Household Impact of Carbon Mitigation Policies: A General Equilibrium Assessment

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Abstract

This paper examines the welfare effect on households resulting from a policy reform aimed at curbing emissions released in Canada. The household category is disaggregated into 50 household groupings. Examining the household category at such a detailed level enables one to determine more accurately which household groups are impacted the most from this policy reform. Two simulations are performed. The first models government transfers to households exogenously while the second models government savings exogenously. The results of both simulations are then compared.

Keywords: General Equilibrium, Carbon Tax, Inequality, Equivalent Variation

1 Introduction

Over the last decade, much research has been done to determine a cost effective environmental policy aiming at reducing emissions without hindering Canada's economy. The Kyoto Protocol, an agreement made under the United Nations Framework on Climate Change (UNFCC) in 1997, was the most important policy proposed and nearly implemented globally. The Kyoto Protocol's objective is to regulate the levels of carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, Hydro fluorocarbons (HFC), and Per fluorocarbons (PFC) produced by industrialized countries at a global level. Countries that ratify this accord are permitted to engage in emissions trading. The main problem with this type of global regulation is the level of difficulty in obtaining the necessary commitment from the participating countries.

*I would like to thank Professor Dissou for all the time he spent working with me writing the GAMS codes for this model. I would also like to thank employees of Statistics Canada for helping me with the SPSD/M micro-simulation program and finally I would like to thank my family and friends for their support.

An alternative type of approach has since been adopted by industrialized countries to counter the effects of climate change on a national, provincial/state and local basis. In British Columbia (Canada), for example, the provincial government introduced a consumer-based carbon tax in 2008. The carbon tax is applied to all fossil fuels, including gasoline, diesel, natural gas, coal, propane and home heating fuel. The province then returns the revenues collected in the form of tax cuts and credits. Denmark, in contrast to Canada, "carries one of the heaviest environmental tax burdens in the world [which brings] in around 10 percent of public revenues" Wier et al. (2005). The authors specify that the country has one of the highest national CO_2 emissions-per-capita levels in Europe. For that reason, it has taken it upon itself to reduce CO_2 emission levels by 21 percent of 1990 levels between 2008 and 2012, surpassing the 8 percent target imposed by the European Union Kyoto commitment.

One problem with this type of approach when dealing with climate change is that not all countries have complex tax systems in place such as Denmark. The type of tax policy in Weir *et al.*'s analysis is effective, when considering distributional impacts of tax policy, as there exists a broad range of tax bases to choose from and the general tax levels are high. McKitrick (1997) states that "as long as there already exists at least one tax which is more distortionary than a new tax on fossil fuels, the potential will exist for efficiency gains through a revenue-neutral switch away from the more burdensome revenue choice". For the purpose of this study, examining the effect of emission taxes on the economy would be most effective, as the central aim is to gain further insight relating to the distributional impact on household welfare is affected by government initiatives aiming to reduce emissions.

This study will try and answer several possible questions. More specifically, the purpose of this study is to determine the potential welfare and redistributive effects of a hypothetical policy reform imposing a tax on emissions, in the context of the Canadian economy. The primary question this study will attempt to answer is whether low income households can be made equally as well-off as wealthier households by implementing a policy reform which redistributes revenues generated from the emission tax. Thereby, this study will pay specific attention to the welfare and distributional impact on the disaggregated household groups. More specifically, this study, like many other studies, will use equivalent variation as a measure of welfare. As well, this study will include various emission types in determining the environmental impact of households, not just carbon dioxide. This added level of detail will provide the reader with a more realistic understanding of consumer preferences and their impact on the environment.

This study is organized as follows. Section 1 presents a brief overview of research that has been conducted on issues surrounding carbon taxes and tax redistribution as well as the different modeling issues that arise. Section 2 then presents the basic features, assumptions, and equations of the model. Additionally, this section presents the data used for simulating the model. Section 3 briefly describes the simulations performed and section 4 presents the economic and environmental impact of the simulations. In section 5, a sensitivity analysis is carried out to give a sense of the impact of slight changes to the model and how the results are affected. Finally, section 6 presents the welfare effect of the two simulations performed and section 7 provides a summary and the main conclusions.

1.1 Literature Review

The existing literature indicates that computed general equilibrium (CGE) modeling has proven to be an effective method of modeling the economy. Benefits of this methodology include its ability to represent the economy in the medium run without having to make oversimplifying assumptions. For the purpose of this paper, using a CGE model is useful since tax incidence is appropriately measured in comparisons to other similar but less complex models. Another feature which makes CGE modeling a powerful instrument is its capability to integrate disaggregated information relating to one or all of its components, commonly referred to as CGE micro-simulation. This enables the user to obtain a detailed description of the effects of a reform on one or more of its specific components included in the model. For the purpose of this study, including disaggregated data relating to households is not only useful to explain the distributional impact of a reform across households but also the welfare effects. Although there are various methods within the model to describe the behaviour of the economic agents, the modeler must be aware of the various types of specifications and ensure that he/she uses the one(s) that best describes the issue being addressed. The current literature is lacking sufficient detail as to which approaches and techniques are the most appropriate when making the link between CGE and microsimulation models. The idea of joining microsimulation with CGE models dates back to the early development of Orcutt in the 1960s. Depending on the issues being addressed some models may be more appropriate than others. Considering that this study focuses on the distributional and welfare aspects of the impact of a tax reform with aim to reduce the level of emission in a specific country, a CGE-microsimulation model is best suited. Like McKitrick (1997), this study will focus on the Canadian economy but will disaggregate households such that one can observe the distributional and welfare effects.

When examining the distributional impact of a tax reform, as does this study, large amounts of household data are required to clearly differentiate the affect of the reform on the various groupings. Creedy (1998) uses the equivalent income approach to determine the welfare effect of the imposition of set of indirect taxes on goods. Creedy observes, after accounting for the direct and indirect effects of the taxes on goods, that a heavier burden will be imposed on the household categories which have higher total expenditure levels. Measures such as the Atkinson, Gini coefficients, and the Lorenz curve are useful in determining the distributional impact of such a reform.

A study produced by Cornwell and Creedy (1997), which focuses on the distributional impact of a carbon tax on households of various groupings, simulates the impact of redistributing tax revenues from the carbon tax to low income individuals. The authors are able to put a dollar value to the levels of compensating variations (CV) and equivalent variation (EV). The authors observe that the levels of CV and EV decrease with income. Cornwell and Creedy interpret their observations by arguing that low income households have higher levels of expenditure on carbon-intensive goods. This corresponds with the generally agreed argument that carbon taxes are regressive. The authors observe the pre- and post-carbon-tax Lorenz curves and determine that the tax is made less regressive from redistributing tax revenues as the minimum income guarantee (MIG) increases as a carbon-tax is implemented. The authors note that increasing the level of MIG results in increased expenditures by the recipients and thereby an increase in carbon dioxide emissions.

The literature on environmental taxation directs its attention to the taxation of commodities based on the level greenhouse gases being emitted. A tax on commodities which have high levels of emissions will divert consumers from polluting goods to environmentally friendly goods. The advantage of this method is that it does not penalize one specific industry that produces one particular commodity but instead penalizes a broad range of industries which have high GHG emission levels. Wier et al. (2005) examine the distributional impact of a carbon tax on industries and households in Denmark. The authors observe that no proportional relationship exists between the carbon intensities for each commodity group and tax payments. The authors explain this observation by the fact that energy-intensive industries are accorded tax rebates so that they can remain competitive with other countries. On the household side, the authors observe, as does Poterba (1991), that the carbon tax is regressive. As a result of comparing rural and urban household expenditures levels, the authors observe that rural families have higher direct carbon tax payments due to the high levels of consumption of fuels for transportation and energy for heating. As can be expected, the level of indirect carbon-tax payments is higher for urban households. Overall, the difference between urban and rural household carbon-tax payments is quite small. The authors suggest that governments which implement emission taxes should compensate low-income households by reducing other taxes that are more distortionary. Wier *et al.* also propose that the tax burden should be shifted from households towards businesses in order to reduce the level of regressivity. However, this tax policy should be complemented by a policy which ensures that international competitiveness is secured.

Brännlund and Nordström (2004) simulate an econometric model (revenue neutral) for Sweden representing a 100 percent increase in a carbon tax from which the revenues collected are recycled in the form of lower general VAT. The authors also run a second simulation similar to the first, except that the revenues are recycled in the form of a 23 percent subsidy on public transport to society. Brännlund and Nordström (2004) investigate the distributional impact on households of these models. Like Wier et al. (2005), the authors observe that the tax reform in the first model is regressive. In this model, the authors determine that the welfare loss, measured using CV, is greater for households in the northern part of Sweden. In the second model, the authors determine that the distributional effect of the tax reform has only a very slight impact. Again, the authors determine that households in the northern part of Sweden pay more taxes than urban households, who receive a subsidy. It was also observed that low-income households bear a smaller tax burden than high-income households. Overall, in terms of the distribution of the tax burden and the welfare loss, the authors observe that the second model is less equitable than the first.

2 Methodology

The CGE model used in this paper is based on the model developed by Dissou (2005) in a study entitled "Cost-Effectiveness of the Performance Standard System to Reduce CO2 Emissions in Canada: A General Equilibrium Analysis". This study will contribute to the current literature by focusing specifically on the impact of environmental reform on different household categorizes to capture the distributional impact. In turn, this will capture the impact of a tax on emissions on consumer prices. Ultimately, since the objective of this paper is to gain insight on the welfare and distributional effect of the policy reform, the government sector will be considered to be revenue neutral as in the study by Brännlund and Nordström (2004). Therefore, any additional tax revenues collected by the government will be redistributed to the households in the form of a lump-sum manner.

2.1 The Model

2.1.1 Overview

The CGE model used in this paper follows very closely the one developed by Dissou (2005) which builds upon the previous contributions from authors such as Iorwerth (2000), Bernstein et al. (1999) and Dissou et al. (2002). The model used in this paper is a static, multi-sector general equilibrium model of Canada with perfect competition. This model is ideal for simulating the aggregate and sectoral impacts of new policies such as environmental policy reforms. Unlike Dissou (2005), this paper disaggregates the household category by income bracket into 50 groupings. The methodology used to disaggregate households will be discussed in more details in the next paragraph. It is important to highlight that this study takes a national perspective. However, the data source, SPSD/M, does not include survey data from Yukon, Nunavut, Northwest Territories, persons residing on reservations and armed forces personnel residing in barracks. The following section will describe the model used and explain in detail what modifications have been made in order to answer the questions addressed.

2.1.2 Households

The representative household in this study is slightly different than in Dissou (2005). Figure 1 is a schematic representation of household preferences. For simplicity, this study characterizes the representative household's preferences by a Cobb-Douglas (C-D) function for which the representative household chooses whether to substitute consumption for leisure. The consumption category is then split into two sub-categories, energy goods and non-energy goods, which are characterized by a CES function. Energy goods are then split into two more sub-categories: electricity and fossil energy. Once again, these sub-categories are characterized by a CES function. Furthermore, fossil energy is characterized by a nested CES function which splits into three sub-categories: gas, coal and refined petroleum. Gas is then characterized by a Leontief function which is composed of natural gas and gas pipelines. On the other hand, refined petroleum splits into different types of refined petroleum. As opposed to gas, refined petroleum is described by a Cobb-Douglas (C-D) function. Focusing on the non-energy type goods, which splits into motive fuels and material goods, the model describes this nesting by a CES function. Similarly to refined petroleum, motive fuel is nested into various sub-categories of motive fuels characterized by a Cobb-Douglas function. Lastly, the material goods sub-category splits into different types of material goods characterized by a Leontief function. Overall, household preferences are presented such that the model allows for substitution between energy and non-energy goods.

This study models the representative household as obtaining income from various sources.

