The Distributional Consequences of Carbon Pricing in Canada

by

Mark Vodden

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Supervisor's name, Supervisor (Department of Economics)

University of Victoria

Abstract

Using a Statistics Canada Survey of Household Spending in 2007 with an Economic Input-Output Life Cycle Assessment (EIO-LCA) model I estimate the households' carbon emissions 'footprint' associated with all consumption. Assuming producers are unresponsive to a Carbon Pricing policy and pass costs of that policy on to consumers I then estimate an upper bound for the household's carbon tax bill assuming no substitution or responsiveness. I review measures to offset the regressivity of a carbon pricing policy through tax cuts and or rebates under the conditions of revenue neutrality.

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1. INTRODUCTION

Countries such as Canada are examining how best to address climate change because future outcomes are potentially devastating. There are, however, uncertainties about the costs and benefits of taking action against climate change. This paper will examine how a carbon pricing strategy, implemented for the purpose of reducing CO_2 emissions, would ultimately result in increased costs for consumers

Placing a price on carbon internalizes a polluter's negative production externality. British Columbia has imposed a carbon tax on all liquid, gaseous, and solid fuels at a rate of $15/tonne of CO_2 emissions (BC Ministry of Small Business and Revenue, 2008). The European Union with its cap-and-trade policy has established a market equilibrium price of almost € 13 (European Climate Exchange, 2010). Despite enormous differences in the policies listed, B.C. and The EU-27 share the principal idea of imposing a price on CO_2 emissions for the purpose of creating an incentive to reduce pollution output.

The goal of this paper is not to examine different policy methods. This paper analyses how households are affected if a price on carbon emissions were imposed in Canada. Issues for policy makers and voters arise when reviewing the policies impact on households. With a carbon pricing scheme there are good reasons to believe that poorer households will be faced with a larger carbon tax burden than the richest. In this paper I examine in detail the potential for regressivity of a carbon pricing policy in Canada.

I modify and expand on the working paper by Grainger and Kolstad (2009), "Who Pays a Price on Carbon" from the National Bureau of Economic Research. Similar to the Grainger and Kolstad paper, I use a Leontief input-output lifecycle analysis model to calculate an estimate of emissions associated with industry specific economic activity. The Carnegie Mellon Green Design Institute has created an online tool that provides data on emissions from various industry sectors of the Canadian economy. By pairing this industry-specific data to the Statistics Canada Survey of Household Spending in 2007, I match household consumption decisions with production emissions in order to estimate the carbon footprint of Canadian household consumption choices. To the best of my knowledge, this is the first such comprehensive household-level carbon-accounting exercise using Canadian data.

I then examine the effects of a carbon price on households across Canada. The results of this paper may be important to Canadian climate policy decision-making. When considering the potential implications a carbon price could have, governments should review the possible effects on social welfare and the welfare of low-income households. In this paper, I attempt to quantify those affects.

1.1. *Literature Review*

The foundation for my paper is "Who Pays a Price on Carbon" (Grainger & Kolstad, 2009). In their paper, they calculate an estimate for emissions associated with household consumption for the United States. They use US Consumer

Expenditure Survey data with an input-output lifecycle approach to estimate the resulting implications –if the US priced carbon–on family income and expenditure. They find that in the United States a carbon pricing policy would have regressive affects on households because it results in a tax bill that – as share of income – is higher for the poor than the rich.

Grainger & Kolstad (2009) are not the first to find that a carbon pricing policy is regressive. Metcalfs' (1999) analyses of green tax reforms and their distributional consequences, also using US Consumer Expenditure Survey data and an input-output, approach finds a carbon tax to be regressive. Metcalf (1999) concludes that an environmental tax with regressive implications can be designed to have a negligible impact on income distribution when tax revenues are recycled to households' by way of reduced personal income taxes. Parry (2004) uses an analytical model to conclude that grandfathered emissions permits can be highly regressive by creating rents benefiting shareholders. He argues that despite the poor not consuming a large quantity of carbon-intensive goods, a cap-and-trade policy would undoubtedly be regressive.

My paper differs from previous literature as I am sourcing Canadian household and industry production data to show how households in Canada would be adversely affected if carbon is priced. There are significant differences between the results for Canada and the United States. Using first order calculations, I show that the regressive nature of a price on carbon in Canada is substantially less than that of which would occur for the United States.

Understanding the similarities and differences of household consumption in Canada compared with the United States is important for gauging the impact a policy change has on households across Canada. Special consideration must be made for low-income households as they lack disposable income to pay for this new added burden.

I quantify estimates in this paper for the potential carbon burden that households in Canada could soon face. These estimates enable critical analysis of the distributional impact from a carbon pricing policy. They allow for considerations on carbon pricing politics, its feasibility in the political realm, structural design for its implementation, the potential costs borne by consumers and the resulting compensation required to neutralize its impact on the poorest households in Canada.

2. METHOD AND DATA

Calculating a household carbon footprint is nothing new to neither environmental sciences nor the public. Typically, calculations of such a carbon footprint primarily consider consumption of fossil fuels. As a rudimentary measure, all fuel expenditures, such as transportation via airline or public transit, are summed, to come up with a measure of each household's annual addition to the stock of global pollutant. This approach is, however, incomplete, as it fails to consider carbon emissions associated with *all* consumption goods. I pursue an approach which yields an all-encompassing result for a total household carbon ‘footprint’. In order to calculate a household carbon footprint estimate, I need to link emissions from various industry production sectors on the supply side to consumption categories on the demand side.

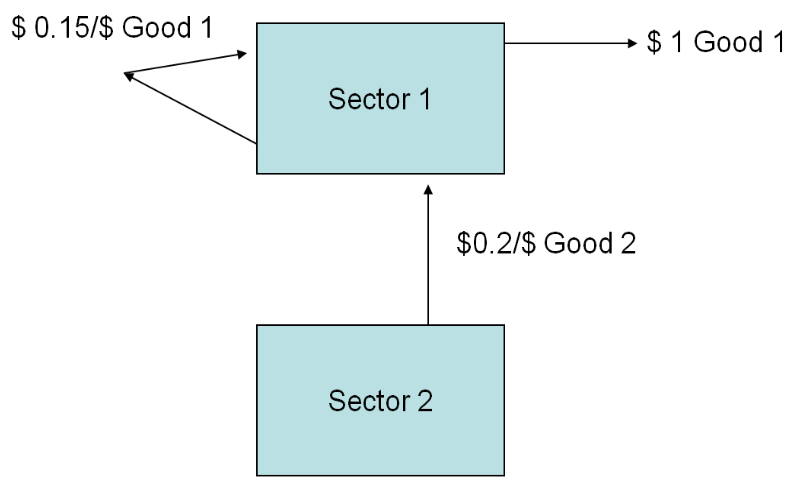
2.1. Supply Side: emissions from production

For industry supply, I use Industry Canada 2002 Canadian Industry Statistics. This data was recalculated in an economic input-output life cycle assessment model to estimate the supply chain, materials, energy resources, and environmental emissions associated with an economic activity (The Green Design Institute at Carnegie Mellon, 2010). From this, I am able to generate a data set containing the greenhouse gas emissions levels (measures in units of $C0_2$) associated with all production sectors in Canada.

2.1.1. Economic Input Output

An economic “input-output analysis describes and explains the level of output [in] each sector of a given national economy in terms of its relationships to the corresponding levels of activities in all the other sectors” (Wassily Leontief, 1970). Leontief founded the concept in the 1930s but it was not until 1973 that he received the Nobel Prize in economics for his efforts (Nobelprize.org, 2010). Leontief’s paper “Environmental Repercussions and the Economic Structure: An Input-Output Approach” (1970), demonstrated that externalities can be incorporated into his original input-output model and can "yield concrete replies to some of the fundamental factual questions…raised by the undesirable environmental effects of…economic growth" (Leontief, 1970, pp. 262). Figure 1 illustrates an example of the inter-industry relationship of supply chain production.

