out of the industry group including all mining. This was done using the split between mining and coal provided in the 1994 benchmark Input-Output accounts.

Permit prices are computed as the ratio of the required revenue from the industry divided by the value of output from that industry. For the carbon permit, the permit price for coal equals

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

where *R* is the total revenue from the carbon permits and α_C the share of the revenue collected from the coal industry (industry 4). Based on carbon emissions in 2003, the share of the revenues coming from the coal industry is 0.361. The permit prices for oil and natural gas are computed in a similar manner.

Equation [6] indicates how price changes in response to the industry level permit costs. We next have to allocate the price responses to consumer goods. The Input-Output accounts provide this information by means of the Personal Consumption Expenditures (PCE) Bridge tables for each year that show how much of each consumer item is produced in each industry. Let *Z* be an *NxM* matrix, where z_{ij} represents the proportion of consumer good *j* $(j=1,..,M)$

derived from industry *i (i=1,….,N)*. The columns of *Z* sum to 1. If P_c is a vector of consumer goods prices (an *Mx1* vector), then

$$P_c = Z'P_{1.} \qquad [8]$$

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

2. Methodology for Computing Regional Electricity Price Increases

For most industries, the use of national rather than regional input-output tables to model the impact of carbon permits will make little difference to the analysis. However, for the electricity industry, the price changes due to carbon permits could vary considerably from region to region. In states with a lot of coal fired generation, costs will go up by more than those where generation is largely gas-fired or hydro powered. To account for this in our analysis, we obtained additional data on electricity generation, emissions and pricing from Dallas Burtraw et al. (2002). These data are available for the 13 NERC sub regions for various years.[10] These regions cover the entire nation, except the states of Hawaii and Alaska. For our study, we used the years closest to our years of analysis. For 2003, we used data from 2004. The price data were inflation adjusted.

The data show the extent of carbon emissions involved in electricity generation. To obtain the regional price impacts, we first transformed the carbon emissions data for each region into carbon dioxide emissions by multiplying by 44/12. Then we applied the permit prices for 2003 to the emissions for 2003 for each region. For instance, in 2003 the total CO_2 emissions for

[10] These are the 13 NERC sub regions as they were defined in 1999: ECAR, ERCOT, MAAC, MAIN, MAPP, NY, NE, FRCC, STV, SPP, NWP, RA, CNV. Recently, some of the regions have been combined bringing the total to about 10. For a map of the different regions, see http://www.rff.org/Documents/RFF-RPT-haiku.pdf (Page 2)

the ECAR region covering Michigan, Indiana, Ohio, West Virginia and Kentucky were 431.76 MMT. To this, we applied the CO2 permit price of $14.13 per metric ton of CO_2, to yield total carbon permit revenue for this region of $6100.76 million. The total electricity generation for the ECAR region for that year was 524.50 million MWH, yielding revenue per MWH as $11.63. As a fraction of the residential price of electricity that year, $67.60, we conclude that the carbon permits would increase the price of electricity for residential consumers by more than 20 percent.[11] We did this for each region (and each year) to obtain the corresponding price increase for that region. Table 3 shows the computed electricity price increases for each of the NERC sub regions as a result of the carbon permits.

Once we obtained these price increases, we then computed the carbon permit cost for each individual in the CEX by allocating to them the electricity price increase for the region that they belonged to, along with the national price increases for all the other industries.[12] The incidence calculations using this methodology show the cost of carbon permits to be slightly more regressive than when we used the national electricity price increases.

3. Incidence of the Electricity Share of the Carbon Permits on Indirect Consumption

First, from the Use matrix, we calculated the share of electricity used in producing the output of different industries. For instance, electricity use for Farms is 1.5% of total output. Next, we applied the derived electricity use for all industries to the total output of commodities produced by the different industries. For instance, if Farms use 1.5% electricity in producing total output, then every commodity that they produce on average uses 1.5% electricity. Therefore

[11] The electricity price impacts were rescaled to match the national electricity price increase that we obtained from our input-output analysis.

