Distribution and Climate Change Policies

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Prepared for:
E. Cerda and X. Labandiera (Eds)
Climate Change Policies: Global Challenges and Future Prospects

DRAFT: May 1, 2010

Abstract: International agreements for cutting greenhouse gas emissions inevitably imply the development of domestic policies and regulations to move individuals and firms to emit less. From a political point of view, a major dimension of any such policy is the distributional consequences – who ultimately bears the burden (cost) of domestic regulations on greenhouse gas emissions. A number of authors from around the world have examined this question, primarily using input-output tables on various economies. We review such studies and provide an example analysis for the US economy, based on the 1997 input-output tables and the 2003 Consumer Expenditure Survey.

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1 Grainger acknowledges financial support from the National Science Foundation, grant No. 0114437.
I. INTRODUCTION

The international community has focused on efforts to reach agreement on a successor to the Kyoto Protocol, involving reductions in greenhouse gas emissions globally. However, whatever agreement is reached internationally, it is very likely that it will involve obligations and commitments from individual signatory countries. Each of those countries will need to devise regulatory mechanisms to apply to polluting firms and individuals in order to assure that national obligations are met. As is well known, there are many ways in which a national target for emissions reductions can be translated into national regulations. Cap and trade is currently a popular approach, though command-and-control regulations continue to play a major role in many countries. Command-and-control may be performance based or technology based. A carbon tax is frequently discussed as a possible policy option. In reality, each country will probably adopt a mixture of these approaches.

In Europe, there is an EU-wide cap and trade system covering member countries – the EU Emissions Trading System (ETS) (eg, see Ellerman and Buchner, 2007). Each country also has a variety of command-and-control measures and some emissions taxes covering the remainder of the economy. In the US, Congress is currently considering a variety of different approaches to regulating greenhouse gas emissions, although it is unclear when legislation will be enacted. Although there are proposals for a national tax on carbon, most proposed policies rely on a national cap and trade program for limiting and reducing carbon emissions (supplemented by a variety of other programs). Like a carbon tax, a cap and trade program for greenhouse gas emissions has the effect of
inducing a price on carbon; this means that for the first time in the U.S. a price will be placed on each ton of CO₂ emitted.

Thus many approaches to regulating carbon emissions within a country involve inducing a price on carbon or CO₂. A fundamental political question associated with carbon regulation, whatever form it takes, is who ultimately pays the cost of the regulation? Ultimately, the costs of such regulations are borne by consumers, shareholders, and workers, though changes in consumer prices, stock returns, wages and other returns to factors of production.² Even though an electric utility may write a big check to the government to buy emissions allowances, they may be able to pass that cost on to electricity consumers. And some consumers may be firms which in turn may or may not be able to pass costs on. How these costs are distributed among these groups and among income classes is a great concern to policymakers and the general public.³

While an emissions reduction can be achieved in many ways, each method has different costs and consequences. In the case of an emissions tax, emitters obviously face the additional cost associated with the payment of the tax. Of course, this is not a net cost to society since the cost of a tax payment is exactly equal to the gain to the government. If a permit is initially auctioned by the government, the same transfer occurs.⁴ There may, in addition, be costs or inefficiencies generated by the interaction of the tax or permit payment with other taxes, such as an income tax (Goulder, Parry, and Burtraw,

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² This is true regardless of statutory incidence; that is, the costs of reducing emissions are ultimately passed on, regardless of the point of compliance.
³ In addition to the distribution across income groups, there may be variation in the spatial distribution of costs and benefits (Burtraw, Sweeney, and Walls, 2008).
⁴ In the case of a grandfathered cap-and-trade program, scarcity rents are created, which can actually benefit shareholders. The distributional impact of a cap-and-trade program depends critically on the allocation method (i.e. auctioning vs. grandfathering). See Parry, 2004.
In economics terminology, who ultimately bears the cost of a regulation, and in what amount, is termed the *incidence* of the regulation.