Figure 1: Input-Output Matrix Fundamentals



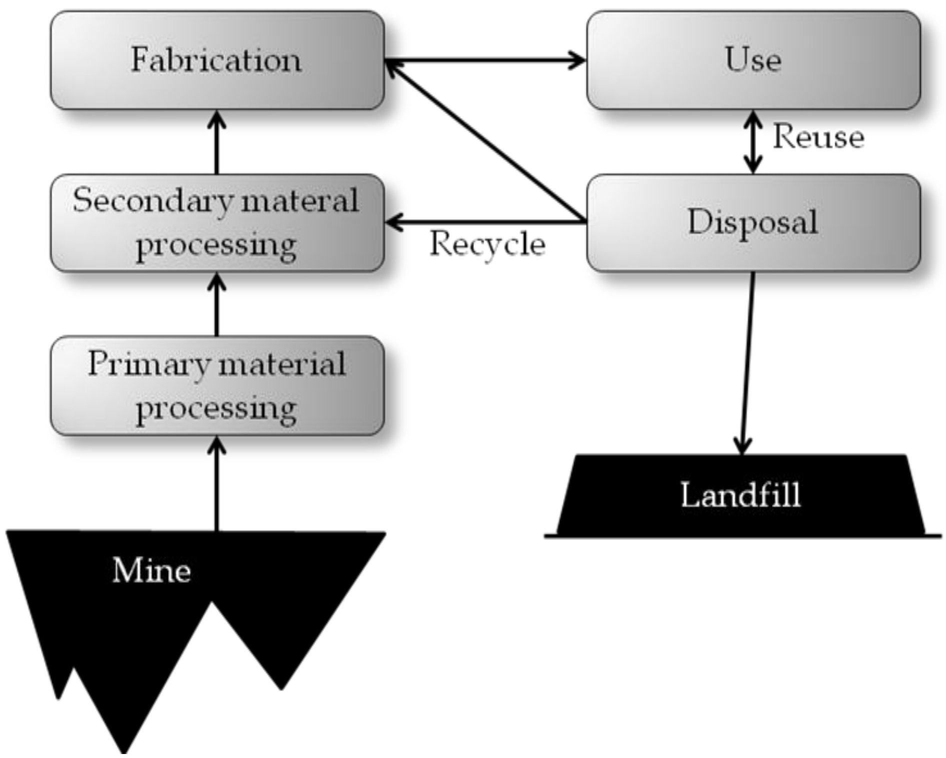
Source: http://www.eiolca.net, Theory and Method behind EIO-LCA

To produce $1 of output from sector one requires $0.15 of goods from within sector 1, as well as $0.20 of goods from sector 2. This model captures both the interconnection between industry sectors and the supply chain requirements of a particular industry.

Leontief's work advanced the idea of looking at economic growth and environment as interconnected and interdependent. This work was extended by Hendrickson et. al. (1998) with the *Economic input-output models for environmental* *life-cycle assessment*. The lifecycle approach measures the environmental impact of goods from their initial manufacturing phase, use phase, and then disposal phase. Under an assumption of linear proportionality in industry production, where we assume constant returns to scale, an economic input-output lifecycle assessment (EIO-LCA) model can approximate the pollution associated with a production process Hendrickson et. al. (1998).

Figure 2 illustrates how the lifecycle approach incorporates all stages of a products life from the material extraction through to the disposal.

Figure 2: Seven-Stage Lifecycle Assessment Product Chain



Source: Henrickson et al. 1998.

The product lifecycle traces the path of an output good from mining primary materials, through fabrication, use, and eventual landfill disposal. Each box represents one or more process models, which account for environmental discharges such as toxic emissions or hazardous wastes. Because products typically require more than one material input, multiple material process chains are usually required to account for all environmental impacts (Hendrickson et al., 1998).

2.1.2. Industry Supply Chain

The Carnegie Mellon Green Design Institute has made available an online tool using the Leontief input-output model in partnership with a lifecycle assessment. This EIO-LCA tool is part of the Green Design Institutes mandate to

> [f]orm partnerships with companies, government agencies and foundations to develop pioneering management, manufacturing, and regulatory processes that can improve environmental quality and product quality while enhancing economic development.
> (Green Design Institute, 2010)

In partnership with Statistics Canada and the University of Toronto, the Green Design Institute created an input-output lifecycle model for the Canadian economy. This model includes one-hundred and five detailed industry production sectors tabulating, based on any given amount of economic activity, the total supply chain effect, direct economic effect, and associated CO_2-equivalent[1](CO_2E) emissions with production. Due to the complicated level of calculations along with the required computing and labor needs, these data sets are not available every year, and are typically only available in five to seven year increments.

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[1] CO_2 equivalent encapsulates all GHG emissions, normalizing other emissions to $C0_2$ for their atmospheric impact.

As an example of these data, Table 1 outlines the top twenty industry sectors by emissions and shows the resulting GHG emissions, measure in CO_2E per million dollars of economic activity. Crop and animal production is the leading producer of CO_2E at 5,270 metric tons, while oil and gas extraction has only 1,820 metric tons of CO_2E per million dollars of economic activity.

Table 1: Top 20 Industry Sectors by Emissions

Per $1 Million Dollars Activity	Green House Gsses
Top 20 Industry Sector	**Metric Tons of CO2-Equivalent**
Crop and animal production	5270
Electric power generation, transmission and distribution	4530
Pesticides, fertilizer and other agricultural chemical manufacturing	3810
Non-residential building and engineering construction	2160
Petroleum and coal products manufacturing	2090
Oil and gas extraction	1820
Meat product manufacturing	1730
Motor vehicle manufacturing	1710
Residential building construction	1640
Pulp, paper and paperboard mills"	1360
Air transportation	1300
Accommodation and food services	1250
Basic chemical manufacturing	1120
Wood product manufacturing	942
Dairy product manufacturing	855
Truck transportation	845
Motor vehicle parts manufacturing	816
Rail transportation	806
Miscellaneous food manufacturing	794
Lessors of real estate	787

Source: The Green Design Institute at Carnegie Mellon University, EIO-LCA model. Unit of GHG are in Metric Kilo-Tons of Carbon Dioxide Equivalent (kMTCO2E) Greenhouse gasses are shown on the industry level. CO_2E encapsulates all GHG emissions normalizing other emissions to $C0_2$ for atmospheric impact.

2.2. Demand Side: Linking emissions with consumption

Having now calculated detailed industry-level emissions associated with production, I next link production emissions to household consumption categories. A Statistics Canada Survey of Household Spending (HHS) in 2007 provides detailed breakdowns on household consumption. These data are available for all provinces and income quintiles, providing comparative statistics of how poor Canadian households spend their money relative to the rich across approximately three-hundred expenditure categories.[2]

All Canadian household expenditure is associated with some production method. For instance, money spent on wheat traces to production processes in the agriculture sector. I match a production processes to every dollar of household expenditure. Depending on the industry sector, varying degrees of CO_2E emissions release into the atmosphere. By pairing household consumption at the highest possible level of specificity to the supply side emissions data, I generate a detailed estimate of the carbon footprint for household expenditure.

3. HOUSEHOLD CARBON FOOTPRINT

Table 2, grouped by income quintile and listed according to the HHS survey categories, shows the average emissions for each quintile in Canada. The Canadian average of household emission for all income classes was 58.93 metric tons of $C0_2E$. The lowest and highest income quintiles have an associated 26.74 and 98.98 metric tons of $C0_2E$ respectively.

[2] Canadian Territories were excluded from my calculations because Statistics Canada data was unable to provide consistent data on household expenditure due to small sample size biasness problems and privacy issues.

Table 2.A: Household Emissions by Income Quintile (Tons of $C0_2E$)

CANADA	All classes	Lowest quintile	Second quintile	Third quintile	Fourth quintile	Highest quintile
Total mean expenditure	$ 69,946	$ 22,339	$ 40,009	$ 60,602	$ 83,420	$ 143,361
Total current consumption	$ 49,766	$ 20,727	$ 33,371	$ 46,103	$ 59,754	$ 88,872
Household Emissions						
Food	18.79	9.72	14.53	18.52	22.04	29.11
Shelter	21.69	11.51	15.59	20.57	25.75	34.95
Household operation	2.31	0.88	1.52	2.01	2.77	4.31
Household furnishings and equipment	0.41	0.13	0.23	0.34	0.47	0.86
Clothing	0.51	0.16	0.30	0.43	0.58	1.07
Transportation	12.08	3.07	6.88	11.55	16.19	22.71
Health care	0.50	0.23	0.43	0.52	0.59	0.74
Recreation	1.04	0.27	0.56	0.89	1.27	2.20
Other	1.62	0.76	1.13	1.40	1.76	3.02
GRAND TOTAL	58.93	26.74	41.19	56.24	71.42	98.98

Source: Authors own calculations yielded estimates using Statistics Canada Survey of Household Spending in 2007 and the CMU model described above. Figures above are in metric tons of $C0_2E$.

Table 2.A show that the household's carbon emissions embedded in food, shelter, and transportation consumption categories account for the majority of a household's carbon footprint. This is unsurprising since they account for the largest shares of our total expenditure. In addition, shelter and transportation categories incorporate energy goods such as electricity, natural gas, and gasoline.

