CARBON DIOXIDE EMISSIONS CONTROL IN THE ELECTRICITY SECTOR: A GENERAL EQUILIBRIUM ANALYSIS

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ABSTRACT

This paper assesses the potential aggregate and sectoral impacts of a carbon dioxide emissions control in the Canadian electricity sector using a carbon tax as policy instrument. A multisector static general equilibrium model of the Canadian economy is developed, using 2009 as base year. Three different electricity generation types (Coal-based, other-fossil-fuels-based and non-fossil-fuel-based) are considered along with the other industries in the economy. Several simulations with different carbon tax levels and two revenue recycling methods are considered. In addition to the traditional lump-sum transfer of the carbon tax revenue to the households, the study also analyses the impact of rebating the proceeds to the electricity sector while giving more credits to clean electricity production. The simulation results suggest that rebating the carbon proceeds to the producers entails a lower welfare cost in comparison to its transfers to households.

Keywords: Carbon Tax; Climate Policy; Canada; Disaggregated Electricity Sector; General Equilibrium Analysis

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1. Introduction

This paper seeks to investigate the impact of regulating greenhouse gas (GHG) emissions in the electricity sector in Canada through the use of a market-based instrument. The increase in worldwide industrial and economic activity resulted in a high amount of global greenhouse gas (GHG) emissions due to the combustion of fossil fuels mainly in industrialized countries (United Nations Framework Convention on Climate Change, 2013). Global warming, which was a main effect of these gases, brought the international community together in an attempt to resolve this issue under the Kyoto Protocol. However, the inability to commit by individual countries as a result of the ease of free riding reduced the effectiveness of this international agreement and saw concerned economies seeking to tackle this issue on an individual basis. Methods proposed to tackle this issue can be broadly grouped into two main categories: the use of market based instruments (MBIs) and command and control methods (CACs). Market based instruments (MBIs) are instruments such as taxes and tradable emissions permits, which put a price on the GHG emissions in an attempt to reduce unnecessary emissions (Asafu-Adjaye & Mahadevan, 2013). The Command and Control (CAC) method involves direct control of GHG emissions by governing bodies which includes the use of regulations or emissions standards to control the level of emissions or the process that causes GHG emissions (Asafu-Adjaye & Mahadevan, 2013).

Numerous studies conducted by economists have revealed that market based instruments are more effective in achieving desired levels of emissions than CAC methods (Asafu-Adjaye & Mahadevan, 2013). As such, this paper will focus on the use of MBIs, more specifically on the use of carbon taxation in controlling GHG emissions, and their effects on various sectors of the economy. Energy-intensive industries play a crucial role in the economic development of highly emitting countries around the world and as such implementing economy-wide policies will be extremely difficult to do. This has led some countries to begin considering GHG emissions control at the sectoral level. Among different sectors of the economy, the energy sector is often found to be the highest source of a country's GHG emissions due to the high use of fossil fuels as inputs in this sector. Within the various components of the energy sector, the electricity sector has been a frequent candidate for GHG emissions control in industrialized countries. One of the main reasons is that high-income countries generate electricity from different sources known as an electricity mix and tend to use coal mainly as a source of electricity (Burke, 2010). Generation of electricity and heat accounted for 41% of the global carbon dioxide emissions from fossil fuel use in 2005 and will most likely keep increasing as electricity is projected to account for 50% of global energy use within 25 years (Burke, 2010). As a result of these figures, the electricity sector is a valuable starting point to study and implement policies which will result in a change of the electricity generation mix from a combination that is high-emitting to one that is low GHG emitting. A carbon tax is a standard MBI used by economists to study the effects of a GHG emissions control on the electricity sector.

There are two ways of implementing a climate control carbon tax policy; economy-wide and sectoral. Although, there are two methods of implementing a carbon control policy, this paper will focus only on the sectoral method. In simulating a sectoral taxation, economists implement an environmental tax on an emitting sector in the economy. The tax could either be a direct tax on the output or input. Imposing a tax by sector can be advantageous as it effectively contributes to reducing an economy's total GHG emissions by tackling one main problem at a time. It also focuses the cost of taxation on the high-emitting industries and as such does not penalize the non-emitting industries. The monitoring costs will most likely be lower when using sectoral taxation because it involves fewer sectors of the economy and less incidence of tax than the economy-wide taxation. The scope of this paper will study the effect of imposing a carbon tax on the Canadian electricity sector as a means of reducing GHG emissions by using a computable general equilibrium (CGE) model.

In order to understand the relevance of the Canadian electricity sector to the total Canadian GHG emissions, it is important to study some major components of the electricity sector. The Canadian electricity sector is an important point of study because, in addition to it being one of the high-emitting sectors of the energy industry, the demand of electricity is a derived demand as it acts as an intermediate good for residential, commercial, industrial and transportation uses (Mori, 2012). In a report presented to the United Nations Framework Convention on Climate Change (UNFCCC), Canada estimated that approximately 82% of its total emissions (572Mt.) came from the energy sector (Environment Canada, 2013). One of the major components of the energy sector is the electricity generation sector. In 2010, Canada generated an estimated 580 billion kilowatt-hours (kWh) and is a net exporter of electricity to the United States (25.3 billion kWh) (U.S. Energy Information Administration, 2012). Canada's electricity mix consists of hydro, nuclear, conventional steam, internal combustion, combustion turbine, tidal, wind, and solar sources with 25% of all electricity generated being GHG emitting (Canadian Electricity Association, 2013). This figure, coupled with the size of the Canadian electricity generation sector, shows that the electricity sector contributes substantially to Canada's total GHG emissions. The heterogeneity of electricity generation sources in Canada makes controlling the emissions intensity by controlling the electricity generation mix in this sector a very viable option in reducing the country's total GHG emissions. But how willing is the Canadian government to put a price on GHG emissions? Böhringer & Rutherford (2010) point out that

Canadian policymakers are unwilling to use carbon pricing systems to control GHG emissions despite their effectiveness. The reason given was that it could negatively harm the economy by putting the energy-intensive industries at a competitive disadvantage with their US counterparts that do not have a similar environmental policy (Böhringer & Rutherford, 2010).

Although few, there have been studies conducted by economists that study the Canadian electricity sector and its effect of total GHG emission. An example of such study is that conducted by Steenhof & Weber (2011) which uses an econometric decomposition method to split the Canadian electricity sector into factors responsible for GHG emissions and study the trends of such factors to determine the growth of GHG emissions from that sector. Steenhof & Weber (2011) mentioned some programs and initiatives taken by the Canadian government in an attempt to reduce GHG emissions in electricity sector but pointed out that very little has been done to study the effects of other ways that might be more effective in reducing emissions from that sector.

As such, our study will focus on a more aggressive approach, the use of carbon taxation as a mechanism to control GHG emissions from the electricity sector. Not much research has been conducted by economists on the effects of implementing of a carbon tax policy on the electricity generating sector in Canada. The use of a computable general equilibrium (CGE) model in this analysis is advantageous in studying the implementation of environmental policies because it takes into account the interactions among different sectors in the economy and the macroeconomic adjustments that occur as a result of a policy implementation (Asafu-Adjaye & Mahadevan, 2013). Previous CGE climate policy researches conducted on the Canadian economy focused on the energy intensive industries and failed to disaggregate the electricity sector into emitting components and non-emitting components and as such might not have provided very accurate information on the impact of controlling GHG emissions from the electricity sector. This paper takes the analysis a step further by disaggregating the electricity sector in the 2009 Canadian input-output table using detailed information on the production and uses of input obtained from Murenzi (2008) into the following three components: coal, other fossil fuels (OFF) and non-fossil fuels (NFF) technologies. It will intend to fill the gap from previous studies by providing a disaggregated analysis of a GHG mitigation policy in the three newly created industries that represent the Canadian electricity sector. This study will analyse the impact of a limited GHG emission control policy on the emitting components of the electricity sector and its repercussions to the other sectors of the economy. It will build off knowledge from previous research done by various Canadian and foreign economists about Canada on GHG emissions control and similar research conducted by economists on the disaggregated electricity sector in other countries. The main research question that will be answered in this paper will be "What are the sectoral impacts of a regulation of GHG emissions limited to the electricity sector in Canada?"

The paper will be organized as follows. The second section will review relevant literature and findings discovered by modelers about this topic. The third section will describe the model used and will include the data and calibration. The fourth section will describe the simulations and analyse the results. The fifth section will conclude the paper.

2. Review of Selected Relevant Literature

The implementation of a carbon control policy in a country without a corresponding execution by neighbouring countries or influence from the international community is considered to be a unilateral decision (Elliot, Foster, Kortum, Jush, Munson, & Weisbach, 2013). This article studies the effects of a unilateral decision by the Canadian government to reduce GHG emissions through carbon pricing in the electricity sector. The issue of a carbon control policy implementation is a very delicate one because each country needs to weigh and try to balance through the use of various instruments its duty to the global environment of reducing GHG emissions and its duty to maintain the economic living standards of its citizens. By using MBIs such as carbon taxes or emission permits, the Canadian government makes the price of fossil-fuel inputs more expensive which subsequently increases the price of energy-intensive outputs. This can have varying effects on different sectors of the economy some of which include carbon leakage, loss of competitiveness by affected industries, and a change in the welfare of the economy. In addition to studying the degree by which these sectors are affected by the implementation of a carbon control policy, economists also try to find ways to mitigate these effects and the extent to which the instruments used help to stimulate the economy.

Carbon leakage occurs when the implementation of a restriction in the use of fossil-fuel in one country results in an increase in its use in countries with fewer restrictions (Riker, 2012). This increase can be attributable to two things; a shift in production to countries with fewer restrictions or a reduction in the global energy prices which can have a rebound effect and stimulate consumption which results in increased global GHG emissions (Winchester, Sergey, & Reilly, 2011). The shift in production and consumption of fossil fuels to foreign countries with fewer restrictions reduces the competitiveness of domestic energy-intensive industries compared to their foreign counterparts.

Economists have studied ways of mitigating the effects of a loss in competitiveness in various countries of study through the use of instruments such as border tax adjustments (BTAs) or output-based recycling of emissions permits (Rivers, 2010). The use of BTAs is an attempt to level the playing field between foreign and domestic firms by levying a charge on imports or a subsidy on exports (Dissou & Eyland, Carbon Control Policies, Competitiveness and Border Tax Adjustments, 2011). Although this method moderately reduces carbon leakage, it is known to cause significant loss in welfare as it can hurt domestic firms that rely on the imported goods as intermediate inputs and which in turn affects domestic consumption (Dissou & Eyland, Carbon Control Policies, Competitiveness and Border Tax Adjustments, 2011). Output-based rebating occurs when emissions permits are allocated based on an index of physical or economic output or when carbon tax revenues is used to subsidize firms based on an output index (Rivers, 2010). While this policy might introduce additional distortion to the permit market in the form of an output subsidy, it provides an incentive for domestic firms to reduce per unit output emissions and can help preserve domestic production where climate policy may be implemented unilaterally (Rivers, 2010).

Despite its importance and the numerous research done by scholars on how to mitigate the effects that unilateral carbon policies have on the competitiveness of domestic energy-industries while simultaneously considering international dynamics, this aspect will be ignored in this article. This is because our study seeks to observe in isolation from the rest of the world the effects a carbon control policy implementation will have on the Canadian economy. Studies such as those done by Rivers (2010) and (Böhringer & Rutherford, 2010) conducted on the Canadian economy have stressed how important the energy-intensive industries are to the Canadian economy with the development and continued growth of main and support industries related to the oil-sands in provinces such as Alberta and Saskatchewan. In addition to the significance of the energy industry, it is important to note that the provincial governments wield substantial power in the decision-making process as a result the imposition of a climate policy that will affect or impose restrictions on the energy-intensive industries will be difficult to pass (Rivers, 2010).

Despite this fact, research has been conducted on economy-wide carbon control policies to study the effects of this policy on the Canadian economy while considering different possible scenarios that might accompany such policy. In a recent study, Rivers (2010) uses a single region dynamic general equilbrium model of the Canadian economy to study the effects of an economy-wide carbon pricing imposed on the energy-intensive industries. The study used a permit system. Revenues received from the carbon pricing were simulated to be recycled in three ways: as a lump sum transfer from the government to the households, as a subsidy to reduce pre-existing labour taxes, or as a subsidy to reduce capital taxes. These three revenue recycling methods were used to observe which method was more effective in reducing the loss in welfare and competitiveness. It was discovered that the lump-sum recycling method was the least effective. While there may have existed economic benefits in either using a labour or capital subsidy, these revenue recycling methods on their own were not sufficient in tackling the issue of competitiveness because the sectors that benefited from this method were those that used more intensively the subsidized factor of production. Thus, industries that used labour more intensively benefitted more from a labour subsidy. Rivers (2010) suggested that Canada could implement unilateral climate policies and minimize its loss in competitiveness of key energy-intensive sectors by adopting carbon pricing policies with appropriate designs such as border-tax adjustments and output based recycling of permits (Rivers, 2010). The study showed that although a greater distortion to the market was seen in both designs, the negative effects to welfare and economic output were smaller with the output-based recycling of permits than in the border-tax adjustment (Rivers, 2010).

Although there are studies that explore the effects of economy-wide carbon control policies in various parts of the world, the focus of this article as mentioned in the introduction is the observation and analysis of sectoral carbon control implementation specifically a disaggregated electricity sector. A study conducted by Goulder, Hafstead, & Williams III (2013) looks at the Clean Energy Standards (CES) federal policy in the United States which seeks to reward clean electricity generation and penalize electriciy generation from fossil-fuel inputs in an attempt to reduce GHG emissions associated with electricity generation. In order to do this effectively, Goulder, Hafstead, & Williams III (2013) dissaggregate the electricity sector into three components; coal-fired electricity generation, natural-gas-fired electricity generation and non-fossil-electriciy generation and allocates credits or subsidies according to their input-based intensity standards. The emissions tax on the "dirty" sector is then combined with an input-based intensity subsidy such that the total revenue received from the emissions tax is given out as a subsidy. The subsidies are allocated such that non-fossil generated electricity is given full credit, natural-gas-fired electricity is given half credit and coal-fired electricity generation is given no credit in an attempt to maintain revenue neutrality and stimulate substitution towards the consumption of clean electicity (Goulder, Hafstead, & Williams III, 2013). Goulder, Hafstead, & Williams III (2013) observe the effect of such policy simulations by using a static general equilbrium model that just considers disutility to the agent and a dynamic general equilibrium that considers the effects of capital accumulation while studing the effect across the years. While the scope of the article by Goulder, Hafstead, & Williams III (2013) is more than the focus of this article, the methodology employed will be used in our analysis of the implementation of a carbon control policy on the disaggregated Canadian electricity sector.