The household obtains its market income from employment, investments, and from other sources. Employment income consists of income from all employment and self-employment income. Investment income, as described by Statistics Canada in their in-house SPSD/M program, is the summation of all dividend income received, capital gains received, interest and other investment income. One exception is that investment income originating from Registered Retirement Savings Plans (RRSPs) is not considered investment income due to the fact that RRSP withdrawals are considered as dissavings. Other income consists mostly of pension income, other taxable income, and alimony income received. In summation, total household income consists of market income and transfer income, of which the later represents all transfers from the government to individuals. Furthermore, households also derive income from foreign sources in the form of transfers. Similarly to Dissou (2005)'s study, households also pay income tax, and Federal and Provincial sales taxes and the after-tax income is either saved or consumed. That is, household savings are a linear function of its disposable income. The objective of the households is to maximize their utility while at the same time being constrained by their budget. The outcome from solving this problem enables one to determine the optimal levels of labour that households should provide and the level of demand for various commodities produced within the Canadian and foreign markets.

A representative household maximizes his utility function (CES) subject to his budget constraint including a composite price for the commodity. The composite commodity demand is derived from these for sub-composite goods ($i = 1, \ldots, 44$). Each of these sub-composites is obtained from domestic and imported sources.

The utility function, not taking account of household leisure time, is given by:

$$U_h = \left[\sum_i \alpha_{i,h}^{\frac{1}{\sigma_h}} C_{i,h}^{\rho_h} \right]^{\frac{1}{\rho_h}} \tag{1}$$

where U_h is the utility of household h, C is the consumption of good i by household h, $\alpha_{i,h}$ is the share of the full income of household h spent on consumption of good i, and ρ_h is the elasticity

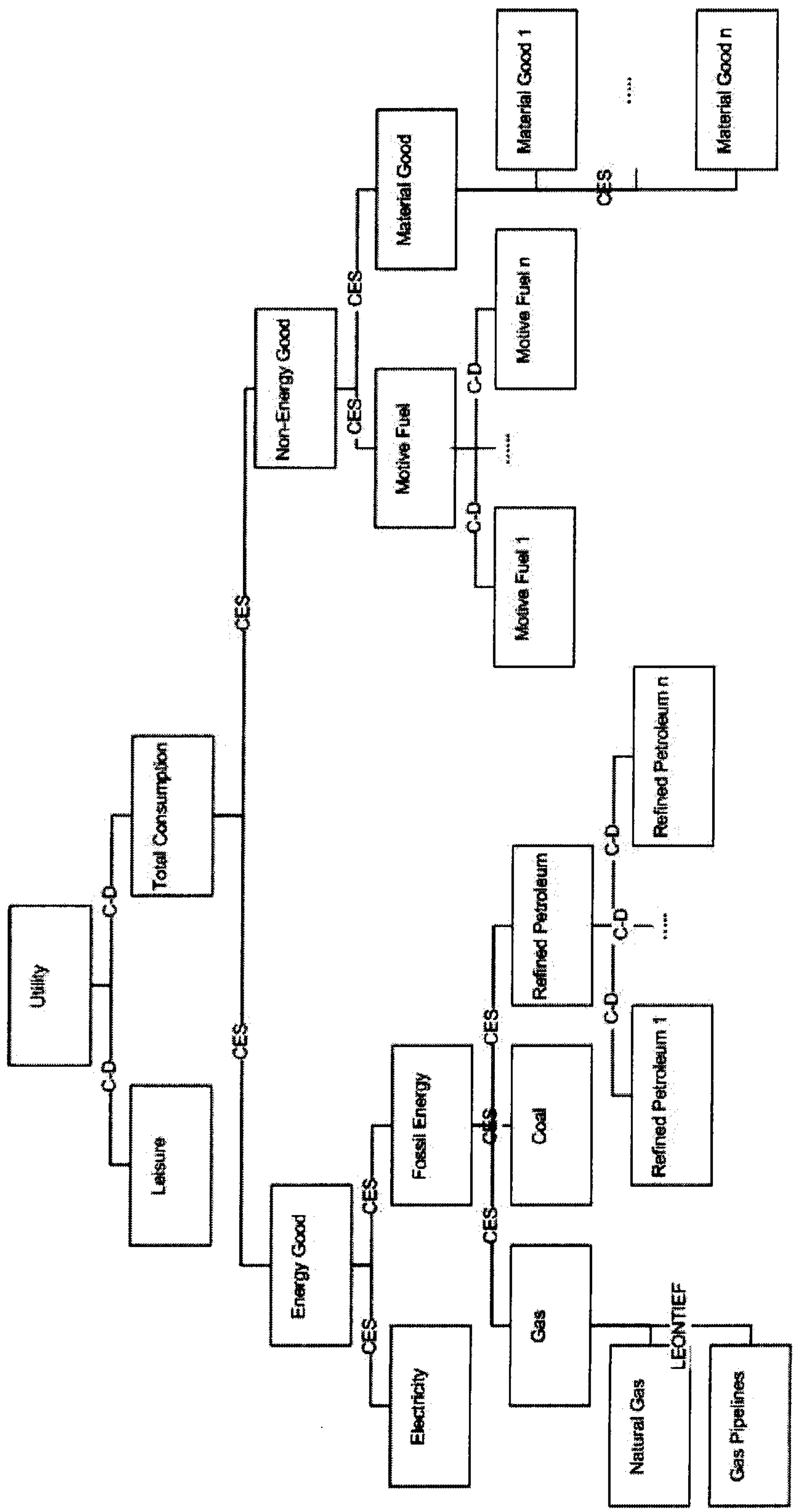

Figure 1: Schematic Representation of Household Preferences

parameter in the utility function; the elasticity of substitution between goods being equal to $\sigma_C = \frac{1}{1-\rho_h}$. Also, $\sum_i \alpha_{i,h} = 1$.

Household disposable income is represented by the following equation:

$$YD^h = \sum_i (1 - t_k) \beta_h^K r \bar{K}_h + \left(1 - t_l^h\right) wL^S + TR_G^h \tag{2}$$

where r is the rental rate of capital, K_i is the sectoral capital for the household, L is the endowment of labour, TR_G are the transfers received, w is the wage rate, t_l is the tax rate on labour income and t_k is the capital income tax. Another representation of disposable income is the following:

$$P(1 + t_C) C^h = YD^h \tag{3}$$

where P and C are prices and quantities of goods respectively and t_C is the sales tax. The demand functions for goods are obtained by maximizing (1) with respect to (2) and (3).

Solving the maximization problem gives the optimal level of consumption.

$$C_i^h = \left[\frac{\alpha_{i,h} YD}{P_i (1 + t_C)^{(1-\sigma)} \sum_i \alpha_{i,h} [P_i (1 + t_C)]^{(1-\sigma)}}\right] \tag{4}$$

2.1.3 Production

Unlike Dissou (2005), the production sector in this model is somewhat less detailed with respect to the degree of detail describing the industries representing the Canadian economy, as it is composed of 40 industries that produce 44 composite commodities sold on the domestic market or otherwise exported. On the other hand, as in Dissou (2005), all firms operate in a competitive environment where labour and physical capital are considered to be mobile across industries. Prices, which are subject to taxes net of subsidies, are considered as given in all markets. The objective of the firm is to maximize its profits such that the optimal levels of labour, capital and intermediate inputs are determined in order to ultimately produce the appropriate level of output which is determined by market demand. Economic theory indicates that it is optimal for the firm to set its price equal to the marginal cost and that the market demand determines the level of output. Firms allocate a share of its after tax profits to households in the form of dividends and save the other share for investment purposes.

The representative firm in each industry utilizes labour, capital, energy and various intermediate inputs such as motive fuels and other material inputs to produces its output using a constant-return-to-scale technology. The primary factor, capital, can be further characterized by decomposing the category into two sub-categories: capital and energy. The model assesses that the index of capital-energy is a Constant Elasticity of Substitution (CES) of capital and of the index of energy. Furthermore, the model breaks down the energy sub-category which is also characterized by a CES function into two other sub-categories: fossil energy and electricity (non-fossil energy). Additionally, fossil energy is decomposed into three more sub-categories, gas, coal and refined petroleum, which are described by a CES. Last but not least, gas is decomposed into two sub-categories: natural gas and gas pipelines. In contrast to the other lower level decompositions, gas is characterized by a Leontief aggregator. Refined petroleum, on the other hand, follows a Cobb-Douglas (C-D) function for the different types of refined petroleum. Figure 2 depicts the structure of firm technology.

The composite of intermediate inputs, composed of motive fuels and other material inputs (or non-motive fuels), follows a CES function. The nesting of motive fuels consists of a C-D function of n different types of motive fuels. Similarly, the nesting of material inputs consists of a nesting of n types of material inputs that follow a Leontief function.

For each of the 40 industries, the production process makes use of labour and capital that yield the value added. The value added is characterized by CES functions.

$$VA_i = \beta_i \left[(1-\psi_i) K_i^{\gamma_i} + \psi_i L_i^{\gamma_i}\right]^{\frac{1}{\gamma_i}} \tag{5}$$

where VA_i is a composite good of non-energy intermediate inputs, β_i is a shift parameter in the production function, K_i and L_i are the amounts of capital and labour used in sector i, Ψ_i is the share parameter of labour in the CES function, and γ_i is the CES factor substitution parameter. The gross output of each sector XTS_i is composed of value added and intermediate inputs. This model accounts for substitution between value added and intermediate inputs, and domestic and imported intermediate inputs, which is discussed further in the next section. The mathematical problem is represented by the following equation in which the producers in each sector maximize profits Π_i subject to their technology constraint:

$$\Pi_i = P_{XTS_i} XTS_i - wL_i - \sum_i r_i K_i - \sum_i P_{INT_j} \left(1 + t^d_{i,j}\right) INT_{i,j} \tag{6}$$

where $INT_{i,j}$ is the demand for intermediate input, P_{XTS_i} the price of gross output, and $t^d_{i,j}$ are taxes on intermediate demands. In equilibrium, factor demands by sectors are determined where the value of the marginal product of factors equals factor prices, and there are no positive profits for producers.

2.1.4 Government and Other Components of Domestic Demand

In this study, the model includes a revenue neutral government sector. That is, the government redistributes all income that it generates from taxes and adjusts to any changes in revenues by increasing or decreasing the level of transfers it makes in order to keep its balance constant. The government sector levies its revenues from four different sources of taxation, of which the tax rates are levied on ad valorem basis. The first two sources are from indirect taxes (net of subsidies) on production activities and on commodities used for final demand purposes. The third source of revenue is from taxes on international transactions. Finally, the last source of income for the government is in the form of direct taxes on households' and firms' incomes. The same tax rate is applied to all commodities if it is used for the same purpose. However, should a particular commodity's reason of purchase vary, whether it be for consumption, investment or government purposes, it would then face different tax rates. For simplification purposes, this study assumes there is only one level of government which does not follow an optimizing behaviour. It would be interesting to account for the three levels of government separately (Federal, Provincial and Municipal) due to the fact that a province like Alberta is taxed at lower level than a province such as Ontario which in turn may impact the choices made by individuals and firms. Including this type of information in the SAM and in the I-O tables would elevate the level of complexity due to the magnitude of information to be manipulated. On the expenditure side, government