Table 2.B combines the results from the Table 2.A with original data from the 2007 Household Expenditure Survey to illustrate the breakdown for both the households' carbon footprint and consumption expenditure as percentage shares.

Notably, although food expenditure only account for 18.3% of the household budget on average for the lowest quintile, it amounts to 36.4% of the overall household carbon footprint. For the highest quintile, consumption expenditure on food falls to 12.7% of the total budget (an approximate 30% reduction relative to the poorest quintile), with an implied carbon footprint of approximately 29.4% of the households' total (a 19% reduction relative to poorest quintile). The shelter category also like food expenditure exhibits a level of disparity between expenditure and its relative carbon footprint shares. Transportation as one of the main three categories is the only one showing very similar results for the expenditure-to-emissions-share relationships across all income groups.

Although there is a positive relationship between expenditure and the share of total carbon created, expenditure and carbon footprint shares do not move in lockstep. Regardless of income quintile, food and shelter expenditure account for the greatest share of the carbon footprint.

Table 2.B: Household Consumption and Carbon Footprint (Tons of $C0_2E$) Shares by Income Quintile

CANADA	Lowest quintile		Second quintile		Third quintile		Fourth quintile		Highest quintile	
Total mean expenditure	$ 22,339		$ 40,009		$ 60,602		$ 83,420		$ 143,361	
	Share of CONSUMPTION Expenditure	Share of CARBON footprint	Share of CONSUMPTION Expenditure	Share of CARBON footprint	Share of CONSUMPTION Expenditure	Share of CARBON footprint	Share of CONSUMPTION Expenditure	Share of CARBON footprint	Share of CONSUMPTION Expenditure	Share of CARBON footprint
Total current consumption	$ 20,727		$ 33,371		$ 46,103		$ 59,754		$ 88,872	
Food	18.3%	36.4%	16.9%	35.3%	15.6%	32.9%	14.3%	30.9%	12.7%	29.4%
Shelter	32.6%	43.0%	28.0%	37.9%	27.4%	36.6%	27.4%	36.1%	26.0%	35.3%
Household operation	7.1%	3.3%	6.8%	3.7%	6.4%	3.6%	6.5%	3.9%	6.6%	4.4%
Household furnishings and equipment	3.1%	0.5%	3.5%	0.6%	3.6%	0.6%	3.9%	0.7%	4.5%	0.9%
Clothing	4.5%	0.6%	5.3%	0.7%	5.5%	0.8%	5.6%	0.8%	6.9%	1.1%
Transportation	13.0%	11.5%	16.8%	16.7%	19.6%	20.5%	20.6%	22.7%	19.5%	22.9%
Health care	4.4%	0.9%	5.0%	1.0%	4.3%	0.9%	3.8%	0.8%	3.2%	0.7%
Recreation	5.2%	1.0%	6.5%	1.4%	7.4%	1.6%	8.0%	1.8%	9.5%	2.2%
Personal care	2.3%	0.6%	2.6%	0.6%	2.3%	0.6%	2.3%	0.6%	2.3%	0.6%
Education	2.8%	0.5%	1.8%	0.4%	1.4%	0.3%	1.7%	0.4%	2.5%	0.6%
Reading materials and other printed matter	0.6%	0.1%	0.6%	0.1%	0.5%	0.1%	0.5%	0.1%	0.5%	0.1%
Tobacco products and alcoholic beverages	3.5%	0.4%	3.7%	0.4%	3.5%	0.4%	2.9%	0.4%	2.7%	0.4%
Games of chance	0.9%	0.5%	0.7%	0.4%	0.6%	0.4%	0.4%	0.2%	0.4%	0.3%
Miscellaneous expenditures	1.8%	0.7%	1.9%	0.7%	1.9%	0.7%	2.1%	0.7%	2.6%	1.0%

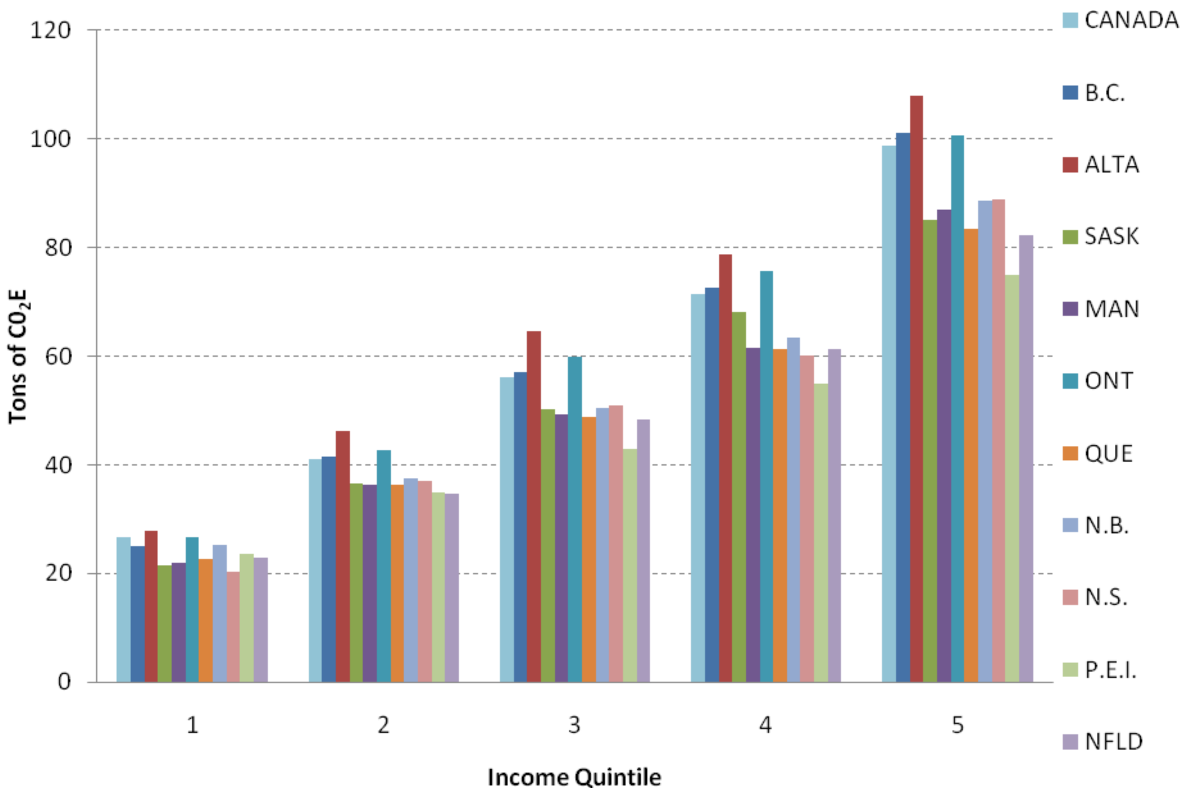
Source: Authors own calculations yielded estimates from HHS in 2007 and the CMU model.

The Canadian average for household emissions by income quintile was show in Table 2.A. With income quintile groups on the horizontal axis and tons of CO_2E on the vertical axis, Figure 3 plots household carbon footprints for each of the five income quintiles and all ten provinces. The first column represents the Canadian benchmark average in each of the five income quintiles and estimates for each province follow.

Figure 3 shows first (as was clear in Tables 2A and 2B) how carbon emissions are increasing in income. Second, there is noticeable cross-provincial variation in the household carbon footprint. In British Columbia, Alberta, and Ontario households in each quintile have above average carbon footprints, while in

Prince Edward Island, Nova Scotia, and Newfoundland households in each quintile have below average carbon footprints.

Figure 3: Household Carbon Footprint



Source: Authors own calculations yielded estimates. Income quintile sorts each household group, measuring a carbon footprint for the quintiles average household of each province and Canada.

This variation is due to (i) regional differences in consumption patterns and (ii) difference across Provinces in the actual average income levels for each quintile.[3] For instance, Alberta has the highest average net income for the highest

[3] Income quintile is calculated from an even distribution of the sample population. The average income for each provinces quintile is then calculated from within the sample group.

quintile households at $170,617, whereas PEI has the lowest average income for the highest quintile earners at $104,511. Arguably, the latter reason for variation in the household carbon footprint is less interesting in this context than the former. Consequently, Figure 4 plots the carbon footprint against the actual average income levels associated with each income quintile by province, effectively collapsing the information from Figure 4 into a single series. Each point in Figure 4 represents a net income and associated carbon footprint for a single quintile of a particular province.