There exist few studies that analyse and show the effects of implementing a sectoral carbon pricing policy on the Canadian electricity sector which is a high emitting sector due to increased demand of electricity and the use of fossil-fuel as inputs in this sector (Steenhof & Weber, 2011). The influence and impact of the electricity sector on the Canadian GHG emissions is expected to increase if left unchecked due to an expected continued increase in the demand of electricity as a result of increase in economic activity (Steenhof & Weber, 2011). Given the different sources used in the generation of electricity in Canada, a study analysing the effects of a carbon control policy implementation on the GHG emitting inputs of the electricity sector as a viable option in reducing Canada's total GHG emissions remains a crucial one. Steenhof & Weber (2011) remains the closest study to be conducted that links this high emitting sector with the total GHG emissions of Canada and analyses the factors that contribute to the high amount of emissions in that sector. Steenhof & Weber (2011) use a Laspeyres sectoral decomposition analysis to study the factors that impact the trend in GHG emissions in the electricity sector and study the effects of a climate policy on emissions for the time period between1990 to 2008. The econometric analysis breaks down the factors that affect GHG emissions in the electricity sector into 6 components: "the activity effect" which is the change in emissions attributable to the amount of electricity generated that year, "the generation effect" which represents the change in emissions attributable to changes in the sources of electricity across the years, "the fuel mix effect" which represents the fossil fuels that makes up the electricity mix, "the efficiency effect" which represents the change attributable to the efficiency of electricity generation, "the emissions intensity effect" which represents the change in emissions attributatble to the amount of fossil fuels used for fossil fuel based electricity generation, and "the auxilliary effect" which represents changes in the amount of electricity lost during transmission and distribution" (Steenhof &

Weber, 2011). The research studies the interaction among these six components and how they affect the amount of GHGs emitted in the Canadian economy. The results showed that the generation mix and the increases in the activity mix accounted had a greater impact on the GHG emissions from the electricity sector over the years than the fuel mix effect and the efficiency effect (Steenhof & Weber, 2011). Also, it was observed that the increase in efficiency and changes in the type of fossil fuels used as inputs in the sector consistently lead to a decrease in the emissions from the electricity sector (Steenhof & Weber, 2011).

While the econometric analysis by Steenhof & Weber (2011) may have contributed to the exisiting literature by highlighting the main factors responsible for most GHG emissions from the Canadian electricity sector between 1990 and 2008, it fails to provide an estimate of the reduction of GHG emisssions as a result of a climate policy implementation or a comprehensive analysis of its effect on various sectors of the Canadian economy. This is where the use of a computable general equilibrium model is advantageous. This article will add to the existing stock of knowledge by using a static general equilibrium model to provide a more comprehensive and accurate analysis of a carbon price implementation on a disaggregated Canadian electricity sector using the year 2009 as the base year.

3. The Model Description

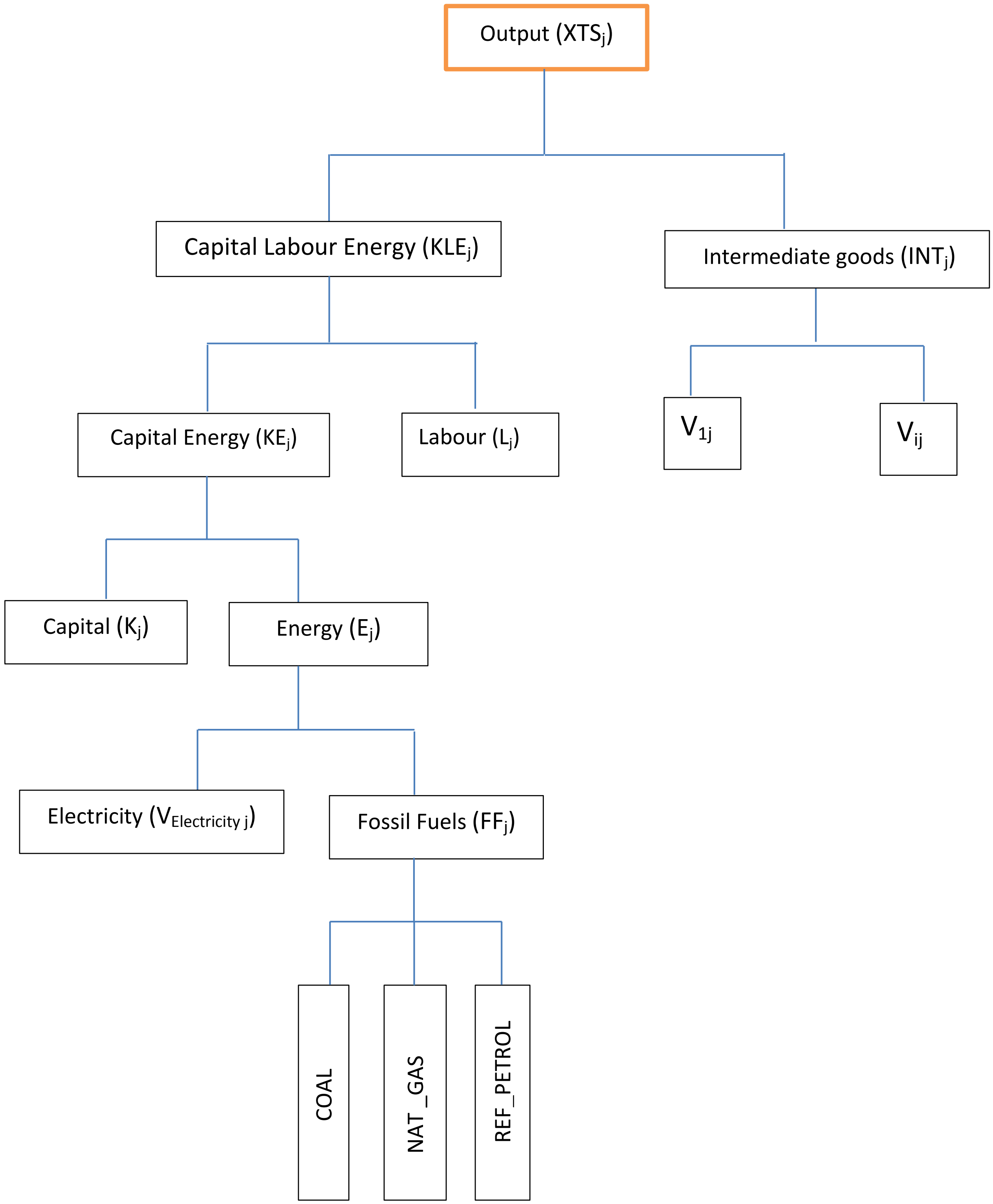
The model used in this study builds upon previous contributions to the CGE literature on GHG control policies using MBIs. Canada is considered to be a small economy with trading partners all over the world and as such this model represents a small open economy model with consumers and firms. This model is a static computable general equilibrium model of the Canadian economy with 2009 as the base year. The 2009 Canadian input-output table used in the formulation of this model was provided by Statistics Canada (StatCan) while detailed information on the production and uses of input that were used in the disaggregation of the electricity sectors into the coal, other fossil fuels (OFF), and non-fossil fuels (NFF) were obtained from Murenzi (2008).

Firms and households are assumed to have an optimizing behaviour. The government is assumed not to have an optimizing behaviour but is considered to consume goods and services in real terms and make transfers to households and firms in nominal terms. Government savings is used to fund investments. Perfect competition is also assumed in this economy where labour and capital are assumed to be perfectly mobile within the country but not internationally due to country boundary restriction. While production occurs within the country, there are also imports and exports between the country and the rest of the world (ROW). Imports and domestically produced goods are treated as imperfect substitutes for goods produced domestically (Armington assumption). The ratio of domestic prices to world prices determines the volume of imports and exports. The world prices are exogenous while the domestic prices are determined by equilibrium.

3.1 Production

The production industries consist of 20 final goods industries that produce 18 commodities as seen in Table 15 in Appendix D below. The final goods industries include the 3 disaggregated electricity generating industries that produce one commodity, electricity. The nested framework of the production technology is illustrated in Figure 1 below. The behaviours and market structures are described in the subsequent sections.

Figure 1: The Nested Framework of the Production Technology



3.1.1 Final Goods Production excluding the Electricity Sector

The industries, j, that produce goods domestically are assumed to produce for both foreign and domestic consumption. Domestic market consumption includes the final consumption of goods by households, firms, and government and as intermediate inputs for other industries. Another assumption in this model is that no tax is imposed on the intermediate goods. Taxes are only imposed on the consumption of final goods.

For simplicity, we assume that all firms and production technology within each industry are identical. We also consider prices of wages (w_j), the rental rate of capital (r_j), and final good markets (PC_i) as exogenous. Depreciation is not considered in this model. All industries within the Canadian economy are assumed to act in a profit maximizing way subject to the available technology.

In the nested framework for production technology in Figure 1, the production of a unit of output can be represented as a constant elasticity of substitution (CES) combination of intermediate goods (INT_j) and capital labour energy inputs (KLE_j). Given the wages, rental rate of capital, and market prices, the firms maximize their profits

$$Max \prod = PXTS_j XTS_j - PKLE_j KLE_j - PINT_j INT_j$$

Subject to the following CES technology constraint of

$$XTS_j = A_j \left[(1 - \propto_j) KLE_j^{\frac{\sigma-1}{\sigma}} + (\propto_j) INT_j^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

Where, $PXTS_j, PKLE_j, PINT_j$ represent the prices of output in industry j, composite capital labour energy inputs and intermediate inputs respectively, $\propto_j$ represents the proportion of intermediate goods used to produce a unit of output, σ represents the constant elasticity of substitution, and A_j represents the total factor productivity attributable to a unit output of production.

Intermediate inputs (INT_j) are combined using a nested Leontief production function. Given the technology in place, it is assumed that intermediate goods are combined in fixed proportions. Given market prices, firms minimize costs

$$Min \sum_i PC_i V_{ij}$$

Subject to the Leontief technology constraint of

$$INT_j = Min \left[\frac{V_{ij}}{\propto_{ij}}\right]$$

Where, V_{ij} represent the value of commodity *i* used as intermediate goods used in industry j, PC_i represent the consumer price of commodity *i*, $\propto_{ij}$ represents the proportion of commodity *i* that is used in the production of intermediate goods in industry *j*. *i* represents all non-energy commodities.

The capital labour energy input (KLE_j) is a CES combination capital energy (KE_j) and labour (L_j). Given wages and the price of capital energy, the firm minimizes its cost.

$$Min\ w_j L_j + PKE_j\ KE_j$$

Subject to the CES technology constraint of

$$KLE_j = AKLE_j \left[(1 - \propto_j) KE_j^{\frac{\sigma-1}{\sigma}} + (\propto_j) L_j^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

Where w_j represents wage in industry *j* which is exogenous to the model, PKE_j represent price of capital energy in industry *j*, $\propto_j$ represents the proportion of labour used by industry *j* in the production of capital labour energy inputs (KLE_j) in industry j and $AKLE_j$ represents the total factor productivity attributable to factor inputs of capital labour and energy.

Capital energy is a CES combination of capital (K_j) and energy (E_j). This combination is made because capital and energy are assumed to be substitutes of one another. Given the rental rate of capital and energy prices, firms minimize costs

$$Min \;\; r_j K_j + \; PE_j \; E_j$$

Subject to the CES technology constraint of

$$KE_j = \; AKE_j \left[(1 - \propto_j) K_j^{\frac{\sigma-1}{\sigma}} + \; (\propto_j) E_j^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

Where r_j represents the rental rate of capital in industry j which is exogenous in the model, PE_j represent price of energy used in industry j, $\propto_j$ represents the proportion of energy used in the production of capital energy, and AKE_j represents the total factor productivity attributable to capital energy.

Energy in this model is defined as a composite of electricity and fossil fuels. Energy is represented as a CES combination of electricity (ELE_j) and fossil fuels (FF_j). Given prices of fossil fuels and electricity, firms minimize costs

$$Min \;\; PFF_j FF_j + \; PC_{Electricity} \; ELE_j$$

Subject to the CES technology constraint of

$$E_j = \; AE_j \left[(1 - \propto_j) FF_j^{\frac{\sigma-1}{\sigma}} + \; (\propto_j) ELE_j^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

Where PFF_j and $PELE_j$ represent price of fossil fuel and electricity in industry j, $\propto_j$ represents the proportion of electricity used in the production of energy in industry j, and AE_j represents the total factor productivity attributable to energy.

Fossil fuel (FF_j) in this model represents all non-electricity emitting energy sources used in industry *j*. It is represented as a CES combination of coal, natural gas and refined petroleum which can be used as substitutes for each other in the production of fossil fuel inputs. Given prices, firms minimize costs of inputs

$$Min \sum_i PC_i V_{ij}$$

Subject to the CES technology constraint of

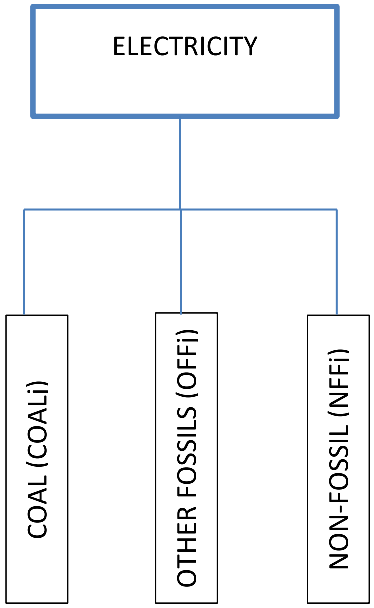
$$FF_j = AFF_j \left[\sum_i \propto_{ij} V_{ij}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

Where *i* = Coal, Natural Gas and Petroleum and the sum of their proportions used as fossil fuel inputs is equal to one: $\sum_i \propto_{ij} = 1$. The profit maximization problems of firms are solved and the optimal price and output solutions can be found in Appendix A.