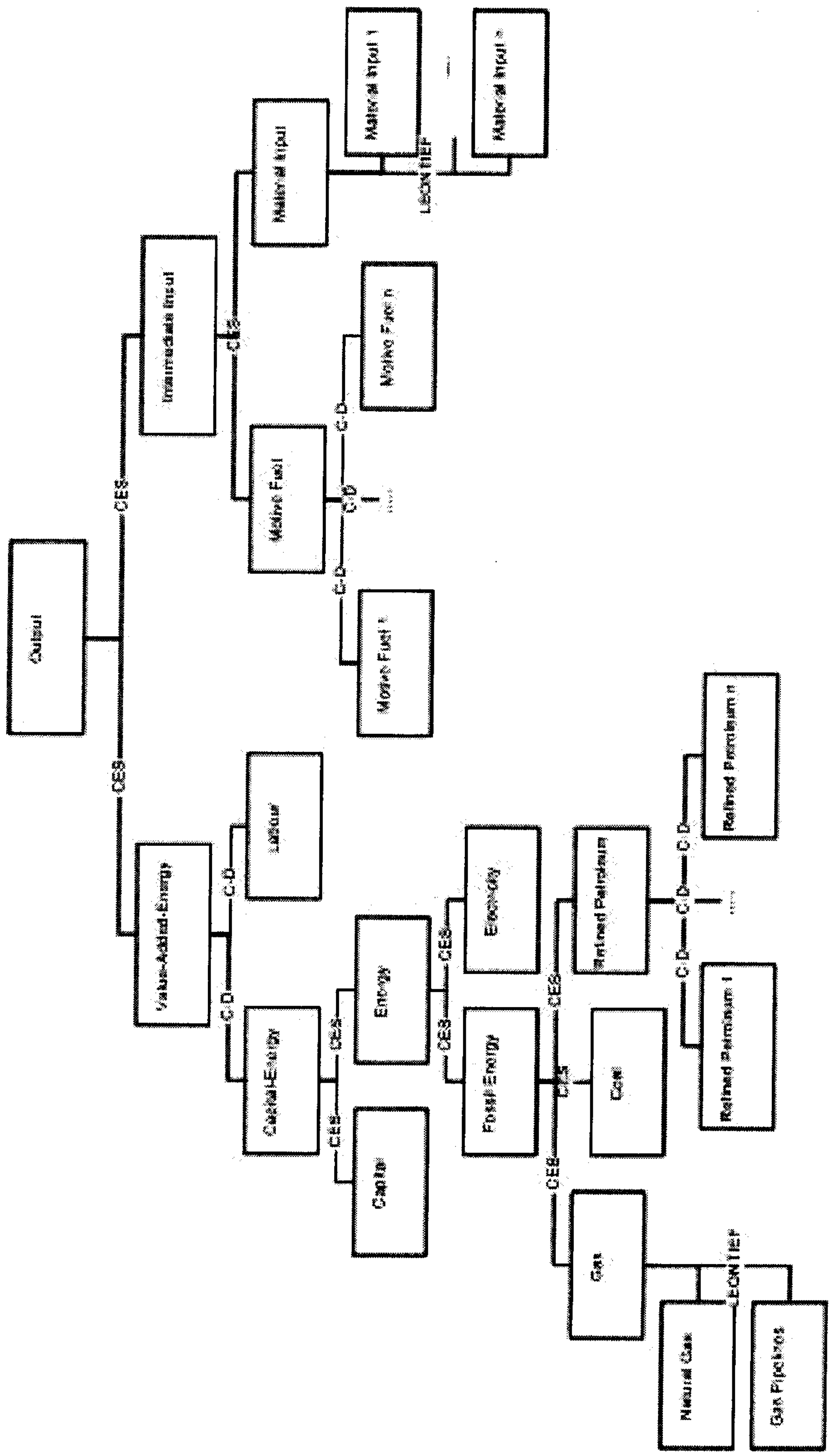

Figure 2: Schematic Representation of Firm Technology

expenditures on goods and services are fixed in real terms, however, its transfers to households are constant in nominal terms. Interest payments on government debt consist of another form of government expenditure. The government collects direct and indirect taxes from households on their income and taxes on consumption.

$$YG = \sum_i tc_i PC_i C_i + \sum_i t_{G_i} PC_i G_i + \sum_i t_{inv_i} PC_i D_{inv_i} + \sum_{ij} tp_j P_{XTS_j} XTS_j + t_{y_E} YE + t_{y_H} YTH \tag{7}$$

$$SAVG = YG - \sum_i P_{C_i}(1 + t_{G_i})G_i - TR_G \tag{8}$$

No study of the Canadian economy would be realistic without accounting for transactions between Canada and the rest of the world (ROW). In this model, firms sell their output on the domestic and export markets. Domestic agents, such as households, firms and government, consume foreign goods along with domestically produced goods. In this model, the price of imports and exports are considered to be exogenous. However, because the government imposes tariffs on imports of all commodities, the pricing system is distorted. To keep this model simple, one should assume that the primary production factors (capital and labour) are not traded between countries. Another simplification made is that the Armington assumption captures the degree of substitutability between domestic and imported goods. This assumption suggests that imports and domestically produced goods be treated as imperfect substitutes. The Armington assumption enables one to overcome the problem of cross-hauling, which is defined as the action of exporting and importing the identical good at the same time. Ultimately this implies that domestic agents will consume a composite commodity made of both domestic and imported goods. Armington characterizes the composite commodity consumed domestically as a CES aggregator of the domestic good and imports. Total demand for each commodity (XTD_i) is a CES composite of the domestic goods, XDD_i, and imports, M_i. The optimal composition of the aggregate is determined by solving a cost minimization problem.

$$MIN\ P_{C_i} XTD_i = P_{d_i} XDD_i + P_{M_i}\left(1 + t_{M_i}\right) M_i \tag{9}$$

subject to

$$XTD_i = A\left[\chi_d XDD_i^{-\omega} + \chi_M M^{-\omega}\right]^{-\frac{1}{\omega}} \tag{10}$$

where P_{C_i}, P_{d_i}, P_{M_i} are respectively, the price of the composite, domestic and import goods. Additionally, ω represents a parameter of substitution between domestic goods and imports. A is a shift parameter and χ_d and χ_M represent share parameters for domestic and import goods, respectively. Tariffs are accounted for in equation (8) by t_{M_i}.

The size of the Armington elasticity significantly impacts imports and thereby affects domestic output following a change in tariffs. Solving this cost minimization problem will give the optimal demands for the import and domestic commodities and the composite price of the aggregate good. The first order condition of this optimization problem is the following:

$$\frac{M_i}{XDD_i} = \left[\frac{\alpha_i^M P_{d_i}}{\left(1-\alpha_i^M\right) P_{M_i}}\right]^{\sigma_i^M} \tag{11}$$

After manipulating the above equation, it is possible to determine an equation for M_i, XDD_i, and P_{C_i}. These three equations enable the model to determine the composite price of the aggregate good and the optimal demands for import and domestic commodities.

$$P_{C_i} = \frac{1}{AM_i}\left[\left(\alpha_i^M\right)^{\sigma_i^M}\left(P_{M_i}\right)^{1-\sigma_i^M} + \left(1-\sigma_i^M\right)^{\sigma_i^M}\left(P_{d_i}\right)^{1-\sigma_i^M}\right]^{\frac{1}{1-\sigma_i^M}} \tag{12}$$

$$M_i = \left(AM_i\right)^{\sigma_i^M-1}\cdot XTD_i\left[\frac{\alpha_i^M P_{C_i}}{P_{M_i}}\right]^{\sigma_i^M} \tag{13}$$

$$XDD_i = \left(AM_i\right)^{\sigma_i^M-1}\cdot XTD_i\left[\frac{\left(1-\alpha_i^M\right) P_{C_i}}{P_{d_i}}\right]^{\sigma_i^M} \tag{14}$$

On the supply side, the output XTS_i of the firm obtained from the combination of primary factors and intermediate inputs would therefore be considered as a composite of the domestic sales XDS_i and exports EX_i. This model assumes that the aggregator function is characterized by a CET function. The firm's objective is to maximize its revenue in order to determine the optimal composition of output.

$$MAX\ P_{XTS_i} \cdot XTS_i = P_{d_i} XDS_i + P_{EX} \left(1 + t_{EXi}\right) EX_i \tag{15}$$

subject to

$$XTS_i = A \left[\delta_d XDS_i^{\lambda} + \delta_e EX_i^{\lambda} \right]^{\frac{1}{\lambda}} \tag{16}$$

where P_{XTS_i}, P_{d_i}, P_{EX_i} are respectively, the price of the composite, domestic and export goods and σ_i^x, α_i^x, AX_i are respectively the substitution, share and shift parameters in the CET function. Additionally, parameter λ represents the elasticity of substitution between domestic goods and imports. A is the shift parameter. Finally, δ_d represents a share parameter for domestic goods and δ_e the share parameter for export goods. In equation (15), t_{p_i} represents a tax on production and t_{EX_i} representing duties.

The effect of an increase in the relative price of exports to that of the domestic good will increase the ratio of exports to domestic sales. Additionally, the higher the elasticity of transformation, the higher the sensitivity of the ratio of exports to domestic sales to relative price changes. The first order condition of this optimization problem are the following:

$$\frac{EX_i}{XDS_i} = \left[\frac{\left(1 - \alpha_i^x\right) P_{EX_i}}{\alpha_i^x P_{D_i}} \right]^{\sigma_i^x} \tag{17}$$

After manipulating the above equation, it is possible to determine an equation for EX_i, XDS_i, and $P_{XTS_i}(1 + t_{p_i})$. These three equations enable the model to determine the price of output, the level of export sales, and the level of domestic sales.

$$P_{XTS_i}\left(1 + t_{p_i}\right) = \frac{1}{AM_i} \left[\left(\alpha^{x_i}\right)^{-\sigma_i^x} \left(P_{EX_i}\right)^{1+\sigma_i^x} + \left(1 + \sigma_i^x\right)^{-\sigma_i^x} \left(P_{D_i}\right)^{1+\sigma_i^x} \right]^{\frac{1}{1+\sigma_i^x}} \tag{18}$$

$$EX_i = \left(AX_i\right)^{-\left(\sigma_i^x + 1\right)} XTS_i \left[\frac{P_{XTS_i}\left(1 + t_{p_i}\right)}{\alpha_i^x P_{EX_i}} \right]^{\sigma_i^x} \tag{19}$$

$$XDS_i = \left(AX_i\right)^{-\left(\sigma_i^x + 1\right)} XTS_i \left[\frac{P_{XTS_i}\left(1 + t_{p_i}\right)}{\left(1 - \alpha_i^x\right) P_{D_i}} \right]^{\sigma_i^x} \tag{20}$$

Domestic demand of each commodity consists of the summation of the demand of households, government and firms for consumption, intermediate and investment uses from all industries. It is assumed that the share of each commodity in total investment is fixed. Because of the Walras Law, the sum of the values of demand for investment equals the economy's aggregate savings, for which the later is the sum of household, firm, government and foreign savings. Dissou (2005) highlights the fact that the "demand for the commodity [is] for investment purposes, i.e., investment goods, instead of investment by sector of destination, which increases the sectoral capital stock". In order to determine the optimal level of each component of the domestic total demand one must solve a cost-minimization problem. Overall, the model ensures that the supply of domestic goods is equal to the demand for domestic goods.

2.1.5 Equilibrium Conditions and Closure Rules

As in all general equilibrium models, it is essential that all markets clear. That is, there must be equilibrium in the domestic goods market which implies that the supply of goods produced in the economy equals the demand for these goods. Additionally, the labour supply must equate the amount of labour demanded for every type of occupation. Once these two equilibrium conditions are obtained, it is then possible to determine the prices of the domestic goods and wage rate respectively. The third equilibrium condition is that the total demand and supply of CO_2 emissions be equal. The demand and supply for emissions are determined endogenously in this model according to the exogenously set price for GHG of 40 dollars per tonne. The fourth and final equilibrium condition established is the balance of payments equilibrium. The purpose of this condition is to "prevent policy changes from being financed by capital inflows coming from the rest of the world" (Dissou, 2005). It should also be mentioned that the current-account balance of Canada is fixed.

The first closure rule establishes the nominal exchange rate as the numeraire. As a result of this closure rule being set, the real exchange rate is therefore responsible for enabling the last equilibrium condition, the balance of payments, to be realized. Another closure rule included in this model is that government transfers to households are used as an adjusting variable to return the balance of the government account into equilibrium. The final closure rule highlights the fact that this model is saving driven, thereby the endogenously determined investment expenditures depend on the level of savings in the economy.

2.2 Data, calibration and numerical solution strategy

The data sources used to build the SAM used in this study originate from the 2004 Canadian National Accounts Input-Output table produced by the Industry Accounts Division at Statistics Canada, the 2003 Survey of Household Spending (SHS) also produced by Statistics Canada and finally greenhouse gas emission data by sector produced by the Environment Accounts and Statistics Division at Statistics Canada.