In this paper we review a number of studies, from around the world, that have examined the question of the incidence of carbon regulation. Although the methodologies and estimates vary from country to country, there is a general pattern: carbon regulations range from modestly regressive or neutral. In just one case (China) study authors find a carbon tax progressive.\(^5\)

Following our review of other studies, and as an example of how these studies are typically conducted, we examine US data in somewhat more detail, computing the incidence of a $15/ton tax on a tonne of CO\(_2\). In our analysis, we use 2003 consumption data, emissions factors and 1997 data on the structure of the US economy to calculate how a price on carbon is ultimately distributed across income groups. Our estimates are admittedly first order; we assume all costs are passed on to consumers, with workers and capital owners bearing none of the costs. Furthermore, we only calculate the direct burden of the price on carbon, not taking into account consumer and firm response to a higher carbon price in terms of reductions in carbon emissions. Finally, we do not examine the incidence of the benefit of a price on carbon, in terms of the benefits of a marginal reduction in climate change.

II. BACKGROUND

Many studies of the incidence of environmental regulations rely on input-output (IO) tables of a nation’s economy (see Carraro, 2000; Speck, 1999). These IO tables are

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\(^5\) A similar finding would likely prevail in other developing countries where poor households consume little carbon.
generated by national income and product accounts, which are maintained by all
developed countries and many developing countries.

A. United States

A number of authors have studied the incidence of a price on carbon in the US;
previous studies have generally found that carbon taxes and tradable emissions permits
are regressive (see Grainger and Kolstad, 2010). Metcalf (1999) studies the incidence of
green tax reforms, including a carbon tax. Using household-level Consumer Expenditure
Survey data and input-output accounts, he finds that a carbon tax is regressive, but
targeted tax cuts can make the policy distributionally neutral (also see Metcalf, 2009).
Parry (2004) uses an analytical model to show that a cap-and-trade program for carbon
emissions is regressive. Furthermore, he argues that even if the poor do not have large
budget shares for carbon-intensive goods a cap-and-trade program with grandfathered
permits can be quite regressive. In a recent paper, Hassett et al (2009) show that it is fuel
and electricity use that drives the regressivity of a carbon tax.6

B. Europe

Brännlund and Nördstrom (2004) use the Swedish Household Expenditure Survey
and data from Swedish National Accounts to estimate demand elasticities by income
quintile. They then simulate a carbon tax combined as well as two revenue recycling
schemes. The first recycles the carbon tax revenue into a reduction in the value-added
tax, and the second is a targeted reduction in the value-added tax on public transportation.

6 Hassett et al (2009) and Grainger and Kolstad (2010) are similar in many but not all respects. They were
apparently developed independently.
They find that a carbon tax is regressive, and that targeting the revenue recycling toward a reduction in the transportation value-added tax leads to the largest decrease in regressivity. Furthermore, they find that regional differences are important, as sparsely-populated areas bear a larger burden than urban areas.

Kerkhof, et al. (2008) use household consumption data and emissions estimates from an input-output model to compare the distributional effects of a CO$_2$ tax to a tax on multiple GHGs. They find that a tax on all GHGs would be less regressive than a tax on only CO$_2$ in the Netherlands.

In Italy, Tiezzi (2005) argues that the carbon tax implemented in 1999 is likely not regressive. Using microdata from 1985 to 1996, Tiezzi estimates an Almost Ideal Demand System (Deaton and Muelbauer, 1980) and calculates welfare changes by income group. Tiezzi argues that, accounting for demand responses, a carbon tax in Italy is actually not regressive. One potential reason for this discrepancy is that the carbon tax studied mainly affects fuel prices, and demand for transportation fuel in Italy is much more elastic than in the United States (e.g. West and Williams, 2004).

Labandeira and Labeaga (1999) use a two-stage approach to study the effects of a carbon tax in Spain. They estimate carbon content for consumption goods using an input-output approach, an Almost Ideal Demand System was estimated to obtain behavioral responses to product price changes. They find that the impact on emissions in the short run would be small, and that the distribution of the carbon tax burden would be approximately neutral. Their demand elasticities are estimated by income group, and their distributional estimates are relative to current expenditures.
Denmark implemented a carbon tax on households in 1992 and on businesses in 1993. Wier, et al. (2005) study the distributional effects of the Danish CO$_2$ tax using household consumption data. They assume that costs are passed through fully to consumers and estimate that the lowest income decile paid 0.8% of annual net income on the tax, while the highest decile paid less than 0.3%. Using expenditures as a proxy for lifetime income, they find that the policy is less regressive.