3.1.2 Electricity Production and Distribution

For this analysis, the electricity sector is disaggregated using the labour factor productivity ratios from Murenzi (2008). The aggregated electricity industry, as illustrated in Figure 2, is disaggregated to make up 3 industries represented by their respective inputs used during electricity generation; Coal ($COAL_j$), Other Fossil Fuels (OFF_j) which comprises of Natural Gas and Petroleum, and Non-Fossil Fuels (NFF_j) which comprises of Hydro, Nuclear, and Biomass-Solar-Wind**.**

Figure 2: Production Framework of Electricity



Electricity is assumed to be produced by these three industries and sold as a commodity to a wholesale industry ($ELEC\_PROD_j$) which distributes the final product, electricity, to the different sectors of the economy. The production technology is modeled such that the final output (XSS_j) allows for a CES composite function of the three newly disaggregated electricity producing industries and is represented by the equation below. Given prices, firms seek to minimize costs

$$Min \sum_j (1 + tp_j) PXTS_j XTS_j$$

Subject to the following CES technology constraint

$$XSS_j = AS_j \left[\sum_j \propto_j XTS_j^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

Where j represents the three power industries: Coal, other fossil fuels (OFF), and non-fossil fuels (NFF), tp_j represents the production tax in industry j, and $\propto_j$is the share of the electricity produced by the 3 electricity generating industries such that the total is equal to one $\sum_j \propto_j = 1$. The solution for the optimal price ($PXSS_j$) and output (XTS_j) of the composite CES production function are presented in Appendix A.

3.1.3 Trade: Import and Export

The Canadian economy is an open one and the goods are imported to be sold domestically and used by domestic industries as intermediate goods. The prices of imports and exports are taken as given. Duties and excise taxes are levied on these imports and exports respectively. Imported goods are assumed to be imperfect substitutes to domestically produced ones following the Armington assumption and as such the total goods demanded and consumed domestically is assumed to be a CES aggregator function of both domestically produced goods, XDD_i, and imports, M_i. Given import and domestic prices, the optimal consumption of imports into the economy is determined by solving the cost-minimization problem

$$\min PC_i XTD_i = Pd_i XDD_i + Pm_i M_i$$

Subject to the following CES technology constraint

$$XTD_i = AM_i \left[\alpha_i M_i^{\frac{\sigma-1}{\sigma}} + (1-\alpha_i) XDD_i^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{1-\sigma}}$$

Where, PC_i, Pd_i, Pm_i represent the composite, domestic and import prices respectively, AM_i is the shift parameter of the Armington aggregate of total domestic demand of commodity i. and $\alpha_i$is the share parameter of imports in the CES function of total domestic demand of commodity i. When the solution is solved optimally, the equations for the composite price and output can be obtained as those presented in Appendix A.

Goods produced domestically are assumed to either be sold domestically or exported. The output is obtained from a constant elasticity of transformation (CET) aggregator function of domestic sales (XDS_i) and exports (EX_i). Given prices, domestic sales and exports are combined by firms to maximize revenue

$$\max PXSS_i XSS_i = Pd_i XDS_i + PX_i EX_i$$

Subject to the following CET technology constraint

$$XSS_i = AX_i \left[\alpha_i \, EX_i^{\frac{(-\sigma+1)}{\sigma}} + (1 - \alpha) XDS_i^{\frac{(-\sigma+1)}{\sigma}} \right]^{\frac{\sigma}{1+\sigma}}$$

Where PX_i represent the export prices respectively, AX_i is the shift parameter of the CET production function of total supply of commodity i. and $\alpha_i$is the share parameter of exports of commodity *i* in the CET function. When the solution is solved optimally, the equations for the dual price and output can be gotten as those presented in Appendix A.

3.1.4 Other Conditions for Firms

For this model, the firm's income, *YE*, is described as the total income obtained from the activities of firms in the industry net the amount that is returned to households as dividends.

$$YE = (1 - \beta_{kh}) r \sum_j K_j$$

Where β_{kh}represents the amount of dividends paid to households. The firms are assumed to save a fixed proportion of their after tax income. The savings rate is considered to be exogenous in this model.

$$SAVE = (1 - T_E) YE$$

Where $T_E$represents the corporate income tax.

3.2 Household Behaviour

We assume that all different consumers have similar preferences which can be represented as a CES utility function. Given prices, consumers are assumed to maximize their utility function

$$Max\ U(C_i) = \left[\sum_i \alpha_i\, C_i^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

Subject to the household's budget constraint of

$$\textstyle\sum_i (1 + tc_i) PC_i C_i = CY, \text{ where } \sum \alpha_i = 1$$

Where C_i, tc_i, and CY represent household consumption of commodity *i*, consumption tax on commodity *i*, and household's total consumption expenditures. When the utility maximization function is solved, the consumption of commodity *i* by households can be represented as seen in Appendix A

Total consumption expenditures (CY) can be described as the income households have after saving a portion of their disposable income which can be represented as $CY = (1 - Sav_H)YDH$ where YDH represents disposable income. The disposable income is the income that consumers have after income tax is paid to the government which is represented as $\mathrm{YDH} = (1 - \mathrm{T_{YH}})\,\mathrm{YTH}$ where YTH represents total household income. Total household income represents income gained from labour, return of capital from firms, government transfers (GOVTRANS) and transfers from households to the rest of the world (ROWTRANS). Total household income is represented in the model as such:

$$YTH = \left[wL + B_H \sum_j rK_j\right] + GOVTRANS - [ER * ROWTRANS]$$

Where *ER* represents the exchange rate used in the model. The total household savings can be represented as

$$SAVH \ = Sav_H * YDH$$

3.3 Government

The Government is seen as a passive component of the economy that makes transfers to households and firms. It seeks to balance the budget and levies indirect taxes on the production activities, consumption, imports and exports and also direct taxes on households and firms. The total income that accrue to the government (YG) are the taxes received from activities within the economy such as income earned by households and firms, consumption, investment, production, import and export activities. It can be represented below as

$$YG = T_{YH}YTH + T_E YE + \sum_i TC_i PC_i C_i + \sum_i TINV_i PC_i DINV_i + \sum_j TP_j PXTS_j XTS_j + \sum_i TM_i ER * PWM_i M_i + \sum_i TX_i PX_i EX_i.$$

Where $T_{YH}YTH$represents the total corporate tax, $T_{YH}YTH$represents the total household income tax, $\sum_i TC_i PC_i C_i$ represents the total consumption tax, $\sum_i TINV_i PC_i DINV_i$ represents the total investment tax, $\sum_j TP_j PXTS_j XTS_j$ represents the total production tax, $\sum_i TM_i ER * PWM_i M_i$ represents the total import duties, and $\sum_i TX_i PX_i EX_i$ represents the total export tax. Savings is defined as residual income after government consumption and transfers to households. Savings in the model is represented as below.

$$SAVG = YG - \sum_i PC_i (1 + TC_i) G_i - GOVTRANS.$$

Government saving, *SAVG*, is assumed to exogenous in this model.

3.4 Market Clearing and Equilibrium Conditions

For the market to clear, the following assumptions and equilibrium conditions must hold. Total savings in the economy ($TOTSAV$) must be equal to the total savings by households ($SAVH$), firms ($SAVE$) and government ($SAVG$). A portion of the total savings (β_V) is re-invested in the economy and a tax ($TINV_i$) is paid on that investment. The labour supplied by households (LS_j) must equal the labour demanded by firms (LD_j). The total stock of capital ($KTOT$) in the economy is a sum of the capital stock in the industries in the economy. The amount of goods supplied domestically (XDS_i) must equal to the amount of goods demanded domestically (XDD_i). The total amount of goods demanded in the economy (XTD_i) is a total of goods demanded as investment ($DINV_i$), for consumption by households (C_i), by government (G_i) and as intermediate goods by firms in the economy ($\sum_j V_{ij}$). The price of imports (PM_i) is assumed to include the duties (TM_i) and must be converted from the world price (PWM_i) to the local currency by using the exchange rate (ER) specified in the model. Likewise, the price of export (PEX_i) must be converted to the world currency ($PWEX_i$) by using the exchange rate (ER). A full list of the equations used in this model can be found in Appendix A.

4 Data and Parameter Calibration

4.1 Parameters

4.1.1 Elasticity of Substitution

The elasticities of substitution used in different CES production functions in this model vary depending on their use. In the similar research conducted by economists, we were able to discover the values of the different types of elasticity of substitution. The various elasticities of substitution used in this study were gotten from the range of values used by Dissou (2006) in the study of distributional impacts of emissions allowances in Canada (Dissou, 2006). Based on the suggestion by Dissou (2006), Table 1 shows the values of the elasticity of substitution used in this model.

Research conducted by the International Monetary Fund (IMF) on the various elasticities of different OECD countries estimated different values for the elasticity of substitution for imports and exports in Canada. It estimated the Constant Elasticity of Transformation (CET) of exports in Canada to be 1.4 in the short-run and 1.89 in the long run (Tokarick, 2010). The short-run value of 1.4 was used in this model. The estimated Armington elasticity of substitution of imports in Canada was 1.34 in the short-run and 1.82 in the long-run (Tokarick, 2010). The short-run value of 1.34 was used in this model.

Table 1: Elasticity of Substitution

Parameters	**Value**
Substitution Elasticity	
between Capital-Energy-Labour and Intermediate Inputs	0.5
between Capital-Energy and Labour	0.8
between Capital and Energy	0.7
between Fossil-Fuels and Electricity	0.6
between Types of Fossil-Fuels	0.7
of Production (including electricity producing industries)	0.5
of Consumption	2

Data Source: (Dissou, Efficiency and Sectoral Distributional Impacts of Output-Based Emissions Allowances in Canada, 2006)

4.1.2 Emissions

Data on Canadian industry emissions by fuel was requested from and provided by Statistics Canada. Latest available data was that of 2008. This figure was projected to the 2009 figures used in the model by projecting according to the growth rate of total output from 2008 to 2009 and then normalizing it to the total 2009 emission figures obtained from the National Inventory Report (NIR) submitted by the Canadian government to the UN Framework Convention on Climate Change (UNFCCC). The emission by fuel type were aggregated into three main groups; coal, natural gas and refined petroleum. The sum of emissions from these three fossil fuel types equalled the total CO_2 emissions from the various industries in 2009 and was also used to calculate the carbon emissions intensity for households and industries on which the carbon tax was imposed.

4.2 Data

4.2.1 Source

The 2009 National Symmetric Input-Output Tables - Aggregation Level L (15-208-XCB2012000) used in this model was provided by Statistics Canada. The information was supplemented by data retrieved from the national income and expenditure accounts tables (13-019-X). Information about the income and corporate taxes received by government, government savings and the transfers to households from the government was retrieved from the government section (table 9) of the national income and expenditure accounts. The figures for the net outlay to the rest of the world and the gross savings and capital transfers by consumers were gotten from the persons and unincorporated businesses (table 5) of the national income and expenditure accounts. (Statistics Canada, 2013).

The original industries presented in the input-output table were aggregated into 20 industries and 18 commodities where three industries, coal electricity producers, other fossil fuel electricity producers, and non-fossil fuel electricity producers all produce one commodity, electricity. These industries in addition to other energy intensive ones, coal, natural gas and refined petroleum will be carefully studied in this model. The year 2009 is used as the benchmark year in this static general equilibrium model. Parameters will be calibrated to that base year and results gotten from the different carbon tax simulations will be compared to the original values from the benchmark year.

4.2.2 Revenue Recycling Method

In order to maintain revenue-neutrality, the carbon tax imposed in this model is recycled in two ways; as a lump-sum to households or a subsidy to low-emitting industries. In a revenue-neutral carbon tax policy, all revenue that accrues from the carbon tax policy implementation is returned to the economy such that the net-carbon tax revenue is zero. One method of maintaining revenue-neutrality involves all revenue distributed to households as a lump-sum, while the other method involves using the parameter TAU, which is determined endogenously, as a distribution mechanism such that low-emitting industries receive a higher subsidy than the high emitting ones. The subsidies are allocated such that non-fossil fuel electricity producers recieve the most credit, other fossil fuel electricity producers recieve the second highest credit and coal-fired electricity producers receive little or no credit in an attempt to maintain revenue neutrality and stimulate substitution towards the consumption of clean electicity. By increasing the credits given to cleaner industries through the subsidy revenue recycling method, the policy provides incentives for lower emitting industries to increase production and output and reduce the production level for dirty industries.

5. Simulation, Results, and Analysis

5.1 Simulations

There are two parts to this study. The first part involves the use of two different tax rates in the economy; \$25 and \$50 per ton of CO_2. The second part involves the use of the carbon tax revenue. The carbon tax proceeds are distributed in two ways; as a lump-sum to households and as a discriminatory subsidy to industries. The two parts are combined to obtain four different scenarios. Scenario 1 involves a \$25 carbon tax combined with a subsidy favouring low-emitting electricity producers according to the tax revenue distribution method stated above. Scenario 2 involves a \$50 carbon tax combined with a subsidy favouring low-emitting electricity producers according to the tax revenue distribution method stated above. Scenario 3 involves a \$25 carbon tax combined with a lump-sum transfer to households. Scenario 4 involves a \$50 carbon tax combined with a lump-sum transfer to households. Given these scenarios, we can observe the change in different factors of the economy from four sets of results that are obtained.

5.2 Policy Results and Analysis

This section discusses the results of the four scenarios used in the economy. We will use an eclectic approach in the discussion of the results, whereby all simulations will be compared on a sector basis. Section 5.2.1 discusses the effect of the carbon tax on the power industries. Section 5.2.2 discusses its effects on the fossil-fuel industry. Section 5.2.3 discusses its effects on other non-power and non-fossil-fuel industries in the economy. Section 5.2.4 discusses the effects of the tax on different general aspects of the economy.

5.2.1 Power Industries

Table 3 in Appendix B presents the sectoral changes of the simulations in the scenario 1 and 2 of the model. The first three columns give the sectoral changes in the power industries.