The objective is to build a complete SAM representative of the Canadian economy and sufficiently detailed to enable a thorough analysis to answer the previously mentioned questions. The first step is to modify the I-O table by modifying the industry categories by using a new taxonomy which is better suited for this study. This requires that I aggregate the 105 industrial activities into forty categories. The industries are aggregated to summarize the leading industrial activities in Canada, while at the same time conserving an appropriate level of detail. The complete list of industry mapping is indicated in figure 3. An example of such a grouping would be the merging of the "Crop and Animal Production" category with the "Forestry and Logging" category to form the "Agriculture" industry category. Once the industry data is properly formatted, the data is included in the SAM.

The second step is to include the intermediate input consumption by the various industries into the SAM. This implies including the commodities consumed by the industries in their manufacturing/production process. The data included in this portion of the SAM is collected from the re-mapped I-O table. Data relating to the sales of manufactured products sold to the various industries is also included in the SAM. This data is obtained from the I-O table, but more specifically from the section composed of personal expenditure (PE) data. The totals in this section include taxes whereas the section including intermediate input data is gross of tax.

Table 20
Industrial Sector Mapping

Industrial Sector	2004 Input-Output Matrix Code	Description
Agriculture	11A0; 1130	Crop and Animal Production; Forestry and Logging
Fishing & Forestry	1140; 1150	Fishing, Hunting and Trapping; Support Activities for Agriculture and Forestry
Oil & Gas	2111; 2131	Oil and Gas Extraction; Support Activities for Mining and Oil and Gas Extraction
Coal	2121	Coal Mining
Mining	2122; 2123	Metal Ore Mining; Non-Metallic Mineral Mining and Quarrying
Electricity	2211	Electric Power Generation, Transmission and Distribution
Gas Pipeline	221A; 4860	Natural Gas Distribution, Water, Sewage and Other Systems; Pipeline Transportation
Construction	230A; 230X; 230H; 230I	Residential Building Construction; Non-residential Building and Engineering Construction; Repair Construction; Other Activities of the Construction Industry
Food	3111; 3113; 3114; 3115; 3116; 3117; 311A	Animal Food Manufacturing; Sugar and Confectionery Product Manufacturing; Fruit and Vegetable Preserving and Specialty Food Manufacturing; Dairy Product Manufacturing; Meat Product Manufacturing; Seafood Product Preparation and Packaging; Miscellaneous Food Manufacturing
Beverage	312A; 312B; 312C; 312D;	Soft Drink and Ice Manufacturing; Breweries; Wineries; Distilleries
Tobacco	3122	Tobacco Manufacturing
Textile	31A0; 3150; 3160	Textile and Textile Product Mills; Clothing Manufacturing; Leather and Allied Product Manufacturing
Wood	3210	Wood Product Manufacturing
Pulp & Paper	3221; 3222	Pulp, Paper and Paperboard Mills; Converted Paper Product Manufacturing
Printing	3231	Printing and Related Support Activities
Refineries	3241	Petroleum and Coal Products Manufacturing
Chemical	3251; 3252; 3253; 3254; 325A	Basic Chemical Manufacturing; Resin, Synthetic Rubber, and Artificial and Synthetic Fibres and Filaments Manufacturing; Pesticides, Fertilizer and Other Agricultural Chemical Manufacturing; Pharmaceutical and Medicine Manufacturing; Miscellaneous Chemical Product Manufacturing
Plastic	3261	Plastic Product Manufacturing
Rubber	3262	Rubber Product Manufacturing
Non metallic	3273; 327A	Cement and Concrete Product Manufacturing; Miscellaneous Non-Metallic Mineral Product Manufacturing
Steel	3310	Primary Metal Manufacturing
Metal fabrication	3320	Fabricated Metal Product Manufacturing
Machinery	3330	Machinery Manufacturing
Electricity Production	3341; 334A; 3352; 335A	Computer and Peripheral Equipment Manufacturing; Electronic Product Manufacturing; Household Appliance Manufacturing; Electrical Equipment and Component Manufacturing
Transportation equipment	3361; 3362; 3363; 3364; 3365; 3366; 3369; 3370	Motor Vehicle Manufacturing; Motor Vehicle Body and Trailer Manufacturing; Motor Vehicle Parts Manufacturing; Aerospace Product and Parts Manufacturing; Railroad Rolling Stock Manufacturing; Ship and Boat Building; Other Transportation Equipment Manufacturing; Furniture and Related Product Manufacturing
Other manufacturing	3390	Miscellaneous Manufacturing
Wholesale	4100	Wholesale Trade
Retail trade	4A00	Retail Trade
Transportation	4810; 4820; 4830; 4840; 4850; 4880	Air Transportation; Rail Transportation; Water Transportation; Truck Transportation; Transit and Ground Passenger Transportation; Scenic and Sightseeing Transportation and Support Activities for Transportation
Storage	49A0; 4930	Postal Service and Couriers and Messengers; Warehousing and Storage
Communication	5120; 5131; 513A; 51A0	Motion Picture and Sound Recording Industries; Radio and Television Broadcasting; Pay TV, Specialty TV and Program Distribution and Telecommunications; Publishing Industries, Information Services and Data Processing Services
FIRE	5A01; 5A02; 5A03; 5A04; 5A05; 5A06	Monetary Authorities and Depository Credit Intermediation; Insurance Carriers; Lessors of Real Estate; Owner-Occupied Dwellings; Rental and Leasing Services and Lessors of Non-Financial Intangible Assets (except Copyrighted Works); Other Finance, Insurance and Real Estate and Management of Companies and Enterprises
Services to Businesses	5418; 541A; 541B; 5610; 5620	Advertising and Related Services; Legal, Accounting and Architectural, Engineering and Related Services; Computer Systems Design and Other Professional, Scientific and Technical Services; Administrative and Support Services; Waste Management and Remediation Services
Education	611A	Educational Services (except Universities)
Health	62A0	Health Care Services (except Hospitals) and Social Assistance
Amusement	7100	Arts, Entertainment and Recreation
Accomodation	7200	Accommodation and Food Services
Other services	8110; 813A; 81A0	Repair and Maintenance; Grant-Making, Civic, and Professional and Similar Organizations; Personal and Laundry Services and Private Households
Non profit	NP11; NP12; NP13; NP19; NP20	Religious Organizations; Non-Profit Welfare Organizations; Non-Profit Sports and Recreation Clubs; Other Non-Profit Institutions Serving Households; Non-Profit Education Institutions
Government	GS11; GS12; GS21; ; GS22; GS40; GS50; GS60	Hospitals; Government Residential Care Facilities; Universities; Government Education Services; Other Municipal Government Services; Other Provincial and Territorial Government Services; Other Federal Government Services

Source: Author's elaboration and Statistics Canada (2004)

Figure 3: Industry Sector Mapping

Data relating to taxes paid by households for each of the commodity categories is also obtained from the re-mapped I-O table.

Other National Accounts data relating to labour income and direct taxes at home and abroad obtained from Statistics Canada's online catalogue is then included into the SAM. Data relating to exports and imports, obtained from the re-mapped I-O table iss also included into the SAM.

Once the SAM is complete, it is possible to disaggregate industry categories such as "Oil and Gas Extraction" and "Petroleum and Coal Products Manufacturing". The purpose of disaggregating the above categories is to gain insight into the effect of taxing industries that emit large amounts of greenhouse gases.

The next step is to focus on disaggregating the household categories. This entails paying close attention to the 2003 SHS data. This survey is somewhat recent as the latest version of the SHS is for 2006 (published in February 2008). The data from the SHS, which gathers information on the spending habits, dwelling characteristics and household equipment of Canadian households is then categorized according the standards of the Canadian System of National Accounts (SNA). The SHS microdata mapped to the SNA categories is obtained through a program called the Social Policy Simulation Database and Model (SPSD/M), a microsimulation program produced by Statistics Canada to analyze the financial interactions of government and individuals in Canada. This program is founded on a database which uses 2003 as the base year. Thereby, the personal expenditure microdata collected from this program is used primarily to identify the shares of income and expenditures for each household category. Once the micro-data is extracted from the SPSD/M, the groupings are determined by first ranking the 80,783 households according to their incomes in ascending order and then grouping them into the fifty groups, representing the fifty household categories. For the purpose of this study, the use of a large sample of household categories is essential to ensure that the analysis could include a significant degree of detail as to any differences which may exist between household categories. The SPSD/M is composed of individual administrative data from personal income tax returns and unemployment insurance claimant histories, survey data on family incomes and on expenditure data. Statistics Canada, ensuring complete data confidentiality, uses a specialized methodology to ensure that no confidential data is disclosed. The data sample used in this paper includes 80,783 [1] households. No record in this sample contains information for the same individual more than once from the four bases. Statistics Canada describes this database as being constructed to provide a micro-statistically representative sample of Canadians. Because this study uses a 2004 I-O table, only the calculated shares from the SPSD/M program are used. This implies that, although 2003 household data is used, the overall conclusions can be made for year 2004 assuming no drastic changes occurred between the two years.

Similarly to Dissou (2005), the assumption is made that the transactions observed in year 2004 is representative of the outcome of a given equilibrium. The GAMS (General Algebraic Modeling Systems) software is used to solve the model. Data on emission is obtained from the Environmental Statistics Division at Statistics Canada. Similarly to the data I-O tables used in constructing the SAM, the data used for the matrix of emission by industry is for year 2004. However, to determine the emission intensity for industries without information due to confidentiality issues, the replacing values were estimated based on emission intensity shares for 2003.

3 Simulation Description

Like McKitrick (1997)'s study which performs five different tax simulations on the Canadian economy, this study compares the results from multiple simulations to a base scenario. The base scenario is the case of business as usual (BAU). The BAU scenario is representative of the Canadian tax structure in its current state. The purpose of this type of policy, labeled as the "polluter pays" principle, is to entice polluting firms to reduce their emissions and adopt new environmentally sound practices. More specifically, this study simplifies the entire structure and simply focuses on a 40 dollar tax per tonne of emissions. However, the simulations differ slightly between one another. The first simulation examine the impact on the Canadian economy of implementing these emission taxes when government transfers to households are held fixed and

[1] The reason SPSD/M generates such a large dataset is to preserve the confidently of the survey data which is based on several STC produced surveys but largely based on the SHS

Simulation Results for Aggregate Economic Indicators

Indicator (expressed in the form of a percentage change)	*Simulation*	
	Simulation 1	*Simulation 2*
Percentage change in the Gross Domestic Product at Market Prices	-0.28	-0.34
Percentage change in real total consumption	-1.08	0.63
Percentage change in real total investment	1.56	-3.35
Percentage change in real total net exports	-0.02	-0.01
Percentage change in total real imports	-0.84	-1.63
Percentage change in total real exports	-0.75	-1.45
Percentage change in the real exchange rate	0.25	0.26
Percentage change in the consumer price index (CPI) (with permits)	0.86	0.85
Percentage change in the CPI (without permits)	-0.21	-0.22
Percentage change in the domestic good price index	-0.25	-0.26
Percentage change in the rental rate of capital	-3.04	-3.02
Percentage change in the nominal wage rate	-0.84	-0.86
Percentage change in the gross real wage rate CPI	-1.68	-1.70
Percentage change in the total. labour supply	0.08	-0.13
Percentage change in household real consumption	-1.08	0.63
Price of carbon permit	40.00	40.00
Percentage reduction in industry emissions	-29.36	-29.90
Percentage reduction in total household emissions	-22.36	-20.94
Percentage reduction in total emissions	-28.15	-28.35

Source: Author's calculations

Figure 4: Aggregate Simulation Results

government savings are endogenous. The second simulation reproduce the same simulations as in the first except, instead of transfers being held fixed, this time government savings is held fixed and government transfers to households are endogenous.