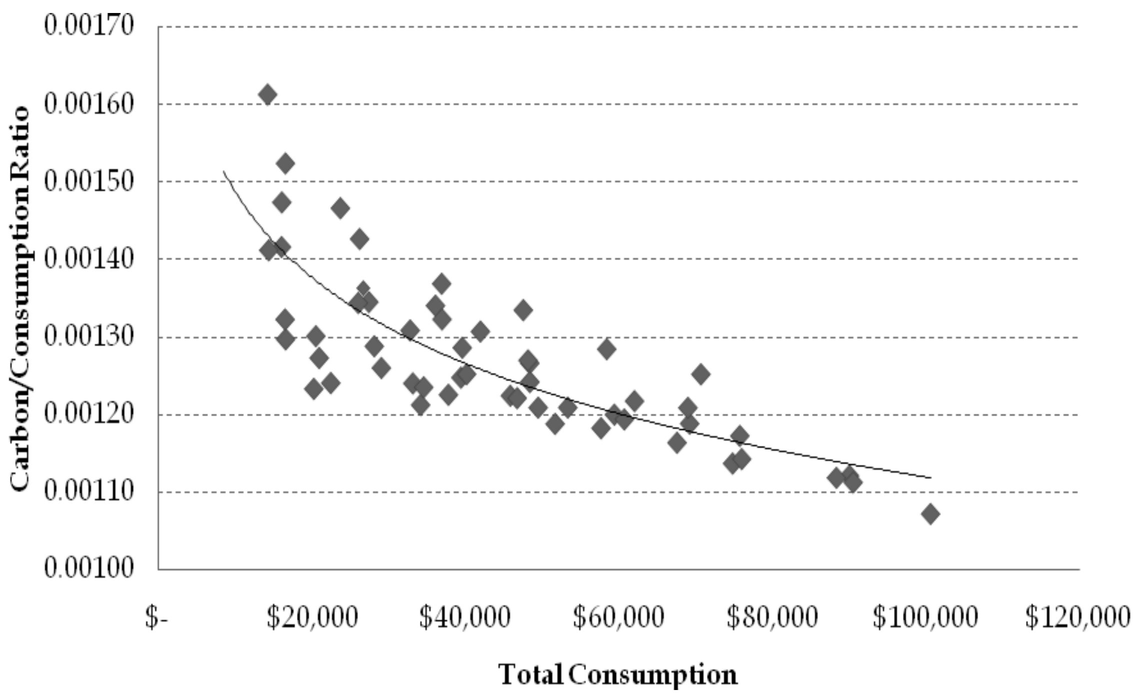
Figure 4: Carbon Footprint-to-Net-Income Ratio[4]

Source: Authors own calculations yielded estimates. Each node is representative of a Province's income quintile.

[4] Net income refers to total income less taxes.

Figure 4 shows a household's carbon footprint increasing with income. It cannot be seen immediately from the figure whether this is simply due to a scale effect, (wealthier households spend more money) or if wealthier households consume carbon more intensively (a kind of 'technique' effect). In order to differentiate these two effects, Figure 5 plots the carbon intensity of consumption (measured in tons per dollar spent) against aggregate consumption expenditure. As can be seen from the figure, the carbon intensity of consumption actually declines considerably as consumption expenditure increases.

Figure 5: Carbon Footprint-to-Consumption Ratio[5]



Source: Authors own calculations yielded estimates. Each node is representative of a Province's income quintile. The vertical axis is the ratio of the households carbon footprint against total consumption Effectively this figure depicts a household's average imbedded carbon on each dollar spent and shows that the richer households have cleaner consumption on a per dollar basis.

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[5] Total consumption differs from net income because it excludes such spending as RRSP contributions, savings, charitable donations, and bequests.

A significant point from Figure 5 is that the rich, although they spend more and have larger aggregate household carbon footprints, do not have dirtier consumption behavior on a per dollar basis.

3.1. Energy Consumption

Not yet mentioned, electricity, natural gas, and gasoline consumption make up a significant amount of the carbon footprint associated with Canadian household consumption. Table 3 provides details of the average energy consumption for each income group in Canada. It shows the largest source of CO_2E comes from electricity generation with 5.196 tons of $C0_2$ annually for all quintiles in Canada[6]. Gasoline ranks second with its share of household consumption accounting for approximately 4.20 tons of $C0_2$ a year.

Table 3: Canadian Household Emissions on Energy Goods (Tons of $C0_2E$)

	1st quintile		2nd quintile		3rd quintile		4th quintile		5th quintile	
Total mean expenditure	**$ 22,339.00**		**$ 40,009.00**		**$ 60,602.00**		**$ 83,420.00**		**$ 143,361.00**	
Total consumption	$ 20,727.00		$ 33,371.00		$ 46,103.00		$ 59,754.00		$ 88,872.00	
		CO2E		*CO2E*		*CO2E*		*CO2E*		*CO2E*
Electricity	$ 670.00	*3.035*	$ 946.00	*4.285*	$ 1,171.00	*5.305*	$ 1,345.00	*6.093*	$ 1,602.00	*7.26*
Gasoline and other fuels	$ 642.00	*1.17*	$ 1,547.00	*2.82*	$ 2,394.00	*4.36*	$ 3,098.00	*5.64*	$ 3,826.00	*6.97*
Natural gas	$ 224.00	*0.408*	$ 359.00	*0.653*	$ 567.00	*1.032*	$ 795.00	*1.447*	$ 1,105.00	*2.01*
Other fuel	$ 133.00	*0.242*	$ 198.00	*0.360*	$ 203.00	*0.369*	$ 209.00	*0.380*	$ 221.00	*0.40*
TOTAL	$ 1,669.00	*4.86*	$ 3,050.00	*8.12*	$ 4,335.00	*11.07*	$ 5,447.00	*13.56*	$ 6,754.00	*16.64*

Source: Authors own calculations yielded estimates using CDN Household expenditure survey (2007) and the CMU model described above. Figures above are in metric tons of $C0_2$.

[6] This estimate for electricity generation does not pick up regional discrepancies in power generation techniques.

4. EFFECTS OF PRICING CARBON

4.1. Assumptions and Scenarios

In Section 3, I calculate a carbon footprint associated with average household consumption decisions for each income quintile in every province of Canada. I now estimate the effects a price on carbon would have on household well-being. More specifically, I estimate *upper bounds* on the carbon tax bill for households by quintile and province.

Due to the following assumptions that I maintain throughout this paper I best describe my estimates to be upper bounds:

1. Any carbon tax is fully passed onto consumers in the form of increased prices.
2. Household consumption choices remain unchanged after the introduction of the carbon tax.
3. Production techniques remain unchanged after the introduction of the carbon tax.

With these assumptions, I attach a multiplier to the households' carbon footprint equal to a determined carbon price. A carbon tax burden is thus an extension of the households' carbon footprint in this model.

Admittedly, assumptions two and three are unrealistic; the purpose of a carbon tax is to change behaviour. In response to a carbon tax, consumers are likely to substitute towards less carbon-intensive consumption goods and producers are likely to substitute away from carbon intensive production techniques. These effects that reduce the carbon tax burden of households are not controlled for in this paper. Nevertheless, my estimates are "worst-case scenarios" for consumers and, since it is the belief by some that the burden of carbon taxes may be too much for some the poorest in Canada to tolerate, worst-case scenario estimates are valid to consider.