In Ireland, Callan, et al. (2009) study the direct burden of a carbon tax. That is, they include only direct emissions by consumers and ignore indirect burden (i.e. the pass-through from other consumption goods). They differentiate between the EU emissions trading scheme (EU ETS) and a policy that would combine the EU ETS with a carbon tax on other carbon dioxide emissions not included by the existing policy. They argue that the EU ETS has the smallest distributional effects, and that adding a carbon tax leads to a slightly more regressive scheme. After revenue recycling the effects can be made distributionally neutral or even progressive.

C. South Africa

Van Heerden, et al. (2006) use a CGE model of South Africa to study the effects of four different types of climate policies, all of which are set up to generate the same reduction in carbon emissions: a tax on greenhouse gas emissions, a fuel tax, a tax on electricity, and an energy tax. They consider various revenue recycling schemes, but they find a “triple dividend” (a reduction in emissions, GDP growth, and a reduction in poverty) when tax revenues are recycled into a reduction in food prices.
D. Asia

In contrast to most studies from developed countries, Brenner, et al. (2007) find that a carbon tax in China would actually be *progressive*. This is driven primarily by differences in consumption patterns between poor rural households and wealthy urban households in China. They find that recycling the revenues through directed monetary transfers could make the policy even more progressive.

Fullerton and Heutel (2007b) study the effects of a Japanese carbon tax using a two sector general equilibrium model. Their contribution is to generate analytical results in the spirit of Harberger, which they calibrate to the Japanese economy. The model generates predictions about the relative burdens that will be borne by capital versus labor, and the calibrated model suggests that the share could be larger for either input.

E. New Zealand and Australia

Cornwell and Creedy (1997) study the effects of a carbon tax in Australia using a linear expenditure system. They calculate compensating and equivalent variations and look at compensation schemes to offset adverse distributional effects by using a social welfare function based on equivalent incomes.

In a similar study, Creedy and Sleeman (2004) study the effects of a carbon tax of varying amounts on different demographic groups in New Zealand. They use an input-output approach to determine emissions by product group and estimate a system of demand equations using microdata. They find that a carbon tax is slightly more regressive among smokers than nonsmokers.
III. An Application to the US

As stated above, many of the analyses of the incidence of a carbon price use a similar methodology. Thus it is instructive to go through an example for the US, based on Grainger and Kolstad (2010).

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

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

A much more modest approach would fix economic activities at their current level and apply a price of carbon, assuming that there is no behavioral or secondary price

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7 Metcalf, et al (2008) use a calibrated model to estimate the incidence of alternative greenhouse gas policies under various assumptions about forward and backward shifting. Their results depend on various factors, including the breadth of the tax, whether other countries act, and short- vs. long-run effects. Other studies taking a similar approach include Shammin and Bullard (2009) for the US, and a number of non-US applications, Kerkhof et al (2008), Wier et al (2005) and Labandeira and Labeaga (1999).
response in the economy—the carbon price is passed through in its entirety to consumers and consumers do not adjust behavior. Such an analysis will overstate the burden on consumers since in actuality factors of production will bear some of the cost and, further, a higher price of carbon will induce actions to reduce carbon consumption and thus the household’s burden. However, modeling behavioral responses and all general equilibrium adjustments would require heroic assumptions about the structure of the economy and price response by income groups for each consumption good in the analysis. Instead, we remain agnostic about where, and to what extent, such adjustments will occur, recognizing that our estimates are likely an upper bound on the regressivity of an actual policy. Our results would be most valid if commodity demands were inelastic, or if all industries use inputs in fixed proportions, because this would not lead to changes in relative factor demands and prices.

In our analysis, we examine the effects of a price of $15 per ton of carbon dioxide, equivalent to approximately $55 per ton of carbon.\(^8\) Although there is a great deal of uncertainty regarding what price of carbon may emerge from the current policy debate in the US, this figure is in the range of the allowance prices estimated by the EPA for the Waxman-Markey proposal (EPA, 2009). It should also be noted that, in our analysis, the relative burdens across income groups are independent of our choice of a price.