[12] Since we have missing state identifiers for some observations in the CEX sample, we were unable to allocate the regional price impacts to these observations. In this case, the electricity price increase was assumed to be the same as the national price increase (Table 1).

the derived electricity shares for different industries from the Use table can be applied to every commodity that that industry helps produce. Doing this for every industry, we obtained the total electricity that goes into making different commodities. These shares are shown in Table 4.

These shares were then applied to all the CEX consumption items (in the z matrix) that the commodities help produce using the same logic as above. This gives us the total value of electricity used in the production of different consumption items.

To calculate the indirect burden, we then multiplied the different consumption items by their electricity share. For instance, for “foodhome”, the electricity share in total value is 0.9%. For food out, it’s 1.3% etc. Finally, we applied the national electricity price (12.55%) increase that we had calculated earlier to this indirect calculation.

Once we had the indirect burden of electricity, we took this as a share of the total indirect burden. The ratio was 20%. Since 80% of electricity comes from regulated utilities, if they can't raise rates, then the electricity price only goes up by 20% of what it would otherwise go up by. 20% of 20% is 4 percent. We therefore lowered the indirect burden by 4 percent (relative to Tables 4) for each region to reflect the lower cost of producing goods and services with regulated electricity.

Table 1: Consumer Goods Price Increases as a Result of the Carbon Permits

	CEX categories	**2003**
1	food at home	0.70%
2	food at restaurants	0.58%
3	food at work	0.86%
4	tobacco	0.67%
5	alcohol at home	0.58%
6	alcohol on premises	0.58%
7	clothes	0.40%
8	clothing services	0.41%
9	jewelry	0.43%
10	toiletries	0.72%
11	health and beauty	0.42%
12	tenant occupied non-farm dwellings	0.31%
13	other dwelling rentals	0.42%
14	furnishings	0.55%
15	household supplies	0.71%
16	electricity	12.55%
17	natural gas	12.28%
18	water	0.63%
19	home heating oil	9.56%
20	telephone	0.26%
21	domestic services	0.49%
22	health	0.39%
23	business services	0.50%
24	life insurance	0.31%
25	automobile purchases	0.90%
26	automobile parts	0.65%
27	automobile services	0.40%
28	gasoline	7.73%
29	tolls	0.64%
30	automobile insurance	0.31%
31	mass transit	0.90%
32	other transit	0.62%
33	air transportation	1.86%
34	books	0.34%
35	magazines	0.49%
36	recreation and sports equipment	0.42%
37	other recreation services	0.51%
38	gambling	0.31%
39	higher education	0.30%
40	nursery, primary, and secondary education	0.34%
41	other education services	0.30%
42	charity	0.41%

Notes:
1. Values for alcohol have been set equal to the value for food at restaurants
2. These price increases are calculated using a $15 per unit permit price

Table 2: Regional Electricity Price Increases Due to Carbon Permits

NERC Region	**States Covered**	**2003**
ECAR	Michigan, Indiana, Ohio, West Virginia, Kentucky	20.86%
ERCOT	Texas	14.41%
MAAC	Maryland, DC, Delaware, New Jersey, Pennsylvania	9.40%
MAIN	Illinois, Wisconsin, Missouri*	16.12%
MAPP	Minnesota, Iowa, Nebraska, South Dakota, North Dakota	21.67%
NY	New York	4.23%
NE	Vermont, New Hampshire, Maine, Massachusetts, Connecticut, Rhode Island	5.01%
FRCC	Florida	11.12%
STV	Tennessee, Alabama, Georgia, South Carolina, North Carolina, Virginia, Mississippi	14.52%
SPP	Kansas, Missouri*, Oklahoma, Arkansas, Louisiana	13.59%
NWP	Washington, Oregon, Idaho, Utah, Montana	9.11%
RA	Arizona, New Mexico, Colorado, Wyoming	12.82%
CNV	California, Nevada	5.17%

* Missouri is a part of MAIN and SPP. We have approximated this by allocating half of the total electricity consumption for the state to each of the two regions.