The model was designed such that electricity generated from coal was taxed more heavily than electricity generated from other fossil-fuels and non-fossil-fuels. The result was a 20.98% and 35.11% increase in the output price of electricity generated by coal electricity producers in scenarios 1 and 2 respectively. Electricity generated by other fossil fuel electricity producers and non-fossil fuel electricity producers that received a larger amount of subsidy due to their low carbon emissions intensity than the coal electricity producers both saw a decrease in the price of electricity generated in these industries. This lower price of the non-coal electricity generating industries resulted in an increase in electricity demanded from both industries and as such resulted in an economy that moves away from the use of coal as an electricity generating source. As a result, we can see that the subsidy allowed non-coal electricity producers to be able decrease output price and increase the demand of electricity from those industries. The subsidy also allowed the coal electricity producers to be penalized for the high carbon emissions for that industry.

A different result is obtained in scenarios 3 and 4 as seen in Table 4 in Appendix B. Given that carbon tax revenues are transferred to households as a lump-sum, consumers in these scenarios see a rise in the electricity prices from all three electricity generating industries. This increase in price results in a decrease in output demanded across all power industries. Electricity generating industries with higher carbon intensities show a higher price increase than their counter parts. Coal electricity producers have the highest price increase with 22.36% and 37.20% for $25 and $50 tax rates respectively, followed by other fossil fuel electricity producers with a 1.44% and 2% price increase and non-fossil fuel electricity producers with a 0.21% and 0.42% price increase respectively. Electricity generating industries with lower price increases see a lower reduction in electricity demanded. The lump-sum revenue transfer to households fails to produce results which show an increase in supply of electricity from less emitting industries as was observed in Scenarios 1 and 2 which gave more credits to less emitting industries. It instead resulted in an overall decrease in the supply of electricity from the three electricity producing industries. Scenarios 2 and 4 show that higher tax rates result in an increased tax burden for consumers manifested as a price increase.

The composite price of electricity in scenarios 1 and 2 rose by 1.31% and 2.75% respectively. This price increase resulted in a decrease in the demand for electricity by 1.69% and 3.41% respectively as seen in Table 9 in Appendix C. Households decreased their consumption of electricity significantly in scenarios 1 and 2 with a greater decrease in scenario 2. Scenarios 3 and 4 resulted in a larger increase in the composite price of electricity by 4.9% and 7.92% in scenarios 3 and 4 as seen in Table 10. This larger composite price increase resulted in a greater decrease in electricity supplied. Export supply decreased greatly with a 12.09% and 18.52% decrease in scenarios 3 and 4. Household consumption of electricity reduced by 9.2% and 14.26% which is greater than the reduction seen in scenarios 1 and 2. Given the assumption that more consumption translate to higher utility, households are worse off in scenarios 3 and 4 than they are in scenarios 1 and 2. The economy also suffers as a net exporter of electricity as it sees more reduction in exports in scenarios 3 and 4 than it does in scenarios 1 and 2. The sector greatly affected was the export sector which saw the largest decrease in the supply of electricity. This is important to note as Canada is a net exporter of electricity to the United States (U.S. Energy Information Administration, 2012). There was an increase in electricity imported into Canada as this unilateral climate policy made foreign produced electricity cheaper than domestically produced one.

Scenarios 1 and 2 show a decrease in the demand for electricity by coal-fired electricity producers which was substituted by an increase in demand for capital and labour as seen in Table 3. Although there may have been an increase in the demand of both labour and capital in the industry, the demand for labour is higher than that of capital. In the other fossil fuel electricity producing industry, an increase in electricity generated by that industry resulted in an increase the demand of both factors of production and electricity by the industry in scenario 1. However, scenario 2 shows an increase in output supplied lower than that in 1 and as such resulted in a decrease in the demand for electricity by other fossil fuel electricity producers in that scenario. In the non-fossil fuel electricity producers industry, the increase in output was not as substantial as that of other fossil fuel electricity producers. This resulted in a decrease in the demand for electricity by that industry and a substitution of that demand by an increase in both factors of production. In scenarios 3 and 4 as shown in Table 4, coal electricity producers see a greater decrease in output supplied than in scenarios 1 and 2. This resulted in a greater decrease in the demand for electricity and a lesser increase in its substitution by capital and labour. The decrease in electricity supplied by other fossil fuel electricity producers resulted in a decrease in demand of electricity, labour, and capital demanded in scenarios 3 and 4. The same is seen in the non-fossil fuel electricity producing industry.

Industry emissions fall across all power industries in all scenarios although the reduction in emission is greater in scenarios 3 and 4 than in scenarios 1 and 2. It should be noted that in scenarios 3 and 4, reduction in the consumption of electricity as a good account more for the reduction in industry emissions than it does in scenarios 1 and 2. This means that the household lump-sum transfer revenue recycling method is more effective in reducing industry emissions. However, this lump-sum revenue recycling method causes less distortion in the economy as it leads to a greater reduction in consumption of electricity than the subsidy revenue recycling method.

5.2.2 Fossil-Fuel Industries

This section discusses the effect of the carbon pricing policy on the fossil-fuel industries (coal, natural gas, and refined petroleum) in the model. For the purpose of this study, crude oil is defined as the resource which is extracted from the earth. Given that fossil fuel must be combusted to release greenhouse gases, crude oil was not included in the fossil fuel industries. The effects of the carbon policy on the crude oil industry will be analysed later on in this section. It is important to study this section because outputs from these industries also provide inputs for the sector of main interest in this study, the electricity sector. The carbon tax policy affected the coal industry as follows. The use of coal as an energy source fell by 40.88% and 52.69% with the $25 and $50 tax rate in scenarios 1 and 2 as seen in Table 3 in Appendix B. Scenarios 3 and 4 as seen in Table 4 show a greater decrease in output supplied by the coal industry and a greater reduction in output price than the previous two scenarios. It is important to also note that the coal electricity producing industries reported a substantial decline in the supply of electricity and as such it can be expected that there will be a decrease in the demand of coal from the coal industry and a reduction in price due to its high carbon content. This reduction in price is due to the tax wage caused by the carbon tax and other shifts in demand. However, the decrease in demand of the commodity by consumers was quite substantial that a price decrease was unable to offset this decrease in consumption. Total demand for coal as a commodity decreased by 43.72% and 55.7% in scenarios 1 and 2 in Table 9 in Appendix C. The substantial decrease in supply of coal as a commodity affected the export supply of coal which also decreased substantially. Import of coal as a commodity also decreased in both scenarios. The same is the case in scenarios 3 and 4 as seen in Table 10. The demand, export and import of coal fell in these scenarios. Coal instead is demanded as an investment good. An investment good is one which is used to increase the stock of capital in the next period. It is important to note that coal is not consumed by households as energy source in this model. The proportions of increase and decreases are greater in scenarios 3 and 4 than in scenarios 1 and 2. Export supply, and the demand of natural gas as an import good decreased. Natural gas was no longer demanded by an investment good instead it was demanded as a consumption good by households. This decrease can be explained by a movement away from the use of coal as an intermediate good by industries as the economy moves towards an increased use of less carbon intensive goods.

There is also a decline in the use of natural gas as an energy source; however, this decline in output supplied by the natural gas industry is not as substantial as in the coal industry. Output supplied by the natural gas industry declined by 0.43% and 0.47% in scenarios 1 and 2 respectively while refined petroleum supplied increased by 0.05% and 0.04% in scenarios 1 and 2 respectively. There are two possible explanations for this. The reduction in price was more pronounced in the refined petroleum industry than in the natural gas industry. This made the use of refined petroleum as an energy source cheaper than natural gas as an energy source. Another possible explanation may be that the change in the production process in the other fossil fuel electricity producing industry results in an increase in the use of refined petroleum and a decrease in the use of natural gas as electricity inputs. Given the prices, consumers switch from the use of coal and natural gas as an energy source to refined petroleum and this resulted in an increase in output and industry emissions in that industry in scenarios 1 and 2. However, there is a greater decrease in output price of the natural gas and the refined petroleum industry. This reduction led to a lesser decrease in scenarios 3 and 4 of output supplied by the natural gas industry and a greater increase in output supplied by the refined petroleum industry than was observed in scenarios 1 and 2. It can be explained by an increased substitution away from the use of coal by consumers in these scenarios.

The household demand of natural gas as energy source rose by 0.08% and 0.13% in scenarios 1 and 2 in Table 9 in Appendix C. Given that domestically produced natural gas has become cheaper, there is a decrease in the importation of gas produced by foreign industries. There is a reduction in the natural gas exported and demanded as investment goods because more of the natural gas produced domestically is consumed. In scenarios 3 and 4, output supply, export supply, and demand of natural gas as an energy input decreased at a greater rate than it did in scenarios 1 and 2. There is a greater increase in the demand of natural gas consumed by households and a greater decrease in the demand of natural gas as investment goods in scenarios 3 and 4 than in scenarios 1 and 2. Increased supply of refined petroleum coupled with a decrease in the demand of refined petroleum as energy source resulted in an increase in export supply. Refined petroleum was no longer held as an investment good. It was instead consumed by household. Household consumption of refined petroleum increased by 0.18% and 0.25% in scenarios 1 and 2. A greater increase in the demand of refined petroleum output and a greater decrease in the domestic demand of refined petroleum resulted in a greater increase in export supply in scenarios 3 and 4 than in scenarios 1 and 2. Household demand of refined petroleum as an energy source is also greater in scenarios 3 and 4 than in scenarios 1 and 2. Refined petroleum was demanded as an investment good in scenario 3 when the tax rate was $25. This was reversed in scenario 4 when the carbon tax rate was higher and there was a decrease in the demand of refined petroleum as an investment good.

The decline in output supplied by the coal and natural gas industry in scenarios 1 and 2 resulted in a decline in the demand of electricity, capital, and labour within their respective industries as seen in Table 3. The increase in output supplied by the refined petroleum industry was supplemented by a decrease in the amount of electricity and labour used. This decrease was substituted by an increase in the demand for capital by 0.09% and 0.11% in scenarios 1 and 2. Similar results are noted in scenarios 3 and 4 for the coal and natural gas industries. The decrease in the output supplied by the coal industry was greater in scenarios 3 and 4 and as such resulted in a greater decrease in the demand for electricity, capital and labour within the coal industry. The reduction of output supplied in scenarios 3 and 4 was less severe in scenarios 3 and 4 than in scenarios 1 and 2. This resulted in a greater substitution away from the use of electricity and labour towards the use of capital in scenarios 3 and 4 than in scenarios 1 and 2. The demand for capital decreased at a lower rate in scenarios 3 and 4 than they did in scenarios 1 and 2.The increase in the supply of output by the refined petroleum industry resulted in a greater decrease in the demand electricity and a greater substitution towards to the use of capital and labour in scenarios 3 and 4 than in scenarios 1 and 2.

Given both scenarios, we can see how the effects of a sectoral carbon policy present itself in other supporting industries. It can be observed that the greater the carbon tax imposed, the greater the reduction in output supplied in all scenarios. However, the natural gas and refined petroleum supplied in the 3rd and 4th scenarios is larger than in the first two scenarios. This can be explained as such an increase in household demand for those commodities as a result of the lump-sum transfer to households. Industry emissions fall in both the coal and natural gas industries although the reductions in industrial emissions were greater in scenarios 3 and 4 than in scenarios 1 and 2. The rise in the output supplied by the refined petroleum industry resulted in an increase in the industrial emissions in all four scenarios. However, the increase in industrial emissions is greater when the carbon tax revenue were recycled as a lump-sum to households than when it is recycled as a subsidies given to industries.

In this model, the crude oil industry refers to those industries that extract crude oil as a resource from the earth. In all four simulations, there is a reduction in the supply price of crude oil and an increase in the amount of crude oil supplied. The reduction in price is greater as the tax rate increases and also when revenues are returned as a lump-sum to the industries as seen in Tables 3 and 4. In scenarios 1 and 2, the decrease in the price of crude oil coupled with an increase in crude oil supplied domestically resulted in a decrease in demand of crude oil as an import good by 0.08% and 0.18% respectively as seen in Table 9 which led to an increase in the crude oil supplied in both scenarios. There is also an increase in the demand of crude oil by households and a decrease in the demand of the commodity as an investment good in scenarios 1 and 2. Scenarios 3 and 4 show a greater decrease in the price of crude oil and a greater increase in the amount of crude oil supplied by the industry than in previous scenarios as seen in Table 10. Export supply and demand of the commodity by households increased at a greater rate than in scenarios 1 and 2. We also see a greater decrease in the demand of crude oil as an import good. The difference between the first two scenarios and the last two scenarios can be seen in the demand of crude oil as an investment good. In scenarios 3 and 4, we can see that industries prefer to hold crude oil as an investment good than to use it as intermediate goods. There is instead an increase in the demand of crude oil as an investment good and a decrease in the demand of the commodity as an intermediate one.

Table 3 shows a decrease in the demand of electricity of the crude oil industry by 0.43% and 1.21% in scenarios 1 and 2 respectively. This decrease is substituted by an increase in the demand for capital and labour in both scenarios. Scenarios 3 and 4 boast a greater decrease in the demand of electricity and a greater increase in the demand for capital and labour by the industry as seen in Table 4. Demand for electricity decreased by 2.57% and 4.18% in scenarios 3 and 4 respectively. An interesting observation is that although the increase in output produced in the industry is higher in the last two scenarios, the corresponding increase in industry emissions is smaller than in the first two scenarios. An explanation could be that the crude oil industry uses more of the electricity generated from "dirty" inputs. This observation was also made by Rivers (2010) who stated that Alberta and Saskatchewan was home to most of Canada's oil and gas industries and coal-fired electricity generating industries (Rivers, 2010).

5.2.3 Non-Power and Non-Fossil Fuel Industries

This section discusses how all other industries are affected by the carbon pricing policy as can be seen in tables 5-8 in Appendix B. From the analyses we can see that the clothing & paper (CP) and organizations are the industries mainly affected by the sectoral implementation of the carbon-pricing policy as they show a reduction or no change in output in all four scenarios. These results will be analysed and discussed in scenarios.