A. Carbon and Consumption Data

\(^8\) The conversion between units of CO\(_2\) and units of carbon follows from the ratio of the atomic mass of a carbon dioxide molecule to the atomic mass of a carbon atom (44:12). Therefore, a $15 tax per ton of carbon dioxide is equivalent to a tax on carbon of $55 per ton.
We begin with data from the 2003 Consumer Expenditure Survey (CES) from the Bureau of Labor Statistics. The CES provides annual consumption patterns for households in each income quintile in the U.S. for a variety of products and services. For each income group, we can then calculate the average household-level expenditure for shelter, electricity, gasoline, vehicles, food, clothing, insurance, and a host of other goods and services. A breakdown of the per-capita expenditures of some of the goods and services is shown in Table 1. For example, according to the CES, an average household in the lowest income quintile spent roughly $527 in 2003 on gasoline and motor oil, which was about 4.8% of their net annual income, whereas the corresponding percentage for a household in the wealthiest quintile is only 1.7%.

Income measurement in the low end of the distribution is poor in the CES, as students, retirees, and transitionally unemployed people are included in this category. As a result, the households with the lowest income in the CES have, on average, an extremely high expenditure to income ratio. Therefore we do not include households with income less than $7,500 in our analysis. Including these households leads to a more regressive calculation of the incidence of a price on carbon emissions.

<table>
<thead>
<tr>
<th>quintile 1</th>
<th>quintile 2</th>
<th>quintile 3</th>
<th>quintile 4</th>
<th>quintile 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Household Income After Tax</td>
<td>$10,879</td>
<td>$19,982</td>
<td>$34,007</td>
<td>$54,546</td>
</tr>
<tr>
<td>Income Range</td>
<td>$7,500-$14,761</td>
<td>$14,762-$28,594</td>
<td>$28,595-$47,801</td>
<td>$47,802-$77,670</td>
</tr>
<tr>
<td>Mean Number Persons/Household</td>
<td>1.8</td>
<td>2.3</td>
<td>2.6</td>
<td>2.9</td>
</tr>
</tbody>
</table>

**Mean Household Expenditures:**

9 $7,500 corresponds to around the 5.8th percentile. To be consistent with other studies using these data, as well as studies of the incidence of other taxes, we do not alter our definitions of income quintiles to account for dropping these households.
<table>
<thead>
<tr>
<th>Category</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food &amp; Alcohol</td>
<td>2,708</td>
<td>3,534</td>
<td>4,635</td>
<td>5,943</td>
<td>8,172</td>
</tr>
<tr>
<td>Shelter</td>
<td>4,613</td>
<td>8,570</td>
<td>14,049</td>
<td>17,800</td>
<td>35,486</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>259</td>
<td>258</td>
<td>308</td>
<td>409</td>
<td>567</td>
</tr>
<tr>
<td>Electricity</td>
<td>620</td>
<td>761</td>
<td>912</td>
<td>1,031</td>
<td>1,306</td>
</tr>
<tr>
<td>Fuel Oil &amp; Other Fuel</td>
<td>60</td>
<td>71</td>
<td>92</td>
<td>85</td>
<td>151</td>
</tr>
<tr>
<td>Telephone Services</td>
<td>506</td>
<td>635</td>
<td>833</td>
<td>1,020</td>
<td>1,342</td>
</tr>
<tr>
<td>Water &amp; Other Public Services</td>
<td>177</td>
<td>223</td>
<td>295</td>
<td>362</td>
<td>495</td>
</tr>
<tr>
<td>Household Operations, Supplies,</td>
<td>1,440</td>
<td>2,076</td>
<td>2,907</td>
<td>4,223</td>
<td>7,648</td>
</tr>
<tr>
<td>Furnishings, Equipment &amp; Apparel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation &amp; Vehicle Exp.</td>
<td>1,823</td>
<td>3,306</td>
<td>5,020</td>
<td>7,874</td>
<td>10,955</td>
</tr>
<tr>
<td>Gasoline &amp; Motor Oil</td>
<td>527</td>
<td>861</td>
<td>1,223</td>
<td>1,574</td>
<td>1,940</td>
</tr>
<tr>
<td>Healthcare</td>
<td>1,500</td>
<td>1,723</td>
<td>2,176</td>
<td>2,388</td>
<td>3,264</td>
</tr>
<tr>
<td>Other Expenditures</td>
<td>1,597</td>
<td>2,609</td>
<td>4,230</td>
<td>6,196</td>
<td>10,940</td>
</tr>
<tr>
<td><strong>Total Household Expenditures</strong></td>
<td>15,829</td>
<td>24,626</td>
<td>36,679</td>
<td>48,905</td>
<td>82,266</td>
</tr>
</tbody>
</table>