Figure 6: Budget Line Shift with Income/Substitution Effect

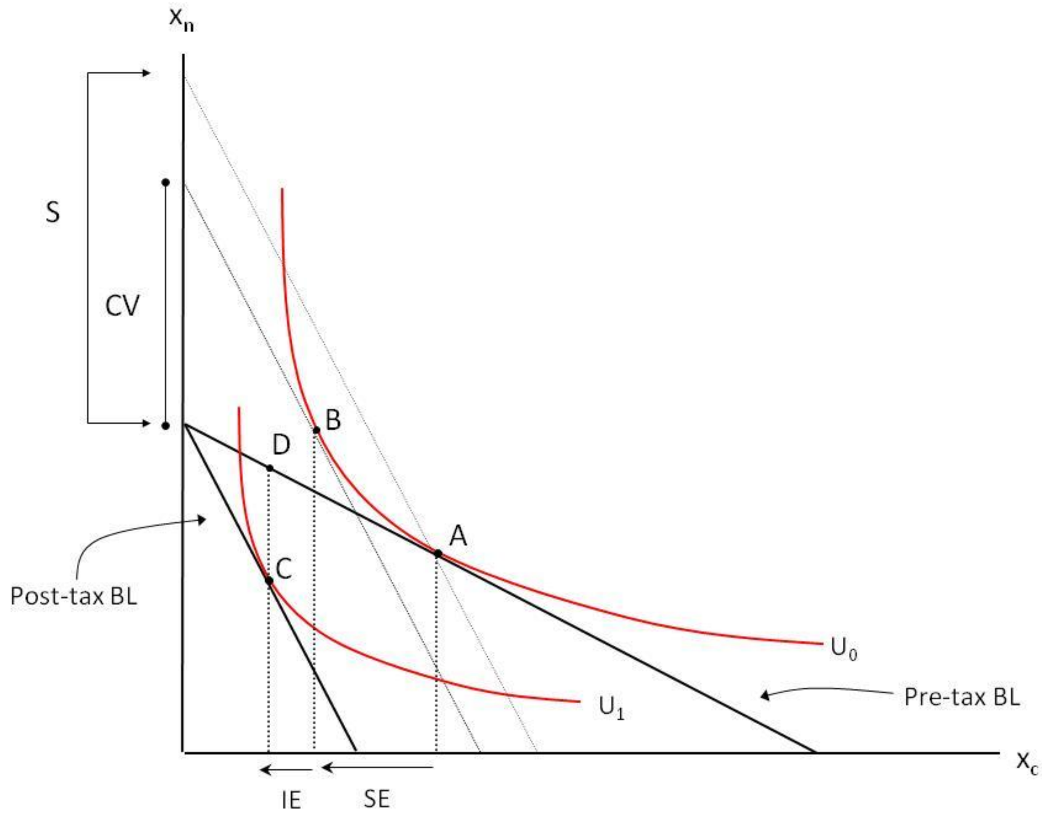


Figure 6 illustrates the effect of a carbon tax in a stylized world for which there are just two goods: zero carbon goods *(Xn)* and carbon intensive goods *(Xc).* The carbon tax increases the relative price of carbon intensive goods and pivots the budget line as shown in the diagram. Both the substitution *(SE)* and income effects *(IE)* result in a reduction of carbon intensive goods, the consumer moves from her original consumption choice *A* to her post-tax consumption choice *C*. If – after the tax were introduced - the consumer were given the amount of income labelled *CV* in the diagram, she chooses consumption point *B*, which results in the same level of utility as she attained prior to the tax being introduced. The amount *CV* is thus the compensating variation of the tax, and is the true measure of the reduction in consumer welfare as a consequence of the tax. A complete analysis of impact on Canadian households of a carbon tax would thus estimate the compensating variation.

Instead of estimating *CV*, I estimate the amount labelled *S* in the diagram. Sometimes referred to as "Slutsky compensation", *S* tells us the amount of money that the consumer would require to be able to afford the *original consumption bundle (A)* after the tax. Note that, the *CV* tells us the amount of money that the consumer would require to be able to afford the original *utility level* after the tax. Clearly *S* exceeds *CV,* and is an upper bound on the effect of the tax on consumer well-being.

4.2. Incidence of Carbon Pricing

In the estimates described in section 4.2.1 through to 4.2.3, I consider three scenarios. The results of the first scenario show the households' carbon tax burden at a $15/ton carbon price. Scenario 1 examines the policy regressivity and compares this measure of regressivity to the policy regressivity of the United States. The second scenario adjusts the emissions associated with shelter expenditure and recalculates the regressive results. Scenario 3 introduces a carbon price of $50/ton of emissions as shows its effects to the overall policy regressivity.

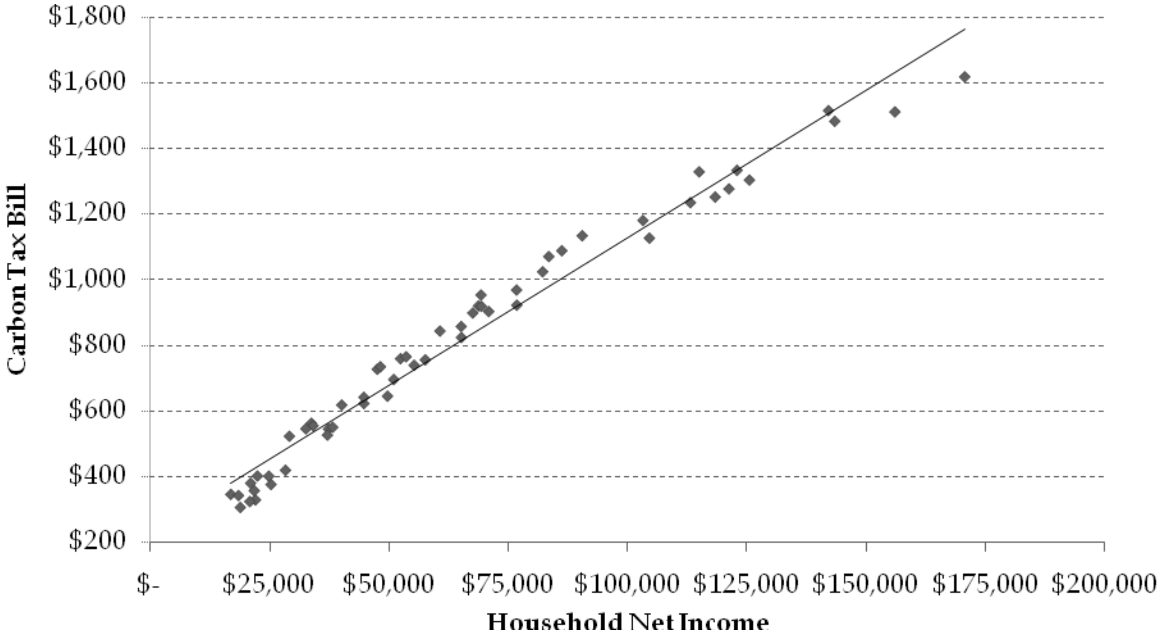
4.2.1. Scenario 1: $15/ton carbon price

Based upon my estimates of households' carbon footprints, I calculate an estimate for households' annual carbon tax bill, initially at a price of $15 per ton of CO_2E.[7] This carbon tax bill as a function of income is illustrated in Figure 7. The lowest income data point in the figure represents the lowest income quintile in Nova Scotia, which faces an average annual tax bill of around $305. The highest income data point in the figure represents the highest income quintile in Alberta, which faces an average annual tax bill of around $1,620. For the national average – ignoring inter-provincial variation – the tax bills ranges from around $400 for the poorest income quintile up to around $1,500 for the richest income quintile.

Each node in Figure 7 is representative of a Province's income quintile. Data was collected from all ten provinces and for each of the five income quintiles. Fifty data points make us the estimate for the households' carbon tax bill. The carbon tax bill for households is shown in comparison to net household income groups.

[7] This tax rate is chosen as the base-case scenario since (i) it is the current tax rate in B.C. and (ii) it allows for comparisons with the US tax burden estimates provided by Grainger and Kolstad (2009).

Figure 7: Household Carbon Tax Burden $15/Ton

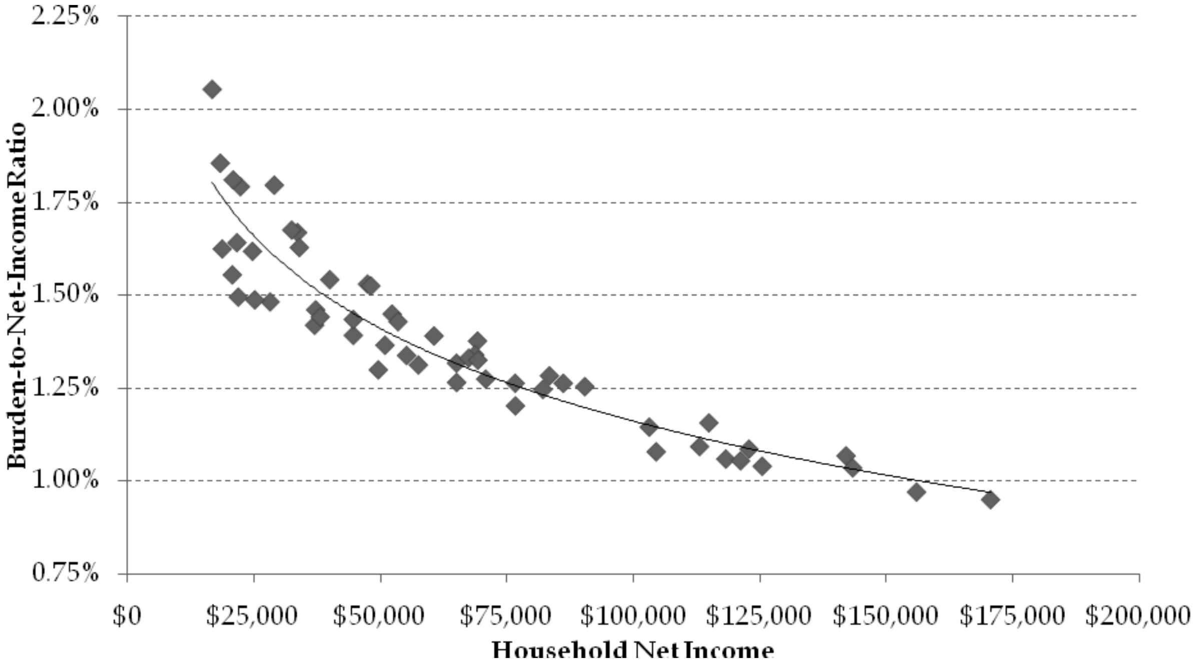


Source: Authors own calculations yielded these estimates.