Scenario 1 which shows the combination of a $25 carbon tax rate and subsidy, as seen in Table 5, resulted in a decrease in the total output by organizations, construction and the clothing and paper industries. From previous analyses, it can be noted scenario 1 provides less distortions than the other three scenarios in both the power and fossil fuel industries. An interesting observation to note is that while there was an increase in price that may have resulted in the decrease in output demand in the CP industry, there was a decrease in price in both the construction and organization industries. This is because a decrease in the output of the clothing and paper industry was caused by an inward shift in the supply curve which results in a decrease in quantity and an increase in price. On the other hand, the decrease in the output of the construction and the organization industries is due to an inward shift in the demand curve which results in a decrease in both price and output. This decrease in total demand of both goods in scenario 1 can be seen in table 11. Price rose by 0.01% in the clothing and paper industry but fell by 0.05% and 0.04% in the construction and organization industries respectively. In table 11, exports rose in both industries in this scenario following a decrease in domestic demand by both households and industries. All other industries in this scenario reported an increase in the output supplied and a decrease in the price of output. The greatest increase in the output supplied was in the machinery industry which saw a 0.23% increase in output despite a 0.03% reduction in price. The greatest reduction in price was noted in the transport and service sector which both saw a 0.07% price reduction and gained 0.1% and 0.04% respectively in increased supply as seen in Table 5. Machinery saw the greatest increase in export supply by a rate of 0.26% as seen in table 11. Household demand of other commodities resulted in the greatest decrease in the consumption of clothing and paper products by 0.12% and the greatest increase in consumption of transport goods by 0.05%. This increase in consumption of transport goods explains the increase in the demand for refined petroleum products in the earlier section.

All industries experienced a decrease in the demand for electricity in scenario 1 with the greatest decrease reported in the clothing and paper industry by 0.93%. The decrease in the consumption of electricity across sectors resulted in an increase in the demand for capital and labour in most non-power and non-fossil fuel industries. Clothing and paper and construction industries reported a decrease in the demand for labour in scenario 1. The carbon pricing policy resulted in an increase in output in all non-power and non-fossil fuel industries except clothing and paper, construction and organization industries. This increase in supply of the outputs of these industries resulted in increase in industrial emissions during the production process. The reduction in output in the construction, clothing and paper, and organization industries resulted in a reduction of emissions from that industry by 0.02%, 0.09% and 0.02% respectively. The greatest increase in the industrial emissions was reported in the machinery industry with an increase in carbon emissions by 0.16% caused by increased production. A plausible explanation for this is that the construction, organizations, and the clothing and paper industries use more dirty energy than other industries. As a result, they experience a negative output supply in the first scenario. Other industries are observed to benefit from the reduced price of energy inputs which in turn reduces output prices and results in an increase in output from that industry. This is due to the substitution effect where dirty energy is substituted for cleaner energy.

By increasing the tax rate in scenario 2, industries previously not negatively affected by the policy showed a decline in their output despite a reduction in the prices of their outputs as seen in Table 6. Miscellaneous manufacturing saw a reduction in its overall output by 0.01% and a greater price decrease of 0.04% in scenario 2 contrary previous results reported in scenario 1. Industries such as construction, clothing and paper, and organization which previously showed a decrease in output saw that decline exacerbated in scenario 2. Scenario 2 saw the output of the clothing and paper industry decline by 0.19% almost four times the result reported in scenario 1 as seen in Table 6. Miscellaneous manufacturing reported the greatest decrease in total demand by 0.1% while transport saw the greatest increase in total demand by 0.08% as seen in Table 12. Scenario 2 resulted in more decrease in household consumption across non-power and non-fossil fuel industries than in scenario 1. The greatest household reduction in consumption was reported in the clothing and paper industry with a decrease of 0.24%. There was an increase in consumption in some sectors with the transport sector reporting the highest increase of 0.08% in this scenario. The increased tax rate in scenario 2 resulted in a greater reduction in the demand for electricity as seen in Table 6. This greatest decrease in the demand of electricity was seen in the clothing and paper industry where demand for electricity reduced by 2%. There was also a larger increase in the demand for labour and capital than was noted in the previous scenario. The clothing and paper industry saw a significant reduction in output which led to a reduction in demand of both factors of production. Industrial emissions increased in some industries but decreased in other industries as seen in Table 4. There was an increase in industrial emissions in the agriculture, mining, construction, chemical, machinery, commerce, and transport industry. The largest increase of 0.18% was seen in the transport sector. The food, clothing and paper industry, metal, miscellaneous manufacturing, service and organization all reported a decrease in industrial emissions. The largest decrease of 0.3% in industrial emissions was reported in the clothing and paper industry. This scenario differs from scenario 1 in that the sectoral changes are more pronounced and industries like miscellaneous manufacturing that previously experienced an increase in output supply experienced a decrease.

The results presented in Scenario 3 where revenue gotten from a $25 carbon tax per ton of carbon is recycled as a lump-sum transfer to households is different from the results gotten from the first two scenarios as seen in Table 7. There is a decrease in the output supplied by the clothing and paper, chemical, and metal industries. All these saw an increase in output price which might explain the decrease in the consumption by consumers of their products by 0.41%, 0.08%, and 0.13% respectively. A plausible explanation is that chemical and metal industries previously took advantage of the reduced energy prices in the previous scenarios. This support is absent in this scenario due to the transfer of carbon tax revenue to the household as a lump-sum. An increase in output supplied coupled with a decrease in price of commodities is observed in all other industries except the three above mentioned. Table 13 provides a more in-depth look at how the price and output changes affect different sectors of the economy. The decrease in output supplied by the clothing and paper, chemical and metal industries resulted in a decrease in export supply of those industries by 0.58%, 0.1% and 0.21% respectively. All other industries experienced an increase in export supply with the greatest increase of 0.34% seen in the transport industry. Households demand changed in scenario 3. There was a reduction in the consumption of clothing and paper, chemicals, metal, machinery and miscellaneous manufacturing products. The greatest reduction was observed in the clothing and paper industry. Households demand increased for all other commodities with the greatest demand increase of 0.19% noted in the transport industry. Table 7 showed a decrease in consumption of electricity by all industries in this scenario with the greatest reduction of 3.55% observed in the clothing and paper industry. The reduction of the demand of electricity was offset by an increase in demand of capital and labour across all industries in scenario 3 except the clothing and paper industry. Clothing and paper industry observed a reduction in the demand for both capital and labour by 0.14% and 0.18% respectively.

Scenario 3 presents mixed results in terms of the effectiveness of this carbon pricing in this scenario. Agriculture, mining, construction, machinery, commerce, and transport experience an increase in industrial emissions while food, CP, chemical, metal, miscellaneous manufacturing, service, and organization industries experience a decrease in industrial emissions from this policy. However, the aggregate effect of the carbon policy resulted in an overall decrease of industrial emissions by 0.98%. The decrease in industrial emissions was most pronounced in the clothing and paper industry (0.63%) which experienced the greatest decrease in output supplied. The increase in industrial emissions was most pronounced in the transport industry (0.22%) which also saw an increase in output as a result of this policy.

Scenario 4 seen in Table 8 shows how the lump-sum recycling method affected non-power and non-fossil fuel industries at a high carbon tax rate of $50 per ton of carbon. In this scenario, we see a greater decrease in the output and a greater increase in price in the clothing and paper, chemical, and metal industries than in scenario 3. In addition to these industries, there is also a decrease in the supply of output from miscellaneous manufacturing industry which saw an increase in output supply in scenario 3. This decrease occurs despite the decrease in output price of miscellaneous manufacturing. All other industries except organizations experience an increase in output and a decrease in price. The greatest increase in output is also noted in the machinery industry with an increase in output of 0.35%. The greatest decrease in output is noted in the clothing and paper industry with 0.7% decrease in output. The decrease in output supplied by clothing and paper, chemical, and metal industries negatively affect the export supplied by those industries as seen in Table 14. Exports supplied by those industries decrease by 0.99%, 0.28%, and 0.44% respectively. Export supply of all other industries except the above mentioned three increased. Total demand increased for all industries expect clothing and paper, chemicals, metal, machinery, and miscellaneous manufacturing which all reported a decrease in demand. The greatest decrease in commodity demanded in scenario 4 was seen in the clothing and paper industry whose commodity decreased by 0.26%. The greatest increase was observed in the service industry whose output demand increased by 0.14%. Household demand of commodities increased across all non-power and non-fossil fuel industries except in the clothing and paper, chemical, metal, machinery, and miscellaneous manufacturing which all reported a decrease in their respective demands by households. The greatest decrease of 0.54% was noted in the clothing and paper industry while the greatest increase of 0.26% was noted in transport sector. There was a greater decrease in the demand of electricity in scenario 4 than is observed in any of the previous scenarios as seen in Table 6. This was substituted by an increase in the demand of capital and labour across all industries in scenario 4 except in the clothing and paper, chemical, and metal industries. The change in the demand of factors of production is more pronounced in this scenario than in all other scenarios. Demand of capital and labour by the clothing and paper industry decreased at a larger rate than in the previous scenario while the demand for labour by the chemical and metal industries fell by 0.04% and 0.02% in this scenario. All other industries realized an increase in the demand for labour by these industries. The demand for capital fell only in the clothing and paper industry but rose in all other non-power and non-fossil fuel industries. Is this policy more effective in reducing carbon emissions by industries? It can be seen that in the fourth scenario, industrial emissions decrease is largest. Carbon industrial emissions decreased in all other industries except in the agriculture, mining, and construction industry where an increase was reported although this increase was not substantial. We can note that when the tax rate imposed in the model is increased the changes across sectors of the economy and the different industries become more pronounced.

5.2.4 General Economic Results

The main aim of this carbon pricing policy is to reduce the Canadian carbon emissions. The results as seen in Table 2 below show that total carbon emissions was reduced in all four scenarios. The outcome showed that total carbon emission reduction was higher when the carbon tax was combined with a lump-sum transfer to household.

Table 2: Simulation Results that show Percentage Change in Key Economic Variables (values in %)

	Subsidy		Lump	
	$25	$50	$25	$50
HOUSEHOLD EMISSIONS	0.15	0.21	0.35	0.49
TOTAL EMISSIONS	-12.64	-15.56	-12.99	-15.90
PRICE OF ELECTRICITY	1.31	2.75	4.90	7.92
RENTAL RATE OF CAPITAL	-0.17	-0.26	-0.34	-0.50
WAGE RATE	-0.02	-0.05	-0.07	-0.13
HOUSEHOLD INCOME	-0.07	-0.11	-0.07	-0.11
CORPORATE INCOME	-0.17	-0.26	-0.34	-0.50
HOUSEHOLD SAVINGS	-0.07	-0.11	-0.07	-0.12
FIRMS SAVINGS	-0.17	-0.26	-0.34	-0.50
GOVERNMENT REVENUE	-0.08	-0.13	-0.11	-0.18
GOVERNMENT SAVINGS	1.10	1.88	1.13	1.94
TOTAL SAVINGS	-0.23	-0.40	-0.25	-0.42
REAL EXCHANGE RATE IMPORTS	0.04	0.05	0.02	0.02
REAL EXCHANGE RATE EXPORTS	0.04	0.05	0.02	0.02
REAL GDP AT MARKET PRICE	-0.04	-0.08	-0.04	-0.08
TOTAL EXPORTS	-0.17	-0.25	-0.20	-0.30
TOTAL IMPORTS	-0.16	-0.24	-0.19	-0.28
EQUIVALENT VARIATION AS % OF BENCH. CONS. EXPENDITURE	-0.03	-0.07	-0.04	-0.09

Total carbon emissions declined by 12.64% and 15.56% when the $25 and $50 carbon tax were combined with the subsidy respectively, while it declined by 12.99% and 15.90%

respectively when combined with a lump-sum household transfer. This might be explained by the larger decrease in the output supply in the last two scenarios than in the first two. Although more carbon emissions were reduced and the environmental benefits are greater in scenarios 3 and 4, the policy implementation shows that consumers are worse off in that scenario as there seems to a higher decrease in welfare in scenarios 3 and 4. Total welfare decreased by 0.04% and 0.09% in scenarios 3 and 4 respectively while it decreased by 0.03% and 0.07% in scenarios 1 and 2. While total emissions may have decreased, household emissions increased in all four scenarios. Given that households were not taxed directly, we may assume that the lack of direct incentives to change their energy consumption pattern resulted in the business as usual (BAU) consumption which is projected to grow according to Burke (2010). It is important also to note that the increase in household emissions is larger in the scenario 3 and 4 because in addition to the lack of incentives to reduce household consumption of energy products, households also receive an increase in income through lump-sum transfers from the carbon tax revenue and as such are able to afford the increase in energy prices.

The price of electricity increased in all four scenarios with the largest increase in scenario 4. In scenarios 1 and 2, the carbon-tax revenue was transferred to industries in the form of a subsidy. Some of this might have been used to reduce their cost of production and offer services at a lower price to consumers. While in scenarios 3 and 4, the consumers are assumed to have shouldered more of the price increase than they did in scenarios 1 and 2. The reduction in energy supply reduces the respective marginal productivities of labour and capital which leads to an overall decrease in household income across all four scenarios. This decrease in household income is responsible for the decrease in household savings. The decrease in corporate income which was affected by the decrease in the rental rate of capital and the demand for capital in some industries explains the decrease in firm savings. Corporate income fell at a greater rate in scenarios 3 and 4 than in scenarios 1 and 2. A plausible explanation of this is the revenue recycling method used. Carbon tax revenue is recycled in the form of lump-sum transfers to households. The reduction in household and corporate income will most likely result in lower income and corporate taxes paid to the government. These lower income and corporate tax revenues in addition to the decrease in other taxes paid help explain the reduction in government revenue. Government savings is observed to have increased across all four scenarios. This increase is slightly higher in the third and fourth scenarios. The combination of all household, firm, and government savings resulted in the decrease in overall savings across all four sectors. The difference between the decrease in savings in scenarios 1 and 3 and scenarios 2 and 4 is not substantial.

Real exchange rate of imports and exports increased in all four scenarios. There was an appreciation of the exchange rate with a higher increase in the first two scenarios. There was also a decrease in both total imports and total exports. The decrease in total imports can be explained in terms of the income effect dominating the substitution effect and as such the decrease in household income was substantial enough to prevent households from demanding domestically produced goods despite the appreciation of the real exchange rate. The reduction in the supply of industrial outputs and the appreciation of the real exchange rate resulted in the decrease in export supply. All factors in the model resulted in a decrease of the real gross domestic product (GDP) at market price. GDP fell in scenarios 1 and 3 by 0.04% and in scenarios 3 and 4 by 0.08%.