*Source:* Consumer Expenditure Survey (2003). The households with the lowest income levels (<$7,500) are dropped from the lowest quintile for reasons described in the text. Figures are annual household expenditures in 2003 dollars. The less emissions-intensive consumption categories were aggregated here for exposition only; all subcategories were used in the estimates produced in this paper.

### B. Using An Input-Output Table for Incidence

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

The standard input-output tables, produced for the US by the US Bureau of Economic Analysis (BEA), divide the economy into a large number of industrial sectors. The IO table for a particular year indicates for each sector $j$, how much was purchased from each of the other sectors $i=1,2,…,n$ to produce $1$ of output for sector $j$. It is thus a straightforward calculation to translate a vector of final demands in these industrial categories into total production in each of the categories, satisfying both final demand and intermediate demand. This same technique can be used to calculate how a tax on direct carbon emissions in each sector will ripple through the economy to increase the
price of final consumption for the sector, assuming no steps are taken to substitute away from carbon intensive goods.

More formally, let $A$ be an $n \times n$ input-output matrix, where the coefficients $a_{ij}$ represent the inputs (in dollars) from sector $j$ necessary to produce $1$ worth of output for sector $i$. Let $c$ be a vector of final demands for goods in each industry (in dollars), and let $x$ be a vector of total output (in dollars) for the various sectors of the economy. Leontief (1986) formulated this input-output model such that

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

(1)

where $I$ is the identity matrix.$^{10}$

A straightforward use of this traditional input output model is to calculate the emissions associated with production of final consumption goods, accounting for emissions of all primary and intermediate processes necessary to produce final goods (Leontief, 1970; Hendrickson, et al, 2006). Let $g$ be a vector with the $j^{th}$ element equal to the greenhouse gas emissions (in CO$_2$) per $1$ of output for that sector. For a consumption vector $c$ (in dollars), the resulting total emissions $e$ (a scalar) are then given by

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

(2)

This method essentially traces emissions through an economy and provides us with estimates of emissions attributable to the consumption of final goods. Now if a tax of $\tau$ dollars per ton of emissions of CO$_2$ (equivalent) were levied, the total tax paid, associated with a consumption vector $c$, would be $\tau e$.

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$^{10}$ We assume that $(I-A)$ is invertible; in practice, this assumption generally holds true.
The input-output matrix for the US is regularly compiled and published by the US Department of Commerce, Bureau of Economic Analysis (BEA). The vector of emissions factors, \( g \), is not as readily available, though can be estimated from available data. Researchers at Carnegie-Mellon University (Hendrickson et al., 2006) have estimated these emissions factors and developed an easily used version of the 1997 US input output tables to allow the tracing of greenhouse gas emissions throughout the economy.\(^{11}\)

C. Results

Using the Carnegie Mellon version of the US input-output model (the “CMU Model”), we obtain the amount of emissions (CO\(_2\)) associated with each of the 491 sectors of input-output accounts.

Table 2 shows the top 20 sectors in terms of CO\(_2\) emissions. Assuming a $15 CO\(_2\) price in 2009, the final column shows the percent cost increase for that sector implied by the model. Considering the large number of sectors in the economy, there are remarkably few sectors that see substantial cost increases (though what constitutes substantial is a subjective judgment). What is relevant to these specific industries is who ultimately bears the burden: consumers, workers or owners.