4 Simulation Results

4.1 The Welfare Effect of Price Changes with Transfers of Permit Revenues to Households - Government Transfers Held Fixed - The Case of a 40 Dollar Permit - Simulation 1

This first section focuses on the impact of imposing a 40 dollars per tonne tax on emissions, while government transfers are modeled exogenously. Similarly to Dissou (2005), the model is designed at the upstream point. That is, this simulation highlights the effect of imposing a permit system which requires suppliers and importers of fossil fuels in Canada to purchase carbon permits. This analysis examines primarily the welfare effect on households as a result of the implementation of a carbon tax. The emissions generated from the consumption of coal, natural gas, gasoline, diesel, liquid petroleum and other refined products are of secondary concern.

The effect of implementing a new regulation requiring firms to pay 40 dollars per tonne of emissions released has a significant impact on the economy. From the results in the first column in figure 4, the effect of this new regulation drives the consumer price index (CPI) up 0.86 percent. This is of no surprise, as the production process for most commodities requires the direct or indirect use of fossil fuels. In the short-run, firms have no alternative but to purchase carbon permits or reduce production levels. In time, firms will look for alternatives to the carbon intensive inputs by investing in research and development and new technologies but seeing as this model is static one cannot make accurate projections. This model quantifies the overall change in real total investment in the economy by a 1.56 percent increase compared to the BAU situation. This change in behaviour is an indicator that firms are adapting to the new policy as expected. Ultimately, the new regulation achieved its purpose in reducing emissions. Total emissions where reduced by 28.15 percent. Reductions by industries surpassed household reductions as industries reduced emissions by 29.36 percent whereas households reduced emissions by 22.36 percent. It is not surprising that industries are affected more significantly than households since they are directly dependent on carbon intensive resources. Additionally, households experience higher prices as a result of a trickle down effect of the emissions tax since it is imposed at the upstream point.

In order to get a better understanding of the effect of the new regulation on the welfare of households, let us start by examining more closely the behaviour of households. At the aggregate level it can be seen that the real wage rate decreases by 1.68 percent, however the labour supply increases very slightly by 0.08 percent. This contradicting behaviour will be further examined by looking at the breakdown of the households by income groups. Again at the aggregate level, one can see that households' real consumption decreases 1.08 percent. This decrease is understandable considering the increase in the CPI and the decrease in the real wage rate.

The change in real total consumption for the four lowest income groups ranges from -0.05 to -0.18 whereas the change for the four highest groups ranges from -1.64 to -1.80 percent.

For the income groups between these two bounds, the change in consumption levels increases gradually. However, one exception was for household groups 41 to 46 who experience a change in consumption levels in the range of -0.72 to -1.20 percent which is considerably lower than the change experienced by the households in close proximity to their groupings.

Looking at the consumption levels of carbon emitting commodities, it can be seen that the change in consumption pattern increases gradually moving from low to high income groups. It is not surprising that the wealthier households are affected in a greater degree since they consume more because they tend to have larger homes, more vehicles, etc. However, the more wealthy households have better means to finding alternative sources of energy which enable them to reduce their consumption levels while at the same time having little effect on their lifestyle.

The change in consumption patterns for refined petroleum products is similar for all household income groupings. The 37 percent decrease for all household groups is relatively high. Motive fuel also decreases by a rather large amount. The range of the decrease in consumption ranges from 19.68 percent for the lowest household income group to 21.27 percent for the highest household income group. The change in consumption pattern for motive fuel is gradual, in the sense that the decrease in consumption increases as household income increases. With respect to the change in consumption pattern for fossil fuels, the range of the decrease varies between 23.40 and 26.20 percent. Although the value of this change is significant, it is somewhat more difficult to make the link between household income and the reduction in consumption of fossil fuels. No direct correlation between income group and consumption of fossil can be observed when examining the results.

The change in disposable income is also reduced as a result of the implementation of the carbon permit system. The size of the reduction in disposable income is positively correlated with income. The reduction ranges from 0.07 percent for the lowest household group to 1.75 percent for the wealthiest household group. Conversely, the amount of labour supplied ranges between -0.19 and 0.23 percent for the least wealthy and wealthiest income groups, respectively. Additionally, it is worth mentioning that the change in labour supply increases gradually as household income increases. The decrease in labour supplied by the less wealthy households can be explained by the fall in the real wage rate and the increase in the price level. The substitution effect is dominant in this case. That is, low income households feel they benefit more by working less and enjoying more leisure time as a result of the new policy reform. In contrast, the wealthier households, which are composed of the 38^{th} to the 50^{th} household groupings, increase the amount labour supplied. In this case, the income effect has a greater impact on these households. That is, this class of households derives a greater benefit from working more hours to compensate for the loss in purchasing power as a result of the increase in prices. This type of observation is of greatest interests as it sheds light on the overall household productivity in the economy as a result of such a policy reform being implemented.

As expected, the implementation of a carbon permit system puts pressure directly on households to reduce their consumption of carbon intensive commodities. The overall impact of this form of emission tax on households is quantified by the equivalent variation measure. The equivalent variation measure is calculated as a percentage of non-labour disposable income. The values range between -0.04 and -1.48 percent. The less wealthy households represent the lower bound of the reduction in welfare whereas the wealthiest households' welfare is affected to a larger extent. The main cause of the larger reduction in welfare for the wealthy households in comparison to the less wealthy is because the wealthy do not increase the amount of leisure time in response to the new regulation whereas the less wealthy do.

Now, let us turn our attention to the impact of the new regulation on the 40 Canadian industries examined. The data from the simulation indicates that industries in the "carbon intensive" category are characterized by the largest reductions in their output levels. "Oil and gas" one of the highest emitting industries is faced with the greatest decreases in prices. This is due to a decrease in demand for intermediate inputs produced by the industry. A good example of this can be explained by the increase in output price for electricity. The electricity industry, which is also highly affected by the carbon tax since its production process uses coal as its main input, provides an alternative for other industries to reduce their carbon footprint by replacing the carbon intensive inputs used in the production process for electricity. For this reason, the increased demand for electricity by industries such as metal fabrication, electricity production industry, machinery manufacturing industry, transportation equipment manufacturing and other manufacturing industries lead to the rise in price for electricity. In turn, these manufacturing industries, as do all the other industries, substitute away from refined petroleum products, fossil energy, and natural gas.

Many of the industries in the "carbon intensive" group are characterized by decreases in the amount of labour demanded. Refineries, chemical, oil and gas, and steel industries are faced with the larges declines in labour demand. Mining and pipeline, which are categorized to the "carbon dependent" group, are the only other two industries that are faced with significant reduction in labour demanded. All of the industries are also characterized by large decreases in the amount of capital used in their production process. This is indicative of a shrinkage occurring within these industries. On the flipside, the transportation equipment and the electrical products industry are the only two industries which increase significantly the level of capital. Furthermore, these two industries are the only two industries that grow significantly as a result of the new regulation.

Focusing on final demand, consumption for most of the commodities is reduced, especially commodities that are carbon intensive. Even commodities that are not high emitting goods are faced with reductions in the level of consumption mainly due to the reduction in disposable income. Consumption of electricity, however, is also reduced but only by about half of the average drop of all the high emitting commodities. This is another indication of a shift occurring from carbon emitting commodities towards more environmentally sound sources of energy.

Industries in the "low emitting" grouping actually increase slightly their supply. The main factor explaining this increase is the increase in demand from abroad. Foreign markets are taking advantage of the lower domestic prices for low emitting commodities. As indicated by the CPI (without permits) which calculates the change in the level of prices for commodities that are not affected by the carbon tax, the price level has decreased 0.21 percent. Services experience especially high demand from the foreign sector. On the other hand, imports for most commodities have decreased largely due to the reduction in the output of most industries, the reduction in the real wage rate and the reduction in labour. However, mainly because of the substitution effect to move away from carbon emitting goods towards environmentally friendly commodities, import demand for commodities such as electricity, steel, transport equipment and electrical products has increased.

In conclusion, one can see that imposing a 40 dollar carbon tax in Canada is effective in changing consumer and producer behaviour as it reduced total emissions by 28.15 percent. However, there are many drawbacks. Households in all categories are made worse off as established by the equivalent variation measures which reported negative values for all households. However, because the model disaggregates households into many categories one can determine that households in the lower income groups fair better than the wealthier households thanks to the redistribution of the revenues from the carbon permit.

4.2 The Welfare Effect of Price Changes with Transfer of Permit Revenues to Households - Government Savings Held Fixed - The Case of a 40 Dollar Permit - Simulation 2

This section differs from the first in that it simulates the effect of setting government savings exogenous. Again, the price of carbon permits is set at 40 dollars per tonne. This simulation differs from the previous simulation since the government redistributes the carbon tax revenues directly to households according to the shares of government transfers used in BAU scenario. More precisely, government savings is modeled as being exogenous and therefore is set fixed at the benchmark level.

From the information presented in figure 4, one can see that the total reduction in emissions is 28.35 percent. This compares to the first simulation where total emission reductions were 28.15 percent. Total emissions by industries are reduced 29.90 percent compared to 29.36 percent. Additionally, total emission reductions by households decrease 20.94 percent compared to the 22.36 percent observed previously. This result is indicative that, although the redistribution of tax revenues to lower income households results in households reducing less emissions, the 0.53 percent increase in emission reductions by industries has a larger effect on the total amount of emissions produced. To explain why households' contribution to the reduction of emission decreased, it is essential to examine in detail the consumption behaviour and other characteristic changes that have been attributed to households as a result of this tax reform.

The effect of the tax reform on real total investment is significantly different than in the first simulation. This factor previously underwent an increase of 1.56 percent. In this case, real total investment decreases by 3.35 percent. Another major shift in the results is that total real consumption increases 0.63 percent as opposed to the 1.08 percent decrease previously observed. Additionally, labour supply decreases 0.13 percent compared to the 0.08 percent increase previously observed. Imports and exports also decrease 1.63 and 1.45 percent, respectively. This is compared to the 0.84 and 0.75 percent decreases previously obtained. Detailed explanations for the variations outlined will be provided as more insight is gained by looking carefully at the behaviour of households and industries.

Focusing on the disaggregated household categories, the data indicate major shifts in behaviour relative to the first simulation. Consumption increases for households in the 1^{st} category up to the 35^{st}. Households in categories 1 through 13 increase their consumption level more that 5 percent. The increases range from 1.06 percent to 4.53 percent for households in the 14^{th} to 30^{th} categories. As in the first simulation, labour supply follows the same downward trend. However, this time the reduction in labour supply by low income households decreases significantly more. As well, reduction in labour supply is now observed for some households that previously increased their labour supply as a result of the carbon tax. These results demonstrate that a tax reform that transfers directly government carbon tax revenues to households increases the dominance of the substitution effect for low income households as well as the lower half of the middle income households. The level of change in disposable income follows closely the changes observed for consumption. As income increases, the change in disposable income approaches more closely the change observed in the first simulation.

Turning our attention to the levels of total energy consumption, it becomes apparent that the effect of transferring the carbon tax revenues back to households has reduced the incentive to reduce consumption levels for energy. Since the amount of tax revenues transferred back to lower income households exceeds that for higher income individuals, the less wealthy households reduce significantly less their consumption of energy than the middle income households. Reductions in energy consumption for households in the 2^{nd} to 9^{th} groupings range between 2.12 and 6.59 percent. This compares to reductions made by households from the 8^{th} to 50^{th} groupings which range from 8.12 to 17.73 percent. Reductions of fossil fuels follow a similar trend but the level of the changes are more elevated. The decreases range between 14.74 and 25.99 percent. Reductions in consumption of motive fuel and refined products are not as widespread between household groupings. For motive fuel, decreases range between 10.02 and 21.40 percent whereas for refined products the range varies from 28.97 to 37.69 percent. The main observation when comparing these results to those obtained in the first simulation is that the consumption behaviour for high emitting commodities by the wealthy is similar in both cases. However, when moving down the rankings towards the less wealthy households, the difference in reduction levels widens significantly. This observation also holds for household consumption of other goods, but this time the direction of the change is in the opposite direction. Less wealthy households increase their consumption of other goods while the consumption pattern for the wealthy does not change as significantly.