6. Conclusion

We can note from previous analyses that when there is an increase in the tax rate imposed, the changes across sectors of the economy and the different industries become more pronounced. The lump-sum revenue recycling method was observed to create more welfare distortion than the subsidy method. While differences may have existed across scenarios, there were some constants that will be pointed out in this section of the paper. The carbon tax resulted in a movement away from the demand of electricity as an energy source and a substitution of this commodity with an increased use of value added i.e. capital and labour. The greatest changes in production and consumption patterns were observed in the power and fossil fuel industries. There was a movement away from the use of high emitting commodities towards the use of less carbon intensive ones. And as such, this new consumption pattern was the main catalyst in the reduction of carbon emissions in the power and fossil fuel industries. The clothing and paper industry was the non-power and non-fossil fuel industry that was most affected negatively in all four scenarios by an increase in the tax rate. While the machinery industry was the non-power and non-fossil fuel industry that was most affected positively by an increase regardless of the revenue recycling method used in all four scenarios.

How effective is this carbon policy in reducing GHG emissions in the Canadian economy? Given the results from all four simulations it can be seen that total emissions in scenarios 1 to 4 were reduced by more than 12% with the greatest reduction of 15.9% observed in the fourth scenario. Total emissions reduction was greater when the lump-sum revenue recycling method was used than when the subsidy method was used. However, welfare is lower when a lump-sum is given to the households than when it is recycled as a subsidy. While the industrial emissions are greatly decreased in the lump-sum scenarios, it is noted to be less distortive than the subsidy method. In deciding which scenario to implement, one must strike a balance between how much in GHG emissions to reduce and how much decline in welfare is acceptable.

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Appendix

Appendix A: List of Equations, Industries and Commodities used in the Model

Firms

1. $PXTS_j = \frac{1}{A_j}\left[\left(1-\propto_j\right)^{\sigma} PKLE_j^{(1-\sigma)} + \left(\propto_j\right)^{\sigma} PINT_j^{(1-\sigma)}\right]^{\frac{1}{1-\sigma}}$
2. $KLE_j = A_j^{\sigma-1} XTS_j \left[\frac{PXTS_j\,(1-\propto_j)}{PKLE_j}\right]^{\sigma}$
3. $INT_j = A_j^{\sigma-1} XTS_j \left[\frac{PXTS_j\,(\propto_j)}{PINT_j}\right]^{\sigma}$
4. $V_{ij} = \propto_{ij}\ INT_j$ where i ϵ non-energy goods
5. $PINT_j = \sum_i \propto_{ij}\ PC_i$ where i ϵ non-energy goods
6. $PKLE_j = \frac{1}{AKLE_j}\left[\left(1-\propto_j\right)^{\sigma} PKE_j^{(1-\sigma)} + \left(\propto_j\right)^{\sigma} w_j^{(1-\sigma)}\right]^{\frac{1}{1-\sigma}}$
7. $KE_j = AKLE_j^{\sigma-1} KLE_j \left[\frac{PKLE_j\,(1-\propto_j)}{PKE_J}\right]^{\sigma}$
8. $LD_j = \left[AKLE_j\right]^{\sigma-1} KLE_j \left[\frac{PKLE_j\,(\propto_j)}{w_j}\right]^{\sigma}$
9. $PKE_j = \frac{1}{AKE_j}\left[\left(1-\propto_j\right)^{\sigma} r_j^{(1-\sigma)} + \left(\propto_j\right)^{\sigma} PE_j^{(1-\sigma)}\right]^{\frac{1}{1-\sigma}}$
10. $E_j = AKE_j^{\sigma-1} KE_j \left[\frac{PKE_j\,(\propto_j)}{PE_j}\right]^{\sigma}$
11. $K_j = \left[AKE_j\right]^{\sigma-1} KE_j \left[\frac{PKE_j\,(1-\propto_j)}{r}\right]^{\sigma}$
12. $PE_j = \frac{1}{AE_j}\left[\left(1-\propto_j\right)^{\sigma} PFF_j^{(1-\sigma)} + \left(\propto_j\right)^{\sigma} PC_{Electricity}^{(1-\sigma)}\right]^{\frac{1}{1-\sigma}}$
13. $FF_j = AE_j^{\sigma-1} E_j \left[\frac{PE_j\,(1-\propto_j)}{PFF_j}\right]^{\sigma}$
14. $V_{Electricity} = AE_j^{\sigma-1} E_j \left[\frac{PE_j\,(\propto_j)}{PC_{Electricity}}\right]^{\sigma}$
15. $PFF_j = \frac{1}{AFF_j}\left[\sum_i \propto_{ij}^{\sigma}\ PC_i^{(1-\sigma)}\right]^{\frac{1}{1-\sigma}}$ Where *i* ϵ {Coal, Natural Gas, Refined Petroleum}
16. $V_{ij} = AFF_j^{\sigma-1} FF_j \left[\frac{PFF_j\,(\propto_{ij})}{PC_i}\right]^{\sigma}$ Where *i* ϵ {Coal, Natural Gas, Refined Petroleum}
17. $PXSS_i = \frac{1}{AS_i}\left[\sum_j \propto_{ij}{}^{\sigma}\left(1+tp_j\right) PXTS_j^{(1-\sigma)}\right]^{\frac{1}{1-\sigma}}$ Where *j* includes {Coal, OFF, NFF}
18. $XTS_j = AS_j^{\sigma-1}\ XSS_j \left[\frac{\propto_j PXSS_j}{(1+tp)PXTS_j}\right]^{\sigma}$ Where *j* includes {Coal, OFF, NFF}

19. $PXSS_i(Dual) = \frac{1}{AX_i}\left[\alpha_i^{-\sigma} PEX_i^{(1+\sigma)} + (1-\alpha)^{-\sigma} PD_i^{(1+\sigma)}\right]^{\frac{1}{(1+\sigma)}}$

20. $EX_i = AX_i^{(-\sigma-1)} XSS_i \left[\frac{PE_i}{\alpha PXSS_i}\right]^{\sigma}$

21. $XDS_i = AX_i^{(-\sigma-1)} XSS_i \left[\frac{PD_i}{(1-\alpha)PXSS_i}\right]^{\sigma}$

22. $PC_i = \frac{1}{AM_i}\left[\alpha_i^{\sigma} PM_i^{(1-\sigma)} + (1-\alpha)^{\sigma} PD_i^{(1-\sigma)}\right]^{\frac{1}{(1-\sigma)}}$

23. $M_i = AM_i^{(\sigma-1)} XTD_i \left[\frac{\alpha\, PC_i}{PM_i}\right]^{\sigma}$

24. $XDD_i = AM_i^{(\sigma-1)} XTD_i \left[\frac{(1-\alpha)PC_i}{PD_i}\right]^{\sigma}$

25. $YE = (1 - \beta_{kh}) r \sum_j K_j$

26. $SAVE = (1 - TY_E) YE$

<u>Households</u>

27. $C_i = \frac{\alpha_i^{\sigma}\, CY}{[(1+tc_i)PC]_i^{1-\sigma} \sum_j \alpha_j^{\sigma} PC_j^{1-\sigma}}$

28. $CY = (1 - Sav_H) YDH$

29. $YDH = (1 - T_{YH})\ YTH$

30. $YTH = \left[wL + B_{KH} \sum_j rK_j\right] + GOVTRANS$

31. $SAVH = Sav_H * YDH$

<u>Government</u>

32. $YG = T_{YH} YTH + T_E YE + \sum_i TC_i PC_i C_i + \sum_i TINV_i PC_i DINV_i + \sum_j TP_j PXTS_j XTS_j + \sum_i TM_i ER * PWM_i M_i + \sum_i TX_i PX_i EX_i$

33. $SAVG = YG - \sum_i PC_i G_i - GOVTRANS$

<u>Market Clearing Conditions</u>

34. $TOTSAV = SAVH + SAVE + SAVG + \mathrm{SAVF}$

35. $DINV(1 + TINV_i)PC_i = \beta_V[TOTSAV - \sum_i VSTK_i]$

36. $LS_j = \sum_j LD_j$

37. $KTOT = \sum_j K_j$

38. $SAVF = \sum_i PM_i M_i - \sum_i PEX_i EX_i (1 + TX_i) + TRROW$

39. $XTD_i = C_i + DINV_i + G_i + \sum_j V_{ij} + DSTK_i$

40. $PM_i = PWM_i(1 + TM_i)ER$

41. $PEX_i = PWEX_i * ER$

Appendix B: Effects on Industries

Table 3: Results of Sectoral Changes in Power, Fossil Fuel and Crude Oil Industries in Scenario 1 and 2 (values in %)

	COAL ELECTRICITY PRODUCERS		OTHER FOSSIL FUEL ELECTRICITY PRODUCERS		NON-FOSSIL FUEL ELECTRICITY PRODUCERS		COAL		NAT_GAS		REF_PETR		CRUDEOIL	
	$25	$50	$25	$50	$25	$50	$25	$50	$25	$50	$25	$50	$25	$50
OUTPUT	-10.20	-16.07	1.35	1.26	0.12	-0.58	-40.88	-52.69	-0.43	-0.47	0.05	0.04	0.49	0.65
OUTPUT PRICE	20.98	35.11	-5.03	-7.18	-2.68	-3.71	-0.09	-0.12	-0.09	-0.14	-0.13	-0.19	-0.11	-0.16
FACTOR INPUTS	-12.08	-18.72	-0.70	-1.57	0.10	-0.62	-40.87	-52.69	-0.43	-0.47	0.03	0.00	0.49	0.67
PRICE OF FACTOR INPUTS	27.77	46.47	5.75	8.07	0.36	0.65	-0.10	-0.13	-0.10	-0.15	-0.09	-0.11	-0.12	-0.18
INDEX OF INTERMEDIATE INPUTS	-0.59	-1.59	2.16	2.39	0.31	-0.25	-40.89	-52.70	-0.44	-0.48	0.06	0.05	0.47	0.63
PRICE INDEX FOR INT. GOODS	-0.05	-0.08	-0.08	-0.12	-0.05	-0.08	-0.05	-0.08	-0.08	-0.12	-0.14	-0.21	-0.07	-0.10
CAPITAL ENERGY	-16.79	-25.29	-2.37	-3.86	-0.09	-0.96	-40.87	-52.68	-0.39	-0.41	0.04	0.01	0.51	0.69
PRICE OF CAPITAL ENERGY	36.88	62.76	8.02	11.30	0.61	1.09	-0.11	-0.14	-0.15	-0.22	-0.10	-0.12	-0.15	-0.21
DEMAND FOR ENERGY	-50.82	-64.90	-11.35	-15.78	-31.38	-46.55	-41.10	-53.05	-0.64	-0.92	-0.04	-0.15	-0.01	-0.35
PRICE OF ENERGY	190.16	378.87	23.98	34.46	72.06	143.97	0.45	1.00	0.21	0.50	0.01	0.11	0.59	1.28
DEMAND FOR FOSSIL FUEL INPUTS	-50.86	-64.93	-11.44	-15.90	-31.68	-46.91	-40.89	-52.72	-0.43	-0.50	0.05	0.03	0.43	0.53
PRICE OF FOSSIL FUELS	190.49	379.62	24.20	34.78	73.33	146.73	-0.14	-0.20	-0.14	-0.20	-0.14	-0.20	-0.14	-0.19
DEMAND FOR ELECTRICITY	-7.54	-11.62	0.07	-1.03	-5.71	-10.20	-41.40	-53.54	-1.29	-2.22	-0.81	-1.70	-0.43	-1.21
DEMAND FOR LABOUR	6.98	10.35	3.86	4.77	0.41	-0.06	-40.91	-52.72	-0.50	-0.55	-0.03	-0.05	0.41	0.56
DEMAND FOR CAPITAL	3.78	5.25	3.17	3.81	0.45	-0.03	-40.84	-52.64	-0.37	-0.39	0.09	0.11	0.53	0.72
INDUSTRY EMISSIONS	-51.53	-65.59	-84.29	-90.04	-31.68	-46.91	-40.89	-52.72	-0.46	-0.54	0.03	0.00	0.41	0.50

Table 4: Results of Sectoral Changes in Power, Fossil Fuel and Crude Oil Industries in Scenarios 3 and 4 (values in %)

	COAL ELECTRICITY PRODUCERS		OTHER FOSSIL FUEL ELECTRICITY PRODUCERS		NON-FOSSIL FUEL ELECTRICITY PRODUCERS		COAL		NAT_GAS		REF_PETR		CRUDEOIL	
	$25	**$50**	**$25**	**$50**	**$25**	**$50**	**$25**	**$50**	**$25**	**$50**	**$25**	**$50**	**$25**	**$50**
OUTPUT	-13.26	-20.00	-4.73	-7.22	-4.14	-6.49	-41.35	-53.11	-0.41	-0.43	0.09	0.09	0.64	0.87
OUTPUT PRICE	22.36	37.20	1.44	2.00	0.21	0.42	-0.12	-0.17	-0.18	-0.27	-0.22	-0.31	-0.19	-0.27
FACTOR INPUTS	-15.06	-22.51	-6.64	-9.79	-4.16	-6.51	-41.35	-53.11	-0.40	-0.42	0.03	-0.01	0.66	0.89
PRICE OF FACTOR INPUTS	27.63	46.25	5.64	7.90	0.24	0.47	-0.13	-0.17	-0.19	-0.29	-0.10	-0.12	-0.23	-0.32
INDEX OF INTERMEDIATE INPUTS	-4.00	-6.23	-3.98	-6.19	-4.00	-6.23	-41.36	-53.12	-0.42	-0.46	0.10	0.11	0.60	0.81
PRICE INDEX FOR INT. GOODS	-0.09	-0.14	-0.15	-0.21	-0.09	-0.14	-0.09	-0.13	-0.15	-0.21	-0.25	-0.36	-0.11	-0.16
CAPITAL ENERGY	-19.61	-28.77	-8.20	-11.87	-4.31	-6.79	-41.35	-53.11	-0.33	-0.34	0.03	-0.01	0.68	0.93
PRICE OF CAPITAL ENERGY	36.71	62.49	7.88	11.10	0.44	0.85	-0.14	-0.18	-0.28	-0.39	-0.10	-0.12	-0.26	-0.36
DEMAND FOR ENERGY	-52.52	-66.57	-16.68	-22.85	-34.35	-49.78	-42.15	-54.12	-1.20	-1.72	-0.26	-0.46	-1.11	-1.91
PRICE OF ENERGY	190.06	378.75	23.91	34.36	72.04	143.97	1.84	2.99	0.98	1.61	0.31	0.53	2.34	3.78
DEMAND FOR FOSSIL FUEL INPUTS	-52.55	-66.60	-16.75	-22.94	-34.62	-50.10	-41.43	-53.21	-0.48	-0.57	0.07	0.06	0.41	0.49
PRICE OF FOSSIL FUELS	190.39	379.47	24.09	34.62	73.23	146.60	-0.24	-0.34	-0.23	-0.33	-0.24	-0.34	-0.23	-0.33
DEMAND FOR ELECTRICITY	-12.59	-18.27	-7.92	-12.01	-11.66	-18.07	-43.16	-55.39	-3.43	-5.21	-2.90	-4.61	-2.57	-4.18
DEMAND FOR LABOUR	3.30	5.14	-2.40	-4.03	-3.92	-6.06	-41.38	-53.13	-0.50	-0.55	0.01	0.00	0.54	0.74
DEMAND FOR CAPITAL	0.30	0.40	-2.96	-4.80	-3.79	-5.91	-41.26	-53.00	-0.29	-0.27	0.20	0.26	0.74	1.02
INDUSTRY EMISSIONS	-53.20	-67.22	-85.25	-90.88	-34.62	-50.10	-41.43	-53.21	-0.52	-0.62	0.04	0.02	0.38	0.46