Then, using data from the BEA, we match sectors of the IO model to the Personal Consumption Expenditure (PCE) categories, which are then comparable to the categories

\(^{11}\) The CMU model (the Economic Input Output Life Cycle Assessment (EIO LCA) model) is available online at [http://www.eiolea.net/about.html](http://www.eiolea.net/about.html).
in the CES version developed by the National Bureau of Economic Research (NBER) and which are used in the analysis.\textsuperscript{12}

In practice, for any product category, the CMU model tells us how many tons of greenhouse gases are emitted to create $1$ Million worth of output. Because the process is linear, we can then calculate the number of tons of CO\textsubscript{2} and total greenhouse gases (in terms of CO\textsubscript{2}) that were emitted so that an average consumer in each income quintile could purchase his or her bundle of goods and services.\textsuperscript{13} It is then a straightforward calculation to determine how much the average consumer in each income quintile would pay for a given price on carbon induced by a tax or permit price.

The total household emissions were calculated for each household’s consumption bundle by simply adding the emissions for each product in the bundle for that year. Annual average emissions estimates are shown for households in each income quintile in Table 3. As shown in the table, the households from the poorest income quintile consumed goods and services associated with 21.7 metric tons of CO\textsubscript{2} in 2003, while the average household in the top quintile was responsible for about emissions of 76 tons of CO\textsubscript{2}.

\begin{table}[h]
\centering
\caption{Sector-Level Emissions}
\begin{tabular}{llll}
\hline
Sector & Sector Description & Annual CO\textsubscript{2} & Cost Increase \\
\hline
\end{tabular}
\end{table}

\textsuperscript{12} The NBER CES extracts, available online, are condensed to 109 categories (including income sources) of the CES. This allows the categories to be more comparable to the PCE categories.

\textsuperscript{13} Emissions resulting from combustion in motor vehicles and the use of natural gas are not included in the CMU Model, as the model only calculates the greenhouse gases associated with the production and distribution of these goods. We add the emissions from using gasoline and natural gas using the standard EPA estimates, imputed by using the average price for these fuels in 2006 to determine the amount purchased. There is evidence that poorer households drive older, less fuel-efficient cars, which would imply that emissions per gallon of gasoline for these income groups could actually be higher (West and Williams, 2004). We assume that each income quintile has similar driving habits and vehicles, though differences across income groups would lead to slightly different incidence estimates. In this case, it would increase the regressivity, though accounting for behavioral responses by income group would lead to a greater decrease in quantity demanded for low-income groups, which would have an offsetting effect.
### Table 3: Estimated 2003 Household CO₂ Emissions by Income Quintile

<table>
<thead>
<tr>
<th>Quintile</th>
<th>Quintile 1</th>
<th>Quintile 2</th>
<th>Quintile 3</th>
<th>Quintile 4</th>
<th>Quintile 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (After Tax) Income</td>
<td>$10,879</td>
<td>$19,982</td>
<td>$34,007</td>
<td>$54,546</td>
<td>$110,878</td>
</tr>
<tr>
<td>Mean Household Size</td>
<td>1.8</td>
<td>2.3</td>
<td>2.6</td>
<td>2.9</td>
<td>3.1</td>
</tr>
</tbody>
</table>

**Mean Household Emissions (metric tons of CO₂ per household)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Quintile 1</th>
<th>Quintile 2</th>
<th>Quintile 3</th>
<th>Quintile 4</th>
<th>Quintile 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food &amp; Alcohol</td>
<td>2.19</td>
<td>2.83</td>
<td>3.69</td>
<td>4.67</td>
<td>6.28</td>
</tr>
<tr>
<td>Shelter</td>
<td>1.87</td>
<td>3.68</td>
<td>6.04</td>
<td>7.32</td>
<td>14.74</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>1.99</td>
<td>1.97</td>
<td>2.35</td>
<td>3.13</td>
<td>4.34</td>
</tr>
<tr>
<td>Electricity</td>
<td>7.26</td>
<td>8.91</td>
<td>10.68</td>
<td>12.08</td>
<td>15.30</td>
</tr>
<tr>
<td>Fuel Oil &amp; Other Fuel</td>
<td>0.68</td>
<td>0.81</td>
<td>1.05</td>
<td>0.96</td>
<td>1.71</td>
</tr>
<tr>
<td>Telephone Services</td>
<td>0.06</td>
<td>0.07</td>
<td>0.09</td>
<td>0.11</td>
<td>0.15</td>
</tr>
<tr>
<td>Water &amp; Other Public Services</td>
<td>0.17</td>
<td>0.21</td>
<td>0.28</td>
<td>0.34</td>
<td>0.47</td>
</tr>
</tbody>
</table>