Accordingly, the changes in household behaviour have fueled significant changes to welfare levels. Seeing as the government transfers were made in a progressive fashion, less wealthy households benefited the most from this tax reform. The equivalent variation values range from 12.51 to -1.39 percent. This compares to the range of -0.04 to -1.48 obtained in the first simulation.

The data on changes in consumption patterns for commodities indicates that goods and services that displayed reductions below 1 percent in the first simulation are now characterized by increases in consumption. For goods and services that use energy inputs that are high emitting, consumption has increased slightly. Overall, the consumption level for these types of commodities is significantly lower than in the BAU situation. In the grand scheme of things, one can observe that this tax reform results in increased consumption for all commodities, thus alleviating the effect of the high carbon tax.

With respect to the supply of commodities, a very different pattern has emerged in comparison to the first simulation. For some goods and services, although the level of consumption increases, the total supply decreases. This observation is made for mining, construction, wood, plastic, rubber, non-metallic products, metal fabricated products, machinery, electrical products, transport equipment, etc. This change can be explained by the fact that, compared to the first simulation, domestic demand and exports have decreased and imports have increased. More importantly, this change is explained by the fact that the demand for these commodities for investment and input usage has fallen significantly. This confirms the hypothesis that transferring carbon tax revenues to households in a progressive fashion will reduce the environmental effect of the reform since lower income households are not changing their consumption behaviour in light of the tax reform. They are only shifting the quantity they consume whereas the wealthier households shift their consumption towards alternative products that produce fewer emissions.

The main observation is that industries that are not carbon intensive do not reduce consumption of carbon intensive commodities as much as in the first simulation. The overall impact of the tax reform on industries is not as significant as the direct impact on households. However, indirect effects exist which increase the demand for goods that are not carbon intensive. Industries that are less harmful to the planet undergo a slight increase in growth. This growth is largely the outcome of increased demand by households resulting from government transfers being directly transmitted to households. The wood industry, which previously grew by 2.43 percent, now shrinks 0.19 percent. This is due to the fact that the income effect is dominant. Households, which are now receiving larger transfers, are consuming more products from industries that are less carbon intensive. However, the industries which are now faced with increased growth are not substituting towards alternative resources as much as in the first simulation. Overall, wood, a substitute for carbon intensive inputs, is thereby faced with a reduction in demand translating into a reduction in the level of output. This indicates that overall this simulation is not achieving its intended purpose. However, this simulation does fair better in redistributing the wealth to counter the regressiveness of the carbon tax.

5 Sensitivity Analysis

This section examines the effect of making slight variations to the model such as a reduction in the price of the carbon tax and a change in the elasticity of substitution in the production function for the different levels of nesting when government savings is held fixed.

5.1 Reducing The Carbon Tax from 40 Dollars to 20 Dollars

Reducing the carbon tax from 40 dollars to 20 dollars for the case where government transfers are modeled exogenously leads to the same overall results as in the first simulation but to a slightly lower magnitude. The overall goal to reduce emissions is achieved as total emissions decrease 18.03 percent compared to the 28.15 percent reduction obtained in the 40 dollar simulation. This is indicative of diminishing marginal returns as the cost of the permit increases. More importantly, benefits can be obtained by performing a smaller shock on the economy. On the supply side, the same trends are observed as in the first simulation. However, this time the changes are more than half of the changes previously observed. This is in indication that a smaller carbon tax may be just as effective as the 40 dollar carbon, if not more, since it allows households and industries to adjust to the tax reform more gradually.

With respect to household behavior, this simulation did not reveal anything different than what was observed in the first simulation. Only the magnitude of the changes was slightly less pronounced, especially for the wealthier households. Results for households in the less wealthy categories do not vary much from one simulation to another since most of the commodities consumed by individuals in these income brackets purchase necessary goods that cannot be substituted for other types of goods for the same price. Reductions in the total level of energy consumed are slightly lower in this simulation but follows the same trend as in the first simulation. Similarly, reductions in consumption of fossil fuels are greatest for middle income households. Overall, this simulation identifies some advantages over a 40 dollar permit but this comes at the expense of the environment.

For the simulation where government savings is held fixed and where the carbon tax is reduced from 40 dollars to 20 dollars per tonne of emission, the results are similar to those observed in the second simulation but again to a lesser extent. In comparison to the simulation of a 20 dollar carbon tax with government transfers held fixed, the reduction in emissions is much less. Overall, total emissions decrease 12 percent. The difference between total industry and household emission reductions is also much smaller. These results are indicative that the affect of government transferring money to households and also taxing individuals at a lower rate than in the second simulation is not really changing household consumption patterns.

The main factors responsible for the lower reductions of emissions by industry are the reduction in real total investment and the lower reductions in consumption of carbon intensive commodities. Overall, total emission reductions are not nearly as high as observed in any of the simulations examined so far. Lower and middle income households increase consumption in response to the tax reform, with households in the lowest income group increasing consumption the most. Total consumption of energy, fossil fuels, motive fuels and refined petroleum products decrease for all income groups. These decreases, unlike the other simulations conducted, are not as significant, especially for low income households. This indicates that the reform is not as effective in persuading lower income household to substitute away from carbon intensive commodities towards low emitting goods in comparison to wealthy households. One factor which is partly responsible for this outcome is that disposable income for low and middle income households increases significantly. Household labour supply also decreases in response to the reform. This is due to the fact that the substitution effect is dominant over the income effect which characterizes only the top four wealthiest households. Overall, one can conclude that this reform is not very effective in changing consumption behaviour of lower income households but is effective in redistributing the wealth from the tax.

5.2 Modifying The Elasticity of Substitution

First of all, it is important to clarify the effect of the selected values for the elasticity of substitution in the production function at the various levels of nesting. A higher elasticity is associated with decreasing dependence on carbon intensive inputs and substituting these inputs with more environmentally sound resources. The effect of reducing the elasticity of substitution has the reverse effect. The purpose of this simulation is to observe how changing the behaviour of producers will impact the overall economy, especially households.

As a result of setting the elasticity of substitution to 2 for the simulation where government savings is fixed and the carbon tax is set at 40 dollars, the first observation made is the significant decrease in the level of emissions released. In comparison to the BAU scenario, industry emissions decrease 43 percent. The effect of this modeling change contributes largely to industries shifting away from carbon intensive processes to greener practices. When examining the household data, the modeling change plays a very small role in affecting household behaviour. Overall, when comparing the levels of equivalent variation between this simulation and the situation where only government savings is fixed, equivalent variation for households in the low and middle income groups increases slightly less. For the higher income households the decrease in equivalent variation is slightly less. One can conclude that households in the lower and middle-income groups are better off in the third scenario but wealthier households are better off in this simulation.

Turning our attention to final demand, it can be observed that carbon emitting commodities are affected the most as a result of this policy reform. Fishing and forestry, coal, mining, electricity, gas pipeline, construction, pulp and paper, chemical, plastic, non-metallic, steel, metal fabrication, transport, natural gas, gasoline, diesel, liquid petroleum and other refined oil commodities all suffer from reductions in consumption. The other 26 commodities analyzed in this study are characterized by slight increases in their consumption. Although consumption for these carbon intensive commodities decrease, the magnitude of the change in total supply is not as pronounced for commodities that are considered "low emitting" and "carbon dependant". On the other hand, gas pipeline, crude oil, natural gas, gasoline, diesel, liquid petroleum and other refined oil commodities, all of which are categorized to the "carbon intensive" group, experience significant increases in reductions in total supply in comparison to the second simulation performed in this study. Similarly to total supply, domestic sales follow a similar pattern. The same "carbon intensive" group of commodities are affected the most by the imposition of carbon permits. Additionally, the effect of modifying the model by changing the elasticity of substitution in the production process further accentuates the movement away from carbon intensive commodities. There also appears to be a substitution towards other "low emitting" and "carbon dependant" commodities.

The industries that rely on the use of carbon intensive inputs in their production process reduce their consumption of high emitting inputs the most. The only industry that increases its consumption of natural gas, although a very modest increase, is the transport industry. This is likely due to the fact that the demand for public transportation has increased. With respect to industry consumption of refined petroleum, all industries reduce their consumption of this type of fuel significantly. Industrial consumption of electricity on the other hand increases for many industries as it is considered as a substitute for carbon intensive inputs in the production process. Overall, consumption of fossil energy decreases for all industries, with carbon intensive industries being affected the most. Total energy consumed by all industries decreases. Again, this decrease is a result of the preference change modeled in the production function. The reduction in demand for energy resulting from the change in preferences puts downwards pressure on prices.

Other factors of production such as labour and capital are also significantly affected by this modeling change. Compared to the first simulation, the magnitude of the decrease in labour and capital is accentuated especially in carbon intensive industries. Many of the other industries increase their labour force and use of capital. Evidence of slow economic growth comes from lower output levels for industries that rely on carbon based resources to produce their output. When examining the price of value added products, of which carbon based products represent a large portion, one can observe that prices are decreasing. This coincides with the decreasing demand for carbon intensive value added products.

The effect of modifying the model by reducing the elasticity of substitution in the production function to 0.5 reduces the GDP at market price the least of all the simulations performed for which the carbon tax is set at 40 dollars. This is directly correlated with the degree of the reduction in emissions in Canada. Carbon emission reductions are the lowest of all simulations with a 40 dollar carbon tax. Interestingly enough, the reduction in emissions is the same for industries and households. As opposed to the scenario where the elasticity of substitution is set to 2, in this scenario, the change in real total consumption increases. Additionally, the change in real total investment decreases. This occurs mainly because the modeling change reduces the incentive for industries to substitute towards cleaner inputs and thus reducing their willingness to invest in new technologies. Total labour supply decreases and so does the gross real wage rate index. The reductions in these two indicators are more significant than observed in the previous simulation. Overall, the effect of industries' unwillingness to adjust to the policy change by not reducing their consumption of carbon intensive inputs is penalizing the industries and society. This simulation describes the case where firms are not forward looking and do not see the potential from investing in greener production processes.

From the industries' perspective, the results follow a similar trend to that observed just previously except in the opposite direction. That is, as a result of setting the elasticity of substitution in the production function equal to 0.5, industries are shifting away less from carbon intensive inputs. The nature of this modeling change is geared at affecting the behaviour of industries, therefore the changes are expected to be of a larger magnitude in comparison to the effect on household consumption. The trend in the consumption of natural gas is somewhat different among the 40 industries in this simulation. Although most firms reduce their consumption, the size of the reduction has diminished significantly. Even more significantly affected by this policy change is industrial consumption of refined petroleum. Overall, total energy consumption decreases proportionately less for carbon intensive industries relative to the services and goods producing industries. The size of the reductions is significantly less than in the previous simulation. The same observations are made for the consumption of fossil energy except the size of the reductions is less for services and goods producing industries. Prices for fossil energy increase for the "Refineries", "Steel" and "Electricity" industries. For total energy prices the trend is very similar to the trend observed for fossil energy however the increases are slightly greater for goods producing and services industries.

The change in value added in this simulation is lower than the change observed in the previous simulation. The only exception is for the carbon intensive industries. Although the amount of value added occurring in these industries is decreasing in this simulation, the magnitude of the decrease is not as significant as in the later case. With respect to the price of value added, prices simply move in the opposite direction of the quantity demanded. In other industries, the change in demand for value added is matched by a proportional change in price.

Modifying the model in such a way that represents industries' unwillingness to switch to non-carbon intensive inputs depicts a general picture of how industries will be affected by the new policy reform. The main effect of the implementation of the carbon permit system is to reduce output in many of the carbon intensive industries. The degree of the reduction in output is less than in the previous simulations. Output prices do not change much in comparison to the third simulation. Demand for labour increases in the carbon intensive industries and demand for capital decreases in most industries except for the "Oil and Gas", "Coal" and "Gas Pipeline" industries.