Table 3: Electricity Share of Energy and Non-Energy Goods and Services

	CEX categories	Electricity Share in Total Value
1	food at home	0.97%
2	food at restaurants	1.39%
3	food at work	0.96%
4	tobacco	0.93%
5	alcohol at home	1.39%
6	alcohol on premises	1.39%
7	clothes	0.50%
8	clothing services	1.41%
9	jewelry	0.64%
10	toiletries	0.92%
11	health and beauty	0.97%
12	tenant occupied non-farm dwellings	0.80%
13	other dwelling rentals	1.70%
14	furnishings	0.71%
15	household supplies	1.07%
16	electricity	0.29%
17	natural gas	0.29%
18	water	0.89%
19	home heating oil	0.60%
20	telephone	0.33%
21	domestic services	0.69%
22	health	0.50%
23	business services	0.80%
24	life insurance	0.55%
25	automobile purchases	0.49%
26	automobile parts	0.61%
27	automobile services	0.80%
28	gasoline	0.59%
29	tolls	1.36%
30	automobile insurance	0.80%
31	mass transit	0.47%
32	other transit	0.44%
33	air transportation	0.11%
34	books	0.38%
35	magazines	0.28%
36	recreation and sports equipment	0.50%
37	other recreation services	0.70%
38	gambling	0.91%
39	higher education	0.69%
40	nursery, primary, and secondary education	0.67%
41	other education services	0.63%
42	charity	0.71%

Notes:

1. Values for alcohol have been set equal to the value for food at restaurants

Table 4A: Consumer Burden of Cap-and-Trade: 100 % Auction

Region	2003		
	Direct	Indirect	Total
New England	0.73	0.76	1.47
Mid Atlantic	0.75	0.76	1.50
South Atlantic	0.87	0.77	1.62
East South Central	1.19	0.75	1.92
East North Central	1.05	0.76	1.79
West North Central	0.84	0.77	1.59
West South Central	1.08	0.78	1.84
Mountain	0.85	0.91	1.73
Pacific	0.74	0.81	1.54

Source: Authors' calculations. The table reports the within region average ratio of carbon permit burdens to income. Regions are defined in footnote 9.

Table 4B: Distribution of Direct Burden, by Component

Region	2003			
	Gas	Home Fuel	Gasoline	Electricity
New England	0.20	0.15	0.28	0.13
Mid Atlantic	0.23	0.09	0.26	0.18
South Atlantic	0.09	0.02	0.32	0.47
East South Central	0.21	0.02	0.39	0.61
East North Central	0.29	0.01	0.31	0.48
West North Central	0.19	0.01	0.30	0.37
West South Central	0.15	0.02	0.37	0.58
Mountain	0.15	0.004	0.41	0.31
Pacific	0.14	0.01	0.40	0.20

Source: Authors' calculations. The table reports the within region average ratio of carbon permit burdens for each component to income. Regions are defined in footnote 9.

Table 5:Consumer Burden of Cap-and-trade: Free Allocation (Grandfathering)

Region	2003		
	Direct	Indirect	Total
New England	0.67	0.73	1.40
Mid Atlantic	0.67	0.73	1.40
South Atlantic	0.47	0.74	1.21
East South Central	0.61	0.72	1.33
East North Central	0.60	0.73	1.33
West North Central	0.49	0.74	1.23
West South Central	0.93	0.75	1.68
Mountain	0.56	0.87	1.43
Pacific	0.63	0.78	1.41

Source: Authors' calculations. The table reports the within region average ratio of carbon permit burdens to income. Regions are defined in footnote 9.

Figure 1: Distribution of Burden Across Regions