**Note:** Emissions estimates from Carnegie Mellon University Green Design Institute’s EIO-LCA model based on 1997 structure of economy. Emissions include direct and indirect emissions attributable to sales (2009$) from that sector. An emission rate of g/$ is equivalent to tones per million $. The cost increase is computed assuming a $15 charge per ton of CO₂ emissions.
| Household Operations, Supplies, Furnishings, Equipment & Apparel | 0.61 | 0.90 | 1.31 | 1.87 | 3.40 |
| Transportation & Vehicle Expense | 0.44 | 0.96 | 1.58 | 2.53 | 3.39 |
| Gasoline & Motor Oil | 4.99 | 8.15 | 11.59 | 14.92 | 18.38 |
| Healthcare | 0.29 | 0.33 | 0.42 | 0.42 | 0.62 |
| Other Expenditures | 1.16 | 1.66 | 2.38 | 3.65 | 7.21 |
| **Total Emissions** | 21.70 | 30.49 | 41.45 | 51.98 | 75.99 |

*Source:* Authors’ calculations using Consumer Expenditure Survey (2003) data and the CMU model described above.

As shown in Table 3, the most carbon-relevant sectors are fossil-fuel intensive; gasoline, electricity, natural gas and food are the goods purchased by consumers with the highest associated emissions. These tables could also be interpreted in terms of carbon intensity of consumption. Households in the lowest income quintile are responsible for an average of 1.99 metric tons of CO2 emissions per $1,000 worth of income, whereas households in the highest quintile are responsible for about 0.69 metric tons of emissions per $1,000 in income. The upper quintile is nearly three times more efficient than the bottom quintile, but the top quintile accounts for roughly 35% of aggregate emissions. In the next section we use these data to calculate the incidence of a price on carbon.

**D. The Incidence of a Price on Carbon**

Using emissions calculations from the previous section, we calculate the burden of a price on carbon emissions for each household in the CES. For a tax of $15 per ton of CO2 (based on the emissions estimates in Table 3), an average household in the lowest income quintile would pay around $325 per year, while an average household in the wealthiest quintile would pay $1,140 annually. Although wealthier households would pay more in absolute terms, as a percentage of annual income, lower income groups bear
a disproportionate share of the burden. The poorest quintile’s burden (as a share of annual income) is 3.2 times that of the wealthiest quintile’s.

When looking at the extremes in the household income distribution, the regressive nature of a price on carbon is even more pronounced. The burden as a share of annual income for the lowest income group ($7,500-9,999) is almost four times higher than the burden-to-income ratio for the highest income group in the data ($200,000-250,000). This is seen graphically in Figure 1, where the percentage of household expenditures on a price on carbon is plotted against income groups.

There is a debate among economists as to whether current income or lifetime income should be used in the calculation of the incidence of a policy. Because annual income is volatile, and because it tends to increase and then decrease with age, a person’s annual income may not be a good proxy for their permanent income over their lifetime. However, lifetime income is far more difficult to measure.14 Current expenditures can be used as a proxy for lifetime income if consumption is relatively smooth over a person’s lifespan (Poterba, 1989; Metcalf, 1999).15 We use current expenditures as our measure of lifetime income, though some authors find that using current expenditures as a proxy for lifetime income exaggerates regressivity at lower income levels (Caspersen and Metcalf, 1994). When comparing the burden as a percentage of annual expenditures, a

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14 The data used here make measuring lifetime income impossible, so a proxy is used. Fullerton and Rogers (1993) measure lifetime income and classify households accordingly. They find that the bias in regressivity based on annual income is not as severe as suggested by previous researchers. However, their results are based on consumption taxes, not a price on carbon, and the resulting bias in our calculations is unknown.