Also included in Figure 7 is a linear trend line through the data points. As is clear from the figure, observations for the highest income groups lie below this line. That is, the highest income households pay proportionately less of their income in carbon taxes than do poorer households. In other words, my estimates show that carbon pricing is indeed regressive.

To further explore the degree of this regressivity, I next calculate the carbon tax bill as percentage of a household's net income. This is illustrated in Figure 8, which shows that the very poorest households pay around 2% of their net income in carbon taxes and the richest households pay a slightly less than 1% of their net income in carbon taxes. While this is indeed regressive, I would characterize it as mildly so, especially when compared to similar estimates for the US.

Figure 8:$15/Ton Carbon Tax Policy Regressivity

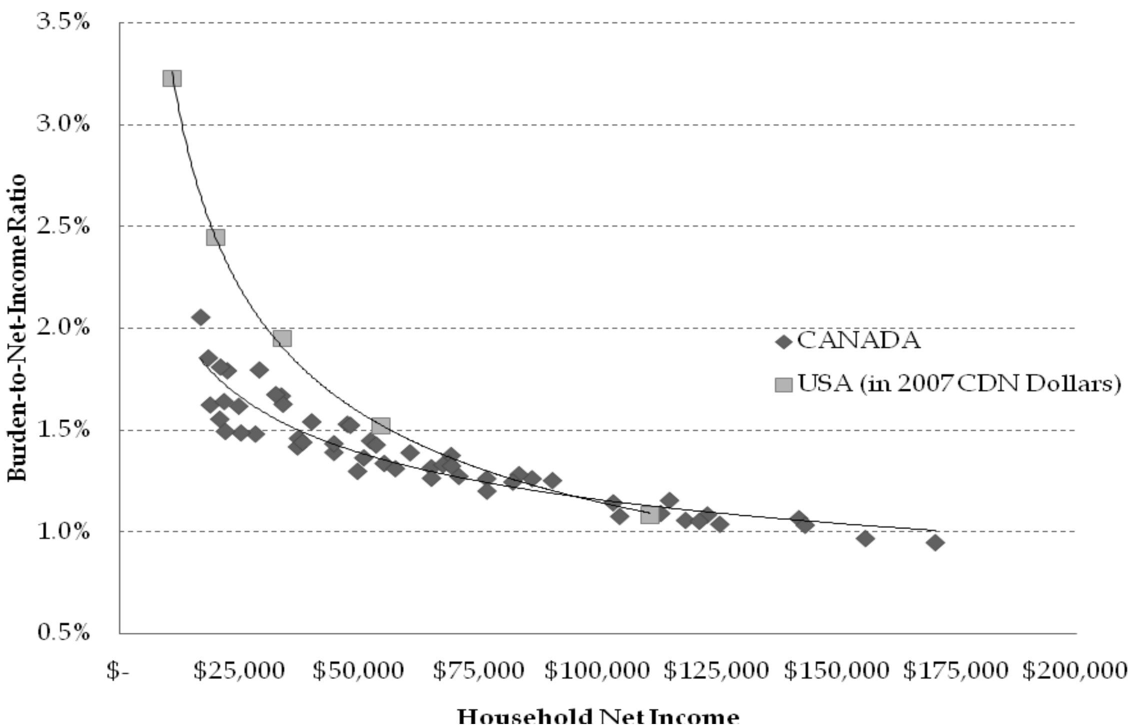


Source: Authors own calculations yielded estimates. This figure shows the regressive nature of a carbon pricing policy without revenue neutrality. Each node is representative of a Province's income quintile.

Figure 9 reproduces the information in Figure 8, but also includes the same information for US households, given the estimates of Grainger and Kolstad (2009). From the figure one can see that a $15/ton carbon price will be more regressive in the US than in Canada. The lowest income quintile for the United States has an approximate tax burden of 3.2% relative to net income it is less than 2% for Canada households. As income levels rise, the disparity between the United States and Canada lessen and tax burdens are nearly identical for the highest quintile.

Grainger and Kolstad (2009) suggest that the high US regressivity level is due to consumption exceeding the average net income as low-income earners, such as senior citizens and students, spend more than their reported incomes. This explains the irregularity between Canada and the United States at the lowest income level. For the first income quintile in the USA, total consumption exceeds net income by an average of $4,950 USD. For the first income quintile in Canada, net income actually *exceeds* total consumption by an average of $1,612.

Figure 9: Canada & USA Comparison ($15/Ton Carbon Price)



Source: Authors own calculations yielded Canadian estimates. Grainger & Kolstad (2009) produced estimated for USA.

4.2.2. *Scenario 2: Adjustments to shelter expenditure emissions*

Recall from Table 2.B. that expenditure on shelter makes up 26% to 32.6% of the households total consumption expenditure. Shelter expenditure is a composite of numerous sub-category expenditures, including mortgage and rental payments. When matching consumption categories to production sectors in Section 2, mortgage and rental payments mapped to residential building construction emissions figures. Clearly, to the extent that such payments do not actually prompt new residential construction, this results in an overestimate of the carbon emissions associated with this consumption category. Unfortunately, no reliable data allows for a more accurate mapping of mortgage payment and rental expenditure to carbon emissions.

In addition to the point discussed above, a second point about mortgage payments is worth noting. Mortgage payments are a function of the market price of a house, and much of the variation in market prices is a function of location. Hence variation in house prices, and thus mortgage payments, will not map cleanly into variations in emissions. Higher mortgage payments are correlated to larger house sizes but are also dependent on property value. As such higher mortgage payments do not necessarily mean higher carbon emissions. Once again, however, the data required to tease out the magnitude of this effect are not readily available.

To attempt to get some sense of the overall importance of the problems associated with the emissions calculations for shelter expenditures, I recalculate household carbon tax bills under four different assumptions of the percentage of mortgage and rental expenditures generating emissions. The percentages used are 0%, 10%, 25%, 50%, and 100% respectively. Note that assuming 100% of mortgage and rental expenditures generate emissions is the initial assumption made in Section 2 and so yields tax bill estimates that are identical to those in subsection 4.2.1.

How changing the emissions associated with shelter expenditure affects the overall carbon tax burden to the households and ultimately the regressivity of the policy is understated in Table 4 and the proceeding scenario diagrams. Table 4 displays the household carbon tax burden, adjusting the share on Rent and Regular Mortgage Payment categories. All other calculations such as energy expenditure in the shelter category remain unchanged.

Table 4: Carbon Tax Bill (Mortgage & Rent Expenditure)

Income Group		Total expenditure	AVERAGE expenditure	Estimated CO2E	Carbon Tax Bill	Tax burden share of Net Income	Total (Rent & Regular mortgage payments)			Adjusted Total With %share inbedded carbon			
Province	Quintile	(NET) $	$	Metric Tons	$15.00	$15.00	Average expenditur	Inbedded	share of total	null	10%	25%	50%
B.C.	1	$ 25,189	$ 20,257	**25.0**	$ 375	1.49%	$ 3,471	5.69	23%	19.29	19.86	20.71	22.14
CANADA	1	$ 22,339	$ 20,520	**26.7**	$ 401	1.79%	$ 4,234	6.94	26%	19.76	20.46	21.50	23.23
B.C.	2	$ 44,661	$ 34,180	**41.4**	$ 622	1.39%	$ 5,992	9.83	24%	31.61	32.59	34.07	36.53
CANADA	2	$ 40,009	$ 33,165	**41.1**	$ 617	1.54%	$ 5,245	8.60	21%	32.53	33.39	34.68	36.83
B.C.	3	$ 65,059	$ 46,769	**57.1**	$ 857	1.32%	$ 8,064	13.22	23%	43.89	45.21	47.20	50.50
CANADA	3	$ 60,602	$ 45,881	**56.2**	$ 843	1.39%	$ 6,924	11.36	20%	44.82	45.96	47.66	50.50
B.C.	4	$ 86,149	$ 60,742	**72.5**	$ 1,088	1.26%	$ 10,637	17.44	24%	55.07	56.81	59.43	63.79
CANADA	4	$ 83,420	$ 59,447	**71.3**	$ 1,070	1.28%	$ 8,583	14.08	20%	57.25	58.66	60.77	64.29
B.C.	5	$ 142,048	$ 90,106	**101.0**	$ 1,515	1.07%	$ 13,916	22.82	23%	78.19	80.47	83.90	89.60
CANADA	5	$ 143,361	$ 88,392	**98.8**	$ 1,483	1.03%	$ 11,224	18.41	19%	80.43	82.27	85.04	89.64

Source: Authors own calculations yielded estimates.