Table 5: Results of Sectoral Changes in Non-Power and Non-Fossil Fuel Industries in Scenario 1 (values in %)

	Agriculture	Mining	Construction	Food	Clothing and Paper	Chemical	Metal	Machinery	Misc. Manuf.	Commerce	Transport	Service	Org.
OUTPUT	0.10	0.12	-0.02	0.07	-0.05	0.12	0.08	0.21	0.02	0.03	0.10	0.04	-0.01
OUTPUT PRICE	-0.05	-0.05	-0.05	-0.06	0.01	-0.03	-0.01	-0.03	-0.03	-0.06	-0.07	-0.07	-0.04
FACTOR INPUTS	0.10	0.12	-0.02	0.07	-0.09	0.11	0.06	0.22	0.01	0.03	0.10	0.05	-0.01
PRICE OF FACTOR INPUTS	-0.06	-0.05	-0.06	-0.06	0.08	0.00	0.04	-0.03	-0.02	-0.05	-0.07	-0.07	-0.03
INDEX OF INTERMEDIATE INPUTS	0.10	0.12	-0.03	0.07	-0.03	0.13	0.09	0.21	0.02	0.03	0.10	0.04	0.00
PRICE INDEX FOR INT. GOODS	-0.05	-0.05	-0.04	-0.05	-0.03	-0.04	-0.03	-0.03	-0.03	-0.06	-0.06	-0.06	-0.06
CAPITAL ENERGY	0.12	0.14	0.06	0.10	-0.27	0.10	-0.02	0.25	0.03	0.09	0.15	0.10	0.02
PRICE OF CAPITAL ENERGY	-0.08	-0.08	-0.15	-0.10	0.31	0.01	0.14	-0.07	-0.04	-0.12	-0.13	-0.14	-0.06
DEMAND FOR ENERGY	-0.11	-0.10	0.00	-0.53	-0.75	-0.17	-0.45	-0.44	-0.49	-0.25	0.09	-0.32	-0.50
PRICE OF ENERGY	0.25	0.26	-0.07	0.81	1.01	0.40	0.75	0.92	0.70	0.36	-0.05	0.46	0.68
DEMAND FOR FOSSIL FUEL	0.13	0.14	0.04	0.03	-0.08	0.15	0.11	0.19	0.01	0.05	0.15	0.04	-0.02
PRICE OF FOSSIL FUELS	-0.14	-0.14	-0.14	-0.13	-0.13	-0.14	-0.19	-0.14	-0.14	-0.14	-0.14	-0.13	-0.13
DEMAND FOR ELECTRICITY	-0.74	-0.72	-0.82	-0.82	-0.93	-0.71	-0.78	-0.67	-0.85	-0.82	-0.72	-0.82	-0.87
DEMAND FOR LABOUR	0.07	0.09	-0.05	0.04	-0.01	0.12	0.10	0.20	0.01	0.00	0.06	0.00	-0.02
DEMAND FOR CAPITAL	0.19	0.21	0.07	0.16	0.06	0.23	0.20	0.32	0.12	0.12	0.18	0.12	0.09
INDUSTRY EMISSIONS	0.12	0.14	0.04	0.02	-0.09	0.15	0.07	0.16	-0.01	0.04	0.14	0.02	-0.02

Table 6: Results of Sectoral Changes in Non-Power and Non-Fossil Fuel Industries Scenario 2 (values in %)

	Agriculture	Mining	Construction	Food	Clothing and Paper	Chemical	Metal	Machinery	Misc. Manuf.	Commerce	Transport	Service	Org.
OUTPUT	0.10	0.12	-0.03	0.08	-0.19	0.07	0.02	0.27	-0.01	0.04	0.13	0.06	-0.01
OUTPUT PRICE	-0.07	-0.07	-0.07	-0.07	0.05	-0.02	0.01	-0.04	-0.04	-0.09	-0.10	-0.11	-0.06
FACTOR INPUTS	0.09	0.12	-0.02	0.08	-0.26	0.05	-0.02	0.27	-0.01	0.04	0.13	0.06	-0.02
PRICE OF FACTOR INPUTS	-0.06	-0.06	-0.10	-0.08	0.18	0.03	0.10	-0.05	-0.03	-0.08	-0.10	-0.12	-0.04
INDEX OF INTERMEDIATE INPUTS	0.10	0.13	-0.05	0.08	-0.15	0.09	0.05	0.27	-0.01	0.04	0.12	0.05	0.00
PRICE INDEX FOR INT. GOODS	-0.07	-0.08	-0.05	-0.07	-0.04	-0.05	-0.04	-0.04	-0.04	-0.10	-0.10	-0.09	-0.08
CAPITAL ENERGY	0.10	0.13	0.07	0.10	-0.68	-0.02	-0.23	0.28	-0.04	0.10	0.18	0.13	-0.02
PRICE OF CAPITAL ENERGY	-0.07	-0.08	-0.22	-0.11	0.70	0.11	0.37	-0.06	0.00	-0.17	-0.17	-0.20	-0.04
DEMAND FOR ENERGY	-0.36	-0.35	-0.04	-1.16	-1.64	-0.56	-1.09	-1.11	-1.08	-0.57	0.08	-0.71	-1.06
PRICE OF ENERGY	0.59	0.61	-0.05	1.73	2.12	0.89	1.62	1.95	1.50	0.80	-0.02	1.01	1.46
DEMAND FOR FOSSIL FUEL	0.11	0.14	0.05	-0.03	-0.28	0.09	0.01	0.16	-0.07	0.02	0.18	0.01	-0.08
PRICE OF FOSSIL FUELS	-0.20	-0.20	-0.20	-0.19	-0.19	-0.20	-0.26	-0.19	-0.20	-0.20	-0.20	-0.19	-0.19
DEMAND FOR ELECTRICITY	-1.62	-1.60	-1.68	-1.75	-2.00	-1.64	-1.75	-1.57	-1.80	-1.71	-1.55	-1.72	-1.80
DEMAND FOR LABOUR	0.08	0.11	-0.06	0.06	-0.08	0.11	0.09	0.27	0.00	0.01	0.08	0.01	-0.02
DEMAND FOR CAPITAL	0.23	0.26	0.10	0.21	-0.01	0.24	0.20	0.42	0.14	0.17	0.24	0.17	0.13
INDUSTRY EMISSIONS	0.11	0.13	0.05	-0.05	-0.30	0.09	-0.04	0.13	-0.10	0.01	0.18	-0.01	-0.09

Table 7: Results of Sectoral Changes in Non-Power and Non-Fossil Fuel Industries in Scenario 3 (values in %)

	Agriculture	Mining	Construction	Food	Clothing and Paper	Chemical	Metal	Machinery	Misc. Manuf.	Commerce	Transport	Service	Org.
OUTPUT	0.08	0.10	0.02	0.12	-0.41	-0.08	-0.13	0.28	0.00	0.11	0.17	0.13	0.00
OUTPUT PRICE	-0.06	-0.06	-0.08	-0.07	0.12	0.02	0.06	-0.04	-0.02	-0.11	-0.12	-0.13	-0.07
FACTOR INPUTS	0.07	0.10	0.05	0.13	-0.51	-0.13	-0.21	0.29	0.01	0.11	0.17	0.13	-0.01
PRICE OF FACTOR INPUTS	-0.04	-0.05	-0.13	-0.08	0.34	0.12	0.22	-0.05	-0.03	-0.11	-0.13	-0.15	-0.05
INDEX OF INTERMEDIATE INPUTS	0.09	0.11	0.00	0.12	-0.34	-0.05	-0.09	0.28	0.00	0.11	0.16	0.12	0.02
PRICE INDEX FOR INT. GOODS	-0.07	-0.08	-0.04	-0.07	-0.01	-0.05	-0.01	-0.03	-0.02	-0.12	-0.12	-0.11	-0.10
CAPITAL ENERGY	0.06	0.08	0.16	0.13	-1.29	-0.28	-0.63	0.24	-0.10	0.17	0.21	0.20	-0.08
PRICE OF CAPITAL ENERGY	-0.02	-0.03	-0.27	-0.08	1.32	0.30	0.75	0.01	0.11	-0.18	-0.18	-0.23	0.04
DEMAND FOR ENERGY	-0.73	-0.75	-0.05	-2.05	-2.94	-1.21	-2.11	-2.14	-1.89	-1.00	0.04	-1.24	-1.86
PRICE OF ENERGY	1.13	1.17	0.02	3.11	3.80	1.65	2.94	3.50	2.72	1.50	0.07	1.85	2.64
DEMAND FOR FOSSIL FUEL	0.08	0.08	0.11	-0.10	-0.61	-0.09	-0.23	0.04	-0.15	0.03	0.22	-0.01	-0.18
PRICE OF FOSSIL FUELS	-0.24	-0.24	-0.24	-0.22	-0.23	-0.23	-0.28	-0.23	-0.23	-0.23	-0.24	-0.23	-0.23
DEMAND FOR ELECTRICITY	-2.89	-2.88	-2.86	-3.05	-3.55	-3.05	-3.21	-2.93	-3.11	-2.93	-2.75	-2.97	-3.13
DEMAND FOR LABOUR	0.10	0.11	0.00	0.12	-0.18	0.02	0.03	0.30	0.04	0.08	0.13	0.08	0.01
DEMAND FOR CAPITAL	0.29	0.30	0.21	0.31	-0.14	0.17	0.13	0.48	0.21	0.28	0.33	0.28	0.19
INDUSTRY EMISSIONS	0.07	0.08	0.11	-0.12	-0.63	-0.09	-0.27	0.01	-0.18	0.02	0.22	-0.02	-0.18

Table 8: Results of Sectoral Changes in Non-Power and Non-Fossil Fuel Industries in Scenario 4 (values in %)

	Agriculture	Mining	Construction	Food	Clothing and Paper	Chemical	Metal	Machinery	Misc. Manuf.	Commerce	Transport	Service	Org.
OUTPUT	0.06	0.10	0.03	0.14	-0.70	-0.23	-0.28	0.35	-0.03	0.15	0.22	0.18	0.00
OUTPUT PRICE	-0.07	-0.09	-0.12	-0.09	0.21	0.04	0.11	-0.05	-0.03	-0.17	-0.18	-0.20	-0.10
FACTOR INPUTS	0.04	0.09	0.07	0.15	-0.86	-0.31	-0.41	0.36	-0.03	0.15	0.22	0.19	-0.01
PRICE OF FACTOR INPUTS	-0.03	-0.07	-0.20	-0.10	0.55	0.20	0.36	-0.08	-0.04	-0.17	-0.18	-0.22	-0.08
INDEX OF INTERMEDIATE INPUTS	0.07	0.11	-0.01	0.14	-0.59	-0.18	-0.22	0.34	-0.04	0.15	0.21	0.16	0.02
PRICE INDEX FOR INT. GOODS	-0.09	-0.12	-0.05	-0.09	-0.01	-0.06	-0.01	-0.04	-0.02	-0.17	-0.17	-0.16	-0.15
CAPITAL ENERGY	0.00	0.04	0.21	0.13	-2.12	-0.56	-1.10	0.25	-0.23	0.21	0.27	0.27	-0.16
PRICE OF CAPITAL ENERGY	0.02	-0.01	-0.38	-0.08	2.16	0.53	1.24	0.06	0.22	-0.24	-0.24	-0.33	0.11
DEMAND FOR ENERGY	-1.25	-1.28	-0.11	-3.31	-4.70	-2.03	-3.44	-3.49	-3.05	-1.63	-0.01	-2.01	-2.97
PRICE OF ENERGY	1.84	1.91	0.08	5.03	6.13	2.68	4.76	5.65	4.41	2.44	0.15	3.00	4.27
DEMAND FOR FOSSIL FUEL	0.04	0.04	0.14	-0.22	-1.04	-0.26	-0.47	-0.06	-0.31	0.00	0.28	-0.06	-0.31
PRICE OF FOSSIL FUELS	-0.33	-0.33	-0.34	-0.32	-0.32	-0.33	-0.39	-0.33	-0.33	-0.33	-0.34	-0.33	-0.32
DEMAND FOR ELECTRICITY	-4.63	-4.62	-4.53	-4.87	-5.65	-4.91	-5.14	-4.71	-4.96	-4.66	-4.39	-4.71	-4.95
DEMAND FOR LABOUR	0.12	0.14	0.01	0.17	-0.33	-0.04	-0.02	0.40	0.04	0.12	0.18	0.11	0.03
DEMAND FOR CAPITAL	0.37	0.38	0.29	0.42	-0.30	0.15	0.10	0.64	0.27	0.39	0.45	0.39	0.26
INDUSTRY EMISSIONS	0.03	0.04	0.14	-0.25	-1.06	-0.26	-0.53	-0.09	-0.34	-0.01	0.28	-0.08	-0.32

Appendix C: Effects on Domestically Produced Commodities

Table 9: Effects on the Demand and Supply of Power, Fossil Fuel, and Crude Oil Commodities in Scenarios 1 and 2 (values in %)