15 According to the lifetime income hypothesis, consumption is relatively smooth across time because people make contemporaneous consumption decisions based on their lifetime (and not current) income. For example, students may take out loans to support themselves during college because they anticipate earning income after graduating, and workers forgo consumption and save so that they have money for retirement.
household’s burden in the lowest income quintile is about 1.4 times that of the highest quintile (Figure 1).

Figure 1 shows the burden-to-income ratios for household annual income and household lifetime income, by household income group. The per-capita burden-to-annual-income ratio for the lowest income group (between $7,500 and $9,999) is nearly 4 times greater than for the highest income group (between $200,000 and $250,000).

A price on carbon, given the assumptions above, would be regressive, but the degree of regressivity depends on the income measure used. On an annual basis, a carbon price is 2-3 times more regressive than on a lifetime basis (i.e. using annual expenditures). In each case the regressivity is largely driven by direct energy consumption. This finding is consistent with other studies of the household incidence of carbon emission policies. Furthermore, as discussed briefly in the next section, the overall regressivity of a policy depends critically on how the revenues are used.

Figure 1. Broad CO₂ Tax Burden by Household Income Group
Note: Assumes CO₂ price of $15/ton. Shows total incidence by income group as a percent of annual net income and current expenditures. Source: authors’ calculations using consumption data from the Consumer Expenditure Survey and associated emissions from the Economic Input Output model from Carnegie Mellon University.

V. Conclusions

We use the Consumer Expenditure Survey and an augmented input-output model of the US economy to determine the extent to which a price on carbon in the United States is regressive. We show that the costs of a price on carbon borne by consumers are regressive by nature because polluting goods are mostly energy-intensive and take up a large percentage of a low-income person’s budget. The degree of regressivity varies with the breadth of the policy. This result is broadly consistent with findings from most other countries.

Although we find that the costs of a greenhouse gas pricing policy in the United States to be regressive, a few caveats are in order. The direct burden is only one channel
through which a climate policy has distributional effects, and as discussed earlier, there are other factors that determine the overall incidence of a carbon tax or emissions trading system (Fullerton, 2009). For example, we do not consider the distribution of the benefits of a greenhouse gas policy. If low income groups have more to gain from a cap-and-trade program or a carbon tax, the ‘net’ incidence of the policy may actually be progressive; alternatively, if wealthier households have more to gain, the ‘net’ incidence may be even more regressive.

There are several other caveats from our analysis. First, producers were assumed not to change production choices, costs were assumed to be fully passed through to consumers, and consumers are assumed to be unresponsive to increased product prices. Other researchers have found that low-income consumers are more responsive to price increases of polluting goods such as gasoline (West and Williams, 2004). Depending on the price elasticity of demand for other energy-intensive products, this would be expected to reduce the regressivity of a price on carbon.\footnote{Because we are not modeling the behavioral response for each commodity group, our estimates are likely an upper bound on the incidence of a price on carbon.} Second, some of the costs may be borne by factors of production, such as labor, capital or natural resource owners (Fullerton and Heutel, 2007a). Environmental regulations may change real wages and returns to capital, which would change the optimal production inputs (and hence emissions) for various sectors, and the distribution of these costs across income groups affects the overall incidence of a price on carbon. Third, while we consider a broad price on carbon that takes into account all emissions, in practice a carbon tax or emissions trading system may have exemptions for emissions from some industries due to political considerations or high monitoring costs.
Our analysis is consistent with evidence from other countries regarding the incidence of a carbon price. While studies in most other areas find that a carbon price is regressive, the regressive nature of the costs of a price on carbon could be alleviated (or eliminated) by carefully recycling revenues. This could be done by targeted transfers, financing cuts in regressive payroll or excise taxes, targeting income tax cuts at lower income groups, or by increasing spending on government programs targeted at lower income groups.\footnote{In an analysis of the Waxman-Markey bill passed by the US House in June 2009, the Congressional Budget Office calculated that the spending programs in the bill offset virtually all of the regressive aspects of the cap and trade system, and furthermore reduced the average household cost from 1.0% of household income to 0.2% (CBO, 2009).}
References