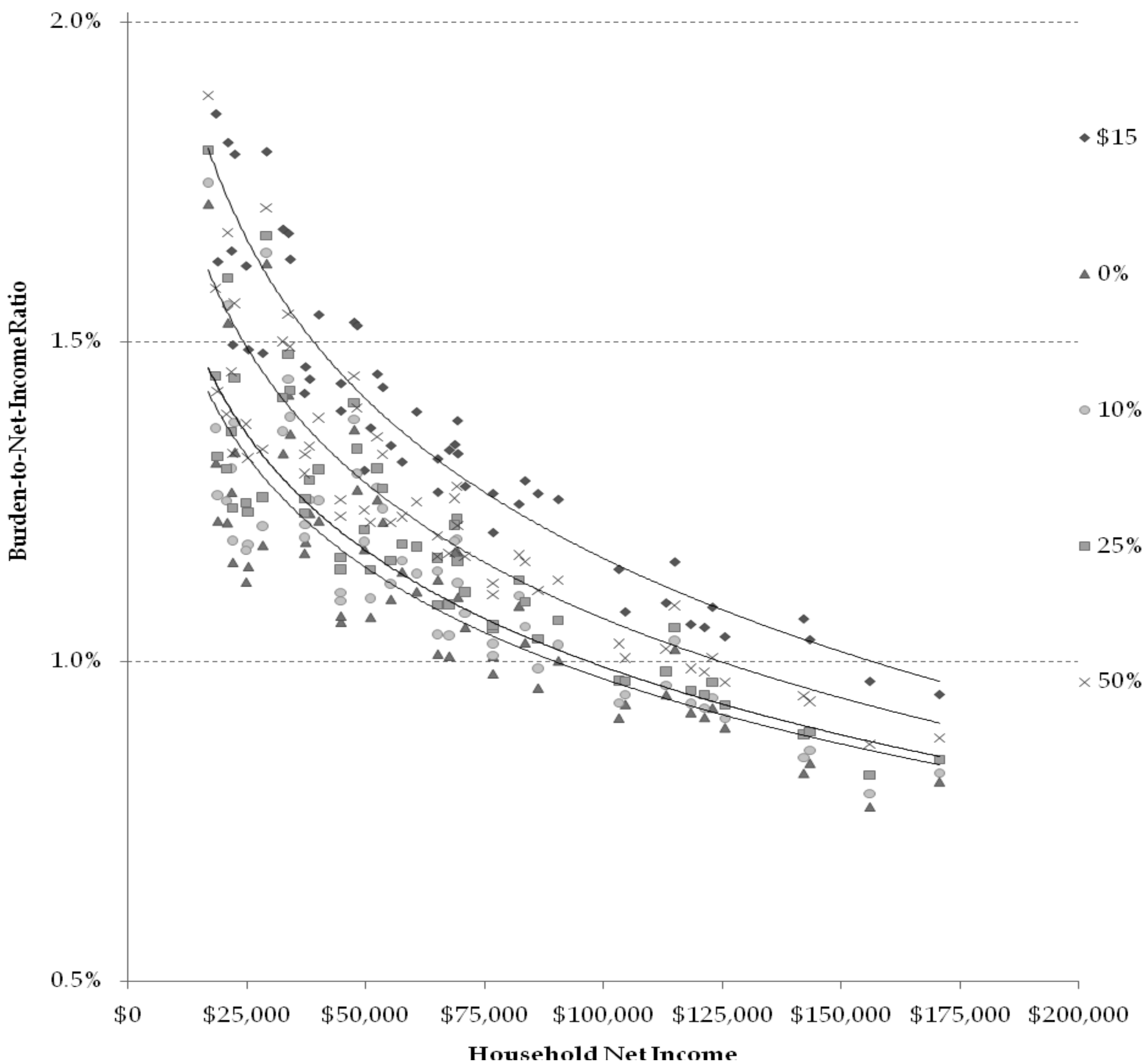
Notably, expenditure on rent and regular mortgage payments categories accounts for between 19% and 26% of the households total embedded carbon footprint. As such, these categories deserve further consideration to approximate a true measure of a household's carbon footprint. Mortgage payment expenditure as a measure of a home's carbon footprint results in an overestimation of the actual and implicit carbon associated with the building of a home.

Figure 10 illustrates graphically an extension of Table 4. The accounting implications of reweighting the carbon burden associated with rent and mortgage payments are shown to alleviate the regressive nature of a carbon pricing policy at $15/ton. Entirely excluding the categories reduces the regressive nature of the policy by approximately 0.4% for the poorest households and approximately 0.2% for the richest. Qualitatively, the results show that the level of regressivity is substantially affected depending on the measure to which housing payments are considered. The lower the share of household payments with imbedded carbon associated, the less regressive a carbon pricing policy becomes.

4.2.3. Scenario 3: Introduction of $50/ton carbon price

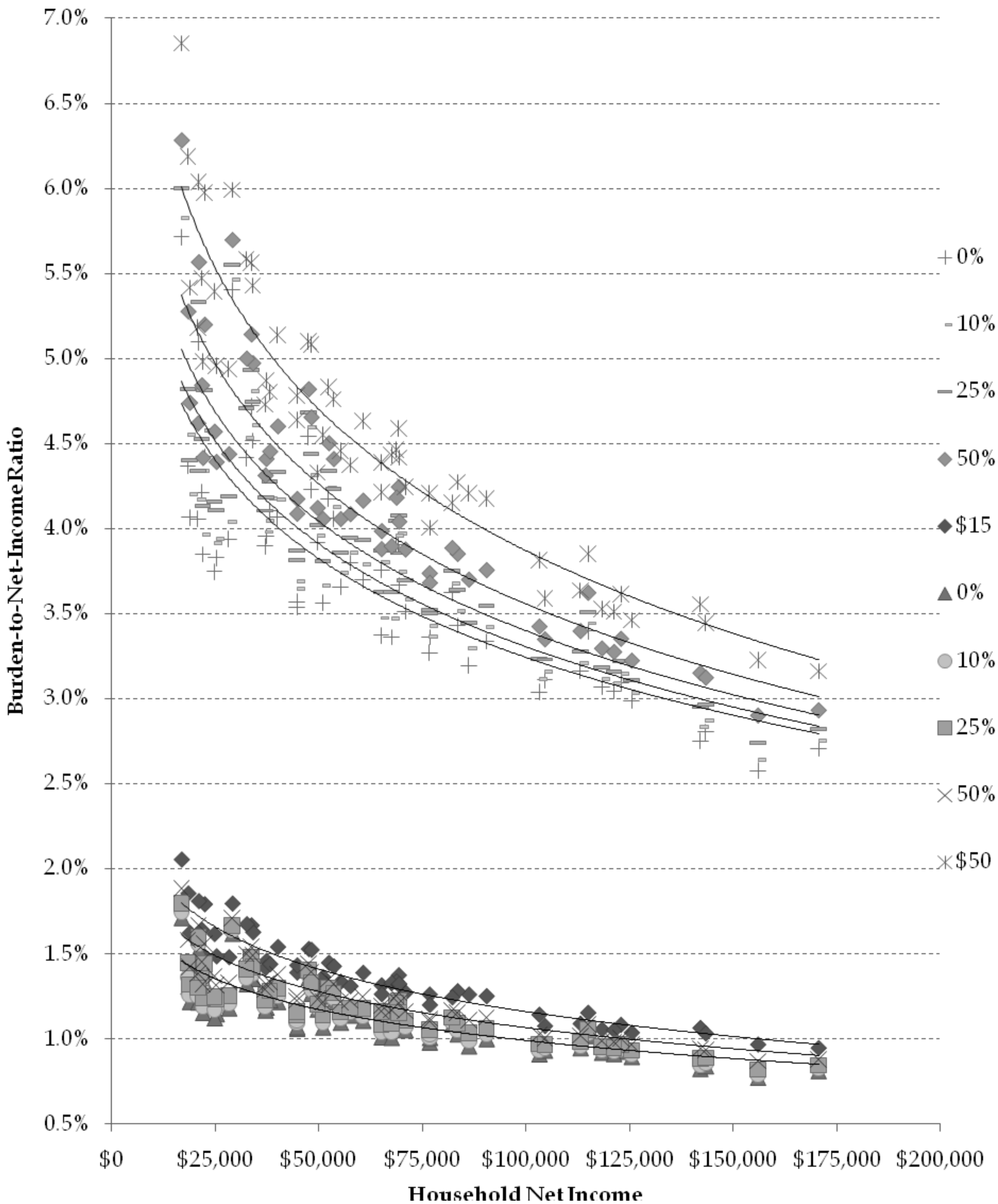
A natural next question to ask is how the regressivity of carbon pricing changes at higher tax rates. Figure 11 presents the same information as Figure 10 , and in addition included the tax rate burden associated with a $50/ton rate. Figure 11 shows that the regressivity of the policy dramatically increases as the price of carbon increases. At the lowest net income levels, approximately 6% of the households' net income would be required to pay the carbon tax bill. For the rich, that number is almost half at 3.2%. Contrasting these results to a carbon price of $15/ton, an increase to the carbon price has significant affect on the policies regressive nature.