	Electricity		Coal		Natural Gas		Refined Petroleum		Crude Oil	
	$25	$50	$25	$50	$25	$50	$25	$50	$25	$50
TOTAL SUPPLY OF COMMODITY i	-1.84	-3.71	-40.88	-52.69	-0.43	-0.47	0.05	0.04	0.49	0.65
PRICE OF TOTAL SUPPLY OF COMMODITY i	1.26	2.64	-0.09	-0.12	-0.09	-0.14	-0.13	-0.19	-0.11	-0.16
PRICE OF COMPOSITE DEMAND	1.31	2.75	-0.26	-0.35	-0.09	-0.14	-0.14	-0.20	-0.16	-0.23
PRICE OF DOMESTIC GOOD	1.34	2.81	-1.95	-2.60	-0.09	-0.14	-0.17	-0.25	-0.26	-0.38
EXPORT SUPPLY	-3.55	-7.16	-40.80	-52.61	-0.31	-0.28	0.24	0.30	0.63	0.87
DEMAND FOR IMPORT GOODS	0.04	0.17	-43.92	-55.91	-0.56	-0.66	-0.24	-0.38	-0.08	-0.18
TOTAL DEMAND FOR COMMODITY i	-1.69	-3.41	-43.72	-55.70	-0.44	-0.48	-0.05	-0.11	0.13	0.14
DEMAND FOR DOMESTIC GOODS	-1.73	-3.49	-42.42	-54.32	-0.44	-0.47	-0.01	-0.05	0.27	0.34
HOUSEHOLD DEMAND	-2.68	-5.42			0.08	0.13	0.18	0.25	0.22	0.31
DEMAND FOR INVESTMENT GOOD	-1.51	-3.03	0.04	-0.02	-0.12	-0.22	-0.07	-0.16	-0.06	-0.13
DEMAND FOR INTERMEDIATE GOODS	-1.00	-1.97	-35.24	-44.90	-0.94	-1.06	-0.14	-0.24	0.14	0.15

Table 10: Effects on the Demand and Supply of Power, Fossil Fuel, and Crude Oil Commodities in Scenarios 3 and 4 (values in %)

	Electricity		Coal		Natural Gas		Refined Petroleum		Crude Oil	
	$25	$50	$25	$50	$25	$50	$25	$50	$25	$50
TOTAL SUPPLY OF COMMODITY i	-6.23	-9.68	-41.35	-53.11	-0.41	-0.43	0.09	0.09	0.64	0.87
PRICE OF TOTAL SUPPLY OF COMMODITY i	4.72	7.64	-0.12	-0.17	-0.18	-0.27	-0.22	-0.31	-0.19	-0.27
PRICE OF COMPOSITE DEMAND	4.90	7.92	-0.36	-0.49	-0.18	-0.27	-0.24	-0.34	-0.29	-0.41
PRICE OF DOMESTIC GOOD	5.01	8.11	-2.72	-3.64	-0.18	-0.27	-0.29	-0.42	-0.47	-0.67
EXPORT SUPPLY	-12.09	-18.52	-41.25	-53.00	-0.15	-0.06	0.40	0.53	0.91	1.25
DEMAND FOR IMPORT GOODS	0.52	0.89	-45.53	-57.55	-0.65	-0.80	-0.41	-0.61	-0.38	-0.59
TOTAL DEMAND FOR COMMODITY i	-5.72	-8.90	-45.26	-57.27	-0.41	-0.44	-0.09	-0.16	0.01	-0.04
DEMAND FOR DOMESTIC GOODS	-5.86	-9.12	-43.48	-55.38	-0.41	-0.44	-0.01	-0.06	0.25	0.31
HOUSEHOLD DEMAND	-9.20	-14.26			0.27	0.39	0.39	0.53	0.48	0.68
DEMAND FOR INVESTMENT GOOD	-4.88	-7.69	0.14	0.11	-0.04	-0.11	0.01	-0.04	0.06	0.03
DEMAND FOR INTERMEDIATE GOODS	-3.25	-5.12	-36.48	-46.16	-1.07	-1.24	-0.27	-0.42	-0.02	-0.09

Table 11: Effects on the Demand and Supply of Non-Power and Non-Fossil Fuel Commodities in Scenario 1 (values in %)

	Agriculture	Mining	Construction	Food	Clothing and Paper	Chemical	Metal	Machinery	Misc. Manuf.	Commerce	Transport	Service	Org.
TOTAL SUPPLY OF COMMODITY i	0.10	0.12	-0.02	0.07	-0.05	0.12	0.08	0.21	0.02	0.03	0.10	0.04	-0.01
PRICE OF TOTAL SUPPLY OF COMMODITY i	-0.05	-0.05	-0.05	-0.06	0.01	-0.03	-0.01	-0.03	-0.03	-0.06	-0.07	-0.07	-0.04
PRICE OF COMPOSITE DEMAND	-0.06	-0.06	-0.05	-0.05	0.01	-0.02	-0.01	-0.02	-0.02	-0.06	-0.08	-0.07	-0.04
DOMESTIC GOOD PRICE	-0.07	-0.08	-0.05	-0.07	0.02	-0.05	-0.02	-0.11	-0.05	-0.06	-0.09	-0.07	-0.04
EXPORT SUPPLY	0.18	0.19	0.04	0.15	-0.07	0.16	0.10	0.26	0.05	0.11	0.19	0.14	0.05
DEMAND FOR IMPORT GOODS	-0.02	-0.02	-0.08	-0.04	-0.02	0.01	0.05	-0.05	-0.08	-0.06	-0.05	-0.06	-0.06
TOTAL DEMAND FOR COMMODITY i	0.06	0.06	-0.02	0.03	-0.03	0.04	0.06	-0.02	-0.06	0.02	0.05	0.03	-0.01
DEMAND FOR DOMESTIC GOODS	0.08	0.08	-0.02	0.05	-0.04	0.09	0.07	0.10	-0.02	0.02	0.07	0.04	-0.01
HOUSEHOLD DEMAND	0.02	0.02	-0.01	0.00	-0.12	-0.06	-0.08	-0.06	-0.06	0.02	0.05	0.03	-0.03
DEMAND FOR INVESTMENT GOOD	-0.15	-0.15	-0.17	-0.16	-0.23	-0.19	-0.21	-0.19	-0.20	-0.16	-0.14	-0.15	-0.18
DEMAND FOR INTERMEDIATE GOODS	0.06	0.08	-0.09	0.06	0.01	0.07	0.07	0.11	0.02	0.05	0.06	0.04	0.03

Table 12: Effects on the Demand and Supply of Non-Power and Non-Fossil Fuel Commodities in Scenario 2 (values in %)

	Agriculture	Mining	Construction	Food	Clothing and Paper	Chemical	Metal	Machinery	Misc. Manuf.	Commerce	Transport	Service	Org.
TOTAL SUPPLY OF COMMODITY i	0.10	0.12	-0.03	0.08	-0.19	0.07	0.02	0.27	-0.01	0.04	0.13	0.06	-0.01
PRICE OF TOTAL SUPPLY OF COMMODITY i	-0.07	-0.07	-0.07	-0.07	0.05	-0.02	0.01	-0.04	-0.04	-0.09	-0.10	-0.11	-0.06
PRICE OF COMPOSITE DEMAND	-0.08	-0.08	-0.07	-0.07	0.04	-0.02	0.01	-0.03	-0.03	-0.10	-0.12	-0.11	-0.06
DOMESTIC GOOD PRICE	-0.09	-0.10	-0.07	-0.09	0.08	-0.04	0.01	-0.16	-0.06	-0.10	-0.13	-0.11	-0.06
EXPORT SUPPLY	0.19	0.22	0.07	0.18	-0.26	0.10	0.01	0.33	0.04	0.16	0.27	0.21	0.07
DEMAND FOR IMPORT GOODS	-0.06	-0.07	-0.13	-0.08	-0.04	-0.01	0.05	-0.11	-0.14	-0.11	-0.10	-0.10	-0.09
TOTAL DEMAND FOR COMMODITY i	0.04	0.04	-0.03	0.02	-0.09	0.01	0.04	-0.07	-0.10	0.02	0.06	0.04	-0.01
DEMAND FOR DOMESTIC GOODS	0.06	0.07	-0.03	0.05	-0.14	0.04	0.03	0.10	-0.05	0.02	0.08	0.05	-0.01
HOUSEHOLD DEMAND	0.00	0.00	-0.02	-0.02	-0.24	-0.13	-0.17	-0.10	-0.11	0.03	0.08	0.05	-0.04
DEMAND FOR INVESTMENT GOOD	-0.29	-0.28	-0.29	-0.30	-0.41	-0.35	-0.37	-0.34	-0.34	-0.27	-0.25	-0.26	-0.31
DEMAND FOR INTERMEDIATE GOODS	0.05	0.07	-0.14	0.07	-0.02	0.05	0.06	0.12	0.01	0.04	0.06	0.04	0.03

Table 13: Effects on the Demand and Supply of Non-Power and Non-Fossil Fuel Commodities in Scenario 3 (values in %)

	Agriculture	Mining	Construction	Food	Clothing and Paper	Chemical	Metal	Machinery	Misc. Manuf.	Commerce	Transport	Service	Org.
TOTAL SUPPLY OF COMMODITY i	0.08	0.10	0.02	0.12	-0.41	-0.08	-0.13	0.28	0.00	0.11	0.17	0.13	0.00
PRICE OF TOTAL SUPPLY OF COMMODITY i	-0.06	-0.06	-0.08	-0.07	0.12	0.02	0.06	-0.04	-0.02	-0.11	-0.12	-0.13	-0.07
PRICE OF COMPOSITE DEMAND	-0.06	-0.08	-0.08	-0.07	0.12	0.01	0.06	-0.03	-0.02	-0.12	-0.14	-0.13	-0.07
DOMESTIC GOOD PRICE	-0.08	-0.10	-0.08	-0.09	0.22	0.03	0.11	-0.14	-0.04	-0.12	-0.16	-0.14	-0.07
EXPORT SUPPLY	0.16	0.19	0.14	0.22	-0.58	-0.10	-0.21	0.33	0.04	0.27	0.34	0.32	0.10
DEMAND FOR IMPORT GOODS	-0.05	-0.08	-0.09	-0.02	0.01	-0.02	0.08	-0.06	-0.08	-0.07	-0.10	-0.07	-0.09
TOTAL DEMAND FOR COMMODITY i	0.04	0.03	0.02	0.07	-0.14	-0.03	0.00	-0.03	-0.05	0.09	0.09	0.10	0.00
DEMAND FOR DOMESTIC GOODS	0.06	0.06	0.02	0.10	-0.28	-0.06	-0.06	0.13	-0.02	0.09	0.11	0.12	0.00
HOUSEHOLD DEMAND	0.03	0.06	0.07	0.04	-0.33	-0.12	-0.21	-0.04	-0.06	0.15	0.19	0.17	0.04
DEMAND FOR INVESTMENT GOOD	-0.16	-0.15	-0.14	-0.16	-0.34	-0.24	-0.28	-0.20	-0.21	-0.10	-0.08	-0.09	-0.16
DEMAND FOR INTERMEDIATE GOODS	0.04	0.04	-0.26	0.10	-0.06	-0.01	0.01	0.10	0.02	0.03	0.05	0.05	-0.02

Table 14: Effects on the Demand and Supply of Non-Power and Non-Fossil Fuel Commodities in Scenario 4 (values in %)

	Agriculture	Mining	Construction	Food	Clothing and Paper	Chemical	Metal	Machinery	Misc. Manuf.	Commerce	Transport	Service	Org.
TOTAL SUPPLY OF COMMODITY i	0.06	0.10	0.03	0.14	-0.70	-0.23	-0.28	0.35	-0.03	0.15	0.22	0.18	0.00
PRICE OF TOTAL SUPPLY OF COMMODITY i	-0.07	-0.09	-0.12	-0.09	0.21	0.04	0.11	-0.05	-0.03	-0.17	-0.18	-0.20	-0.10
PRICE OF COMPOSITE DEMAND	-0.08	-0.10	-0.12	-0.09	0.20	0.03	0.10	-0.04	-0.02	-0.18	-0.20	-0.20	-0.10
DOMESTIC GOOD PRICE	-0.09	-0.13	-0.12	-0.12	0.36	0.08	0.19	-0.20	-0.05	-0.19	-0.24	-0.21	-0.10
EXPORT SUPPLY	0.16	0.22	0.20	0.28	-0.99	-0.28	-0.44	0.42	0.01	0.38	0.47	0.45	0.14
DEMAND FOR IMPORT GOODS	-0.10	-0.15	-0.14	-0.05	0.01	-0.06	0.09	-0.13	-0.13	-0.13	-0.18	-0.13	-0.14
TOTAL DEMAND FOR COMMODITY i	0.01	-0.01	0.03	0.07	-0.26	-0.10	-0.05	-0.08	-0.11	0.11	0.10	0.14	0.00
DEMAND FOR DOMESTIC GOODS	0.03	0.03	0.03	0.11	-0.48	-0.17	-0.17	0.14	-0.06	0.12	0.14	0.16	0.00
HOUSEHOLD DEMAND	0.01	0.06	0.10	0.03	-0.54	-0.21	-0.35	-0.07	-0.11	0.21	0.26	0.25	0.06
DEMAND FOR INVESTMENT GOOD	-0.30	-0.28	-0.26	-0.29	-0.57	-0.41	-0.48	-0.34	-0.36	-0.20	-0.18	-0.18	-0.28
DEMAND FOR INTERMEDIATE GOODS	0.01	0.01	-0.37	0.12	-0.12	-0.07	-0.03	0.10	0.01	0.01	0.04	0.06	-0.04

Appendix D: List of Industries and Commodities used in this Model

Table 15: List of Industries and Commodities Used in this Model

Industries	Commodities
· Agriculture	· Agriculture
· Crude Oil	· Crude Oil
· Coal	· Coal
· Mining	· Mining
· Coal Electricity	· Electricity
· Other fossil Fuel Electricity	· Natural Gas
· Non-fossil fuel Electricity	· Construction
· Natural Gas	· Food
· Construction	· Clothing and Paper
· Food	· Refined Petroleum
· Clothing and Paper Mills	· Chemicals
· Refined Petroleum	· Metal
· Chemical	· Machinery
· Metal	· Miscellaneous Manufacturing
· Machinery	· Commerce
· Miscellaneous Manufacturing	· Transport
· Commerce	· Service
· Transport	· Organization
· Service	
· Organization	