6 The Welfare Effect of The Various Simulations

The main objective of this study is to obtain information regarding the welfare effects of imposing a carbon tax on society in Canada. The main indicator for household welfare used in this study is the equivalent variation. Equivalent variation can also be identified in terms of equivalent income. This study uses the equivalent income and compares the value in the base scenario to the values obtained for each simulation performed. Although all the simulations' welfare results are not significantly different from one another, the simulation that has the least impact on households is when government savings is fixed and the price of a carbon permit is 40 dollars. When transfers are exogenously modeled, households are worse off. Interestingly enough, it appears as though households are slightly better off when the carbon tax is set at the higher 40 dollar per carbon permit in comparison to the 20 dollar carbon permit. Households in all income groupings are the worst off in the simulation where government transfers are exogenous and the price of a carbon permit is set at 40 dollars. The gap in welfare is more significant for low income households as they are not being compensated as much as in any of the other simulations. When comparing the Lorenz curves for the simulations performed, the results are sometimes too close to be able to arrive to a conclusion without examining the numerical data. For this reason, it could be interesting to perform a simulation with a 100 dollar permit price to see if the results will differ significantly when examined in the form of a Lorenz Curve.

Now, focusing on the cases where households are better off, it seems that when the elasticity of substitution is set at 0.5 in the case of government savings being exogenous and where the price of a carbon permit is set at 40 dollars households in the majority of income groupings fair better than in any of the simulations performed. In this scenario, households in income groups between the first and the 37^{th} categories could not be better off in any of the other simulations. However, households in the 38^{th} to the 50^{th} income groupings are best off in the simulation of government savings being fixed at 20 dollars. An interesting observation is that wealthier households are always worse off in simulations where lower and middle income households are benefiting from the policy reform. The opposite is also true but to a lesser extent. This demonstrates the policy reform is progressive.

7 Summary and Concluding Remarks

Acknowledging that it is widely accepted that a carbon tax is regressive in nature (Poterba, 1991), this study focuses on correcting this by using redistributive measures while examining the direct effect on households in many different income groups. This correction is done by compensating households for their welfare loss. The simulations performed in this study model the redistribution of tax revenues in two different ways. The first models tax revenue redistribution when holding government transfers fixed and the second models tax redistribution when government savings are fixed.

This study implements a regulation requiring industries to purchase carbon permit for every tonne of emissions released. This form of tax on emission is advantageous over other types of taxes that penalize a specific industry. Additionally, this type of tax is better suited for reducing emissions on a larger scale. In a study by Wier et al. (2005) which examines the distributional impact of a carbon tax on industries and households in Denmark, the authors observe that no proportional relationship exists between the carbon intensities for each commodity group and tax payments. The main factor responsible for this result is that in reality energy-intensive industries are accorded tax rebates so that they can remain competitive with other countries. Another observation made in this study is that wealthier households are affected negatively from this carbon tax in comparison to the lower income households. Not only as a result of the redistribution, but also because wealthier household have higher total expenditure levels. As in a study produced by Cornwell and Creedy (1997), this paper comes to the same conclusion that the levels of equivalent variation decrease with income. Cornwell and Creedy interpret this as the result of low income households having higher levels of expenditure on carbon-intensive goods. This corresponds with the results obtained in the simulations performed in this study. For this reason, revenue generated from the carbon permit are redistributed to the lower income households to compensate them for the loss in welfare.

The first simulation performed, which consists of the imposition of a 40 dollar carbon permit on producers and where transfers of permit revenues to households are modeled exogenously, reveals that firms respond to the policy reform in the desired fashion by increasing real total investment. Total emissions are reduced significantly in comparison to the BAU situation. Household, on the other hand, are made worse off as they are faced with higher prices and lower wages. The main observation made in this simulation is the reduction in labour supplied by lower income households. The substitution effect plays a dominant role and for this reason low income households increase their leisure time thereby increasing their welfare level as measured by the equivalent variation. The wealthier households are worse off than low and middle income households in this simulation. On the supply side, industries move towards substitutes for carbon intensive inputs. In turn, this results in a rise in consumer prices.

The second simulation performed examines the effect of a 40 dollar carbon tax on emissions when government savings are fixed. That is, in this case households are much better off than in the first simulation as they now received larger government transfers from the government. In turn, household spending increases significantly for the least wealthy and decreases progressively as household income increases. Consumption of carbon intensive goods also decreases less, especially for the least wealthy households. Another factor which is responsible for the increase in welfare for the lowest income categories is that they are working less and taking advantage of the additional transfer income and increasing the amount of leisure accessible. In comparison to the first simulation, even more household groups reduce their level of labour supplied. Overall, total emissions reductions increase as the economy slows even more than in the first simulation. This reduction in growth is largely attributable to the reduction in labour supply and investment in capital by industries.

Further extensions to this study might include examining the differences in household welfare based on the location of their primary residence. This relates to Wier et al. (2005)'s study that examines the carbon footprint of rural and urban family consumption patterns. He concludes that rural households consume carbon intensive commodities in larger quantities than urban households but the difference in carbon tax payments is quite small. Reproducing this study for Canada would be interesting considering the size of the country and the distance many households travel on a daily basis to get to theirs jobs. Combining this more detailed analysis with a more detailed tax structure would enable the modeler to simulate the effect of implementing a tax on emissions, as does this study, but use the funds collected to reduce other taxes that are more distortionary. This study was more simplistic as it returned the tax revenues in the form of transfers. Additional benefits can be obtained by reducing other distortionary taxes and could possibly in turn generate a double dividend. Another factor that should be considered in this study is the additional benefit households receive from a less polluted environment. Because this increase in welfare is not accounted for, social welfare is underestimated. For this reason, if one was examining the possibility of the existence of a double dividend, this added benefit should be accounted for in the analysis. Finally, it should be noted that this study follows Wier et al. (2005) suggestion that the tax burden be shifted from household's towards businesses such that the level of regressivity is reduced. To make this policy reform more realistic, future research should include in the model specific measures to ensure that international competitiveness is maintained.

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Inequality measures: Carbon tax of $40 per tonne of emissions released with government transfers fixed

Household Group	*Equivalent Variation Expressed as a % of Non-Labour Disposable Income*	*Equivalent Income (Base)*	*Equivalent Income (After Policy Reform)*
HH1	-0.04	$3,105.51	$3,104.21
HH2	-0.07	$3,572.95	$3,570.46
HH3	-0.04	$3,807.57	$3,806.15
HH4	-0.17	$3,886.04	$3,879.55
HH5	-0.24	$4,453.17	$4,442.39
HH6	-0.33	$4,536.52	$4,521.41
HH7	-0.45	$4,944.28	$4,921.94
HH8	-0.43	$5,185.14	$5,163.04
HH9	-0.54	$5,462.57	$5,432.87
HH10	-0.58	$5,705.44	$5,672.41
HH11	-0.64	$5,899.73	$5,862.25
HH12	-0.65	$6,089.84	$6,050.15
HH13	-0.63	$6,361.28	$6,320.93
HH14	-0.68	$6,592.11	$6,547.43
HH15	-0.68	$6,691.67	$6,645.84
HH16	-0.71	$7,013.88	$6,964.16
HH17	-0.72	$7,281.17	$7,228.61
HH18	-0.77	$7,252.36	$7,196.22
HH19	-0.80	$7,522.10	$7,461.94
HH20	-0.82	$7,805.52	$7,741.16
HH21	-0.76	$8,134.37	$8,072.18
HH22	-0.82	$8,571.93	$8,501.66
HH23	-0.82	$8,583.44	$8,512.93
HH24	-0.86	$8,511.33	$8,438.29
HH25	-0.89	$8,789.99	$8,711.69
HH26	-0.91	$9,045.14	$8,962.63
HH27	-0.91	$9,180.22	$9,096.85
HH28	-0.85	$9,835.99	$9,752.63
HH29	-0.89	$9,889.74	$9,801.28
HH30	-0.95	$10,498.40	$10,398.72
HH31	-0.96	$10,613.96	$10,511.73
HH32	-0.95	$10,938.21	$10,833.80
HH33	-0.91	$11,649.01	$11,543.47
HH34	-0.90	$12,082.57	$11,973.86
HH35	-0.89	$13,085.85	$12,968.82
HH36	-0.94	$13,758.67	$13,628.95
HH37	-0.95	$15,078.43	$14,935.50
HH38	-1.12	$18,085.41	$17,882.33
HH39	-1.02	$20,737.50	$20,526.41
HH40	-0.97	$22,284.23	$22,069.13
HH41	-0.58	$26,542.67	$26,388.38
HH42	-0.87	$28,072.22	$27,826.82
HH43	-0.97	$25,192.57	$24,949.44
HH44	-0.63	$31,244.27	$31,046.72
HH45	-0.98	$27,681.41	$27,410.29
HH46	-0.73	$34,214.77	$33,965.02
HH47	-1.48	$35,655.62	$35,126.59
HH48	-1.38	$33,194.21	$32,736.48
HH49	-1.41	$36,521.95	$36,007.91
HH50	-1.46	$89,558.57	$88,254.68

Source: Author's calculations.

Inequality measures: Carbon tax of $40 per tonne of emissions released with government savings fixed

Household Group	*Equivalent Variation Expressed as a % of Non-Labour Disposable Income*	*Equivalent Income (Base)*	*Equivalent Income (After Policy Reform)*
HH1	5.51	$3,105.51	$3,276.49
HH2	10.22	$3,572.95	$3,938.21
HH3	12.51	$3,807.57	$4,283.78
HH4	11.96	$3,886.04	$4,350.86
HH5	9.35	$4,453.17	$4,869.53
HH6	8.31	$4,536.52	$4,913.29
HH7	8.49	$4,944.28	$5,364.04
HH8	8.05	$5,185.14	$5,602.29
HH9	7.49	$5,462.57	$5,871.88
HH10	6.23	$5,705.44	$6,060.78
HH11	5.88	$5,899.73	$6,246.38
HH12	6.05	$6,089.84	$6,458.19
HH13	5.25	$6,361.28	$6,695.34
HH14	4.65	$6,592.11	$6,898.66
HH15	4.48	$6,691.67	$6,991.42
HH16	4.08	$7,013.88	$7,300.34
HH17	3.69	$7,281.17	$7,549.56
HH18	3.78	$7,252.36	$7,526.59
HH19	3.38	$7,522.10	$7,776.51
HH20	2.91	$7,805.52	$8,032.33
HH21	2.80	$8,134.37	$8,362.08
HH22	2.72	$8,571.93	$8,805.39
HH23	2.47	$8,583.44	$8,795.43
HH24	2.19	$8,511.33	$8,697.35
HH25	1.97	$8,789.99	$8,963.20
HH26	1.94	$9,045.14	$9,221.05
HH27	1.76	$9,180.22	$9,342.21
HH28	1.68	$9,835.99	$10,001.10
HH29	1.52	$9,889.74	$10,039.69
HH30	1.28	$10,498.40	$10,632.49
HH31	1.00	$10,613.96	$10,720.35
HH32	0.97	$10,938.21	$11,044.66
HH33	0.68	$11,649.01	$11,728.42
HH34	0.68	$12,082.57	$12,164.16
HH35	0.68	$13,085.85	$13,174.80
HH36	0.17	$13,758.67	$13,782.62
HH37	0.02	$15,078.43	$15,081.22
HH38	-0.50	$18,085.41	$17,994.36
HH39	-0.70	$20,737.50	$20,592.08
HH40	-0.57	$22,284.23	$22,156.69
HH41	-0.27	$26,542.67	$26,471.36
HH42	-0.56	$28,072.22	$27,914.31
HH43	-0.67	$25,192.57	$25,023.33
HH44	-0.36	$31,244.27	$31,130.87
HH45	-0.74	$27,681.41	$27,477.32
HH46	-0.51	$34,214.77	$34,039.53
HH47	-1.29	$35,655.62	$35,195.27
HH48	-1.17	$33,194.21	$32,806.88
HH49	-1.23	$36,521.95	$36,071.57
HH50	-1.39	$89,558.57	$88,312.88

Source: Author's calculations.

