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WSU CGE ANALYSIS OF CARBON WA:
TECHNICAL DOCUMENTATION

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Abstract:