Figure 10: Weighted Mortgage Affects ($15/Ton Carbon Price)



Source: Authors own calculations yielded estimates.

Figure 11: Weighted Mortgage Affects ($15/Ton - $50/Ton Carbon Price)



Source: Authors own calculations yielded estimates.

5. COMPENSATING HOUSEHOLDS

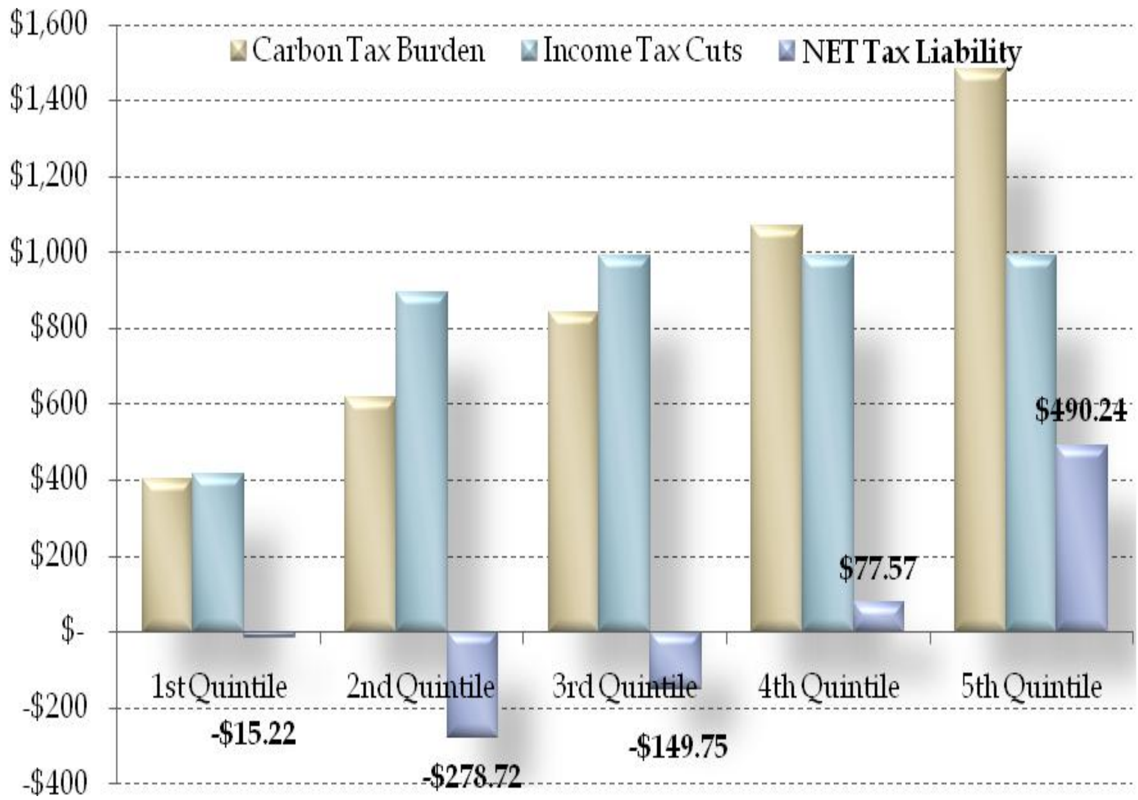
Based upon the above estimate for the household carbon tax burden across the country, with some 'back-of-the-envelope' calculations, I can calculate potential government revenues created by this policy. At a carbon price of $15/ton of emissions, around $11.1 Billion of government revenue are generated.[8] One potential use for this revenue is as compensation in the form of income tax cuts, which may help reduce the regressivity of a carbon pricing policy.

Like any new revenue generating policy, the political feasibility of implementing a tax generating policy create enormous amount of dissent from voters. For instance, British Columbia reduced the provincial income tax rate with the introduction of its Carbon Tax (BC Ministry of Finance, 2009). Provincial income tax rates fell by 5 percentage points for the first two tax brackets of the provincial schedule and, additionally, the BC government introduced a low-income refundable tax credit (BC Ministry of Revenue, 2008). The combination of tax cuts with the new carbon tax was designed to be revenue neutral. Given my estimate of revenue generated, revenue neutrality of a national carbon pricing policy could be achieved by simply reducing the tax rate on the first $40,726 from 15% to 12.56% (an approximate 2.44% reduction). Figure 11 illustrates by income quintile the carbon tax bill imposed by the policy, the tax savings from a reduction to the federal income

[8] Because my estimates of each household's tax burden is an overestimate, so too is my estimate of revenues generated. The correct measure of revenue is given by the vertical distance D-C in Figure 6.

tax rate, and the net effect to the tax liability for the average Canadian household in each quintile.[9]

Figure 11: Revenue neutral tax scheme ($15/ton carbon tax)



Source: Authors own calculations yielded estimates.

With the redistribution of tax revenues generated by a carbon pricing policy – under the condition of revenue neutrality – the policy changes from regressive to progressive in nature.

[9] The calculations were performed using the household data and the Federal tax schedule. As a result, income and tax-cuts do not take into account multiple household earners and the tax cut would be applied on the 'per-household' level.

6. CONCLUSION

In this paper, I use a Statistics Canada Survey of Household Spending in 2007 and an augmented input-output model incorporating a lifecycle analysis for the Canadian economy to create an all-encompassing estimate for the distributional consequences of carbon pricing in Canada. I have shown that a carbon pricing policy in Canada would be mildly regressive, affecting the poor relatively more than the rich due to the fact that the poorest households budget is mostly take up by paying for essential energy intensive and highly carbon imbedded goods, such as food, shelter, transportation and energy needs. The regressivity of the policy can however be offset with a tax cut to the first tax bracket. The tax cut not only serves to change the policy from regressive to progressive, but also yield revenue neutrality (which is often politically popular).

There are several limitations of my analysis. First, I have assumed that the price on carbon is entirely borne by the households. This is less than desirable but my results do provide an upper bound estimate of the costs passed along to the households. Second, I have assumed the economy to be static, and have not incorporated consumer elasticity estimates for more accurate results. Intuitively however, I believe that incorporating consumer elasticity estimates would result in the policy moving to being even less regressive than my figures have shown prior to any change in the federal taxation schedule. Third, I have assumed that a carbon-pricing scheme would be all encompassing for the Canadian economy. Due to both politics and the difficulty of monitoring all fixed sites, undoubtedly some level of exclusion from the policy will occur. Fourth, I have only used production data from the Canadian economy and have not considered the relative cleanliness or resulting implications from foreign trade that would lower the estimated household tax burden and regressive nature of the policy.

Effectively a carbon-pricing scheme adds a new tax, placing an added burden on consumers. This policy can create substantial government revenues. The regressive nature can be eliminated through a well thought out redistribution of revenues from various methods. Lump-sum transfers, offsetting income tax cuts or directly targeting spending on low-income households are all potential ways to minimize the burden on the poor.

When considering the impact and implication of a carbon-pricing scheme, revenue neutrality in the past has been a significant issue for the public. By offsetting this de-facto consumption tax with a reduction in personal taxes, the policy achieves revenue neutrality and the poorest household consumer is without a loss to personal income from the policy.

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