Simulation Results for Commodity Demand: Carbon tax of $40 per tonne of emissions released with government transfers fixed

Commodity	*Consumption*	*Total Supply*	*Exports*	*Domestic Sales*	*Imports*	*Total Demand*	*Demand for Investments*	*Demand for Intermediate Inputs*	*Consumer Price with Permit*	*Domestic Price*
Agriculture	-1.03	-0.13	-0.22	-0.11	0.01	-0.09	1.98	0.06	0.05	0.06
Fishing and Forestry	-2.45	-1.34	-3.07	-0.86	1.40	-0.64	1.00	-0.51	1.02	1.13
Coal	-99.00	-61.29	-61.45	-61.04	-60.63	-62.06	1.95	-62.27	221.53	0.25
Mining	-17.45	-7.87	-8.38	-7.34	-6.29	-7.22	1.82	-7.30	0.20	0.28
Electriciy	-9.98	-6.89	-16.05	-6.31	4.56	-5.94	-3.22	-3.58	5.43	5.64
Gas Pipeline	-23.17	-13.16	-11.30	-13.95	-16.53	-14.08	3.52	-10.36	-1.44	-1.51
Construction	-37.31	0.72	-1.35	0.73	2.84	0.73	0.98	-0.71	1.04	1.04
Food	-0.57	-0.10	0.37	-0.27	-0.91	-0.40	2.29	-0.24	-0.25	-0.32
Beverage	0.20	1.18	2.99	0.79	-1.37	0.22	2.85	0.22	-0.79	-1.08
Tobacco	1.04	1.73	4.29	1.44	-1.33	0.91	3.22	0.05	-1.15	-1.38
Textile	-0.90	1.29	1.89	0.63	-0.60	-0.27	2.20	0.71	-0.17	-0.62
Wood	0.21	2.43	3.35	1.21	-0.90	0.86	2.93	0.84	-0.88	-1.04
Pulp Paper	-2.99	-5.65	-7.23	-3.48	0.41	-2.24	0.69	-2.18	1.34	2.00
Printing	-0.82	-0.20	0.18	-0.28	-0.74	-0.41	2.20	-0.43	-0.16	-0.23
Chemical	-4.58	-15.77	-21.14	-11.33	-0.30	-5.20	-0.48	-5.35	2.52	6.04
Plastic	-1.66	-0.82	-1.44	-0.15	1.15	0.34	1.63	0.44	0.40	0.65
Rubber	-1.15	0.42	0.13	0.91	1.71	1.49	1.90	1.95	0.12	0.39
Non-Metalic	-1.85	-0.44	-1.50	-0.16	1.20	0.24	1.55	0.41	0.47	0.68
Steel	-16.45	-10.32	-14.37	-5.72	3.79	-1.42	N/A	-1.42	2.60	4.92
Metal Fabrication	-1.51	0.42	-0.21	0.77	1.77	1.23	1.76	1.33	0.26	0.49
Machinery	-0.95	2.47	2.77	1.69	0.63	0.83	2.13	0.09	-0.10	-0.53
Electriciy Production	-0.94	6.48	6.89	4.23	1.64	1.84	2.14	2.40	-0.11	-1.25
Transport Equipment	-0.57	6.46	7.07	4.56	2.12	2.83	2.36	4.85	-0.32	-1.18
Other Manufacturing	-0.98	0.52	0.77	0.15	-0.46	-0.31	2.10	-0.07	-0.07	-0.30
Wholesale	-0.16	0.21	1.24	0.00	-1.23	-0.09	2.61	-0.60	-0.57	-0.61
Retail Trade	0.00	0.09	1.47	0.08	-1.29	0.07	2.73	-0.17	-0.68	-0.69
Transport	-3.90	-3.55	-6.51	-2.38	1.94	-1.81	0.14	-1.08	1.89	2.19
Storage	-0.82	-0.22	0.04	-0.26	-0.55	-0.28	2.17	-0.24	-0.14	-0.15
Communication	0.70	0.85	3.25	0.57	-2.03	0.27	3.22	-0.11	-1.16	-1.30
Fire	1.06	0.79	3.66	0.71	-2.15	0.59	3.45	-0.33	-1.37	-1.43
Service Business	0.08	0.43	1.97	0.23	-1.48	0.07	2.83	-0.07	-0.78	-0.86
Education	-0.17	0.21	1.36	0.07	-1.20	0.00	2.65	-0.23	-0.60	-0.64
Health	0.21	0.04	1.84	0.04	-1.74	0.01	2.94	-0.14	-0.88	-0.89
Amusement	-0.02	0.60	2.18	0.33	-1.49	0.02	2.81	0.07	-0.76	-0.91
Accomodation	-0.25	0.32	1.70	0.06	-1.56	-0.24	2.71	-0.21	-0.66	-0.81
Other Services	-0.13	-0.36	0.88	-0.41	-1.68	-0.42	2.68	-0.92	-0.63	-0.64
Non-Profit	-0.76	-0.68	0.08	-0.69	-1.46	-0.70	2.42	-0.47	-0.38	-0.39
Government	-0.26	-0.02	1.03	-0.03	-1.08	-0.04	2.56	-0.48	-0.52	-0.53
Crude Oil	N/A	-6.04	-1.56	-11.44	-20.33	-15.44	3.58	-15.50	-1.49	-2.61
Natural Gas	-23.17	-6.57	0.89	-13.94	-26.58	-15.38	5.80	-14.53	24.07	-3.89
Gasoline	-20.71	-17.96	-24.13	-16.86	-8.90	-16.67	-0.04	-10.51	25.37	2.31
Diesel	-18.43	-17.14	-27.34	-14.33	1.00	-13.21	-1.54	-12.79	21.86	4.20
Liquid Petrolium	-35.63	-21.51	-8.09	-31.26	-48.59	-32.80	9.18	-32.80	29.43	-7.01
Other Refined	-40.73	-23.04	0.08	-31.67	-53.34	-37.58	N/A	-37.50	42.27	-9.10

Source: Author's calculations

Simulation Results for Aggregate Economic Indicators: Carbon tax of $40 per tonne of emissions released with government savings fixed

Commodity	*Consumption*	*Total Supply*	*Exports*	*Domestic Sales*	*Imports*	*Total Demand*	*Demand for Investments*	*Demand for Intermediate Inputs*	*Consumer Price with Permit*	*Domestic Price*
Agriculture	1.15	0.34	0.25	0.36	0.47	0.39	-3.07	0.26	0.05	0.06
Fishing and Forestry	-0.28	-0.42	-2.16	0.06	2.33	0.29	-3.99	0.28	1.01	1.13
Coal	-99.00	-61.28	-61.43	-61.03	-60.63	-62.06	-3.10	-62.26	221.53	0.25
Mining	-14.07	-9.48	-9.98	-8.95	-7.91	-8.87	-3.22	-8.97	0.21	0.28
Electriciy	-7.96	-6.25	-15.48	-5.67	5.28	-5.29	-8.02	-3.72	5.43	5.64
Gas Pipeline	-21.91	-12.76	-10.90	-13.55	-16.11	-13.67	-1.62	-10.28	-1.42	-1.50
Construction	-36.91	-3.47	-5.43	-3.47	-1.46	-3.46	-4.01	-0.30	1.03	1.03
Food	1.66	1.54	2.03	1.37	0.71	1.22	-2.77	0.79	-0.26	-0.32
Beverage	1.97	2.59	4.42	2.18	0.00	1.65	-2.24	0.96	-0.79	-1.07
Tobacco	4.65	5.22	7.86	4.92	2.07	4.12	-1.89	1.41	-1.15	-1.37
Textile	0.28	1.89	2.50	1.21	-0.07	0.28	-2.85	0.32	-0.17	-0.63
Wood	1.66	-0.19	0.70	-1.40	-3.46	-1.72	-2.16	-1.80	-0.88	-1.05
Pulp Paper	-1.27	-5.40	-6.96	-3.25	0.61	-2.01	-4.28	-2.09	1.32	1.97
Printing	0.67	-0.01	0.39	-0.09	-0.58	-0.23	-2.85	-0.31	-0.17	-0.24
Chemical	-2.55	-15.77	-21.12	-11.35	-0.37	-5.24	-5.39	-5.72	2.51	6.01
Plastic	-0.07	-2.06	-2.65	-1.41	-0.16	-0.93	-3.40	-0.93	0.39	0.64
Rubber	0.79	-0.01	-0.29	0.45	1.19	0.98	-3.13	1.09	0.12	0.37
Non-Metalic	-0.52	-3.13	-4.15	-2.85	-1.55	-2.40	-3.47	-2.56	0.47	0.67
Steel	-14.54	-11.90	-15.87	-7.39	1.94	-3.20	N/A	-3.21	2.59	4.92
Metal Fabrication	-0.11	-1.64	-2.24	-1.30	-0.36	-0.86	-3.27	-0.77	0.26	0.48
Machinery	0.47	-0.10	0.21	-0.89	-1.98	-1.78	-2.92	-1.24	-0.10	-0.55
Electriciy Production	0.48	4.52	4.94	2.20	-0.46	-0.23	-2.91	0.94	-0.11	-1.31
Transport Equipment	0.90	5.47	6.09	3.55	1.07	1.77	-2.70	3.86	-0.33	-1.20
Other Manufacturing	0.50	0.74	1.00	0.34	-0.29	-0.14	-2.95	-0.30	-0.08	-0.32
Wholesale	1.69	-0.43	0.60	-0.65	-1.88	-0.74	-2.46	-1.46	-0.57	-0.62
Retail Trade	1.75	1.18	2.59	1.17	-0.24	1.16	-2.34	-0.47	-0.69	-0.70
Transport	-2.62	-3.52	-6.44	-2.36	1.91	-1.80	-4.80	-1.43	1.87	2.16
Storage	1.09	0.15	0.44	0.11	-0.21	0.09	-2.87	0.01	-0.15	-0.16
Communication	2.50	1.32	3.73	1.04	-1.58	0.74	-1.88	0.07	-1.16	-1.31
Fire	3.04	1.81	4.69	1.73	-1.16	1.61	-1.67	-0.15	-1.37	-1.43
Service Business	1.84	-0.04	1.51	-0.25	-1.97	-0.41	-2.25	-0.45	-0.79	-0.87
Education	1.13	0.82	2.01	0.68	-0.64	0.61	-2.42	-0.04	-0.62	-0.66
Health	1.60	0.64	2.48	0.64	-1.16	0.62	-2.15	-0.06	-0.89	-0.90
Amusement	1.33	1.65	3.26	1.36	-0.49	1.05	-2.27	0.26	-0.77	-0.92
Accomodation	0.81	1.14	2.55	0.87	-0.78	0.57	-2.36	-0.15	-0.67	-0.82
Other Services	1.37	0.43	1.70	0.39	-0.91	0.37	-2.40	-1.02	-0.64	-0.65
Non-Profit	0.07	0.09	0.89	0.07	-0.73	0.06	-2.63	-0.36	-0.40	-0.40
Government	1.49	0.06	1.14	0.05	-1.02	0.04	-2.50	-0.50	-0.53	-0.54
Crude Oil	N/A	-6.65	-2.47	-11.67	-20.01	-15.42	-1.65	-15.47	-1.40	-2.45
Natural Gas	-21.89	-7.24	0.29	-14.69	-27.43	-16.16	0.63	-15.56	24.00	-3.96
Gasoline	-19.25	-17.63	-24.77	-16.36	-7.01	-16.01	-5.30	-11.04	25.70	2.68
Diesel	-16.64	-17.06	-27.00	-14.31	0.57	-13.25	-6.33	-12.98	21.76	4.09
Liquid Petrolium	-34.35	-21.40	-7.85	-31.24	-48.69	-32.79	3.83	-32.88	29.38	-7.06
Other Refined	-39.40	-23.06	1.09	-32.08	-54.36	-38.17	N/A	-38.19	41.98	-9.47

Source: Author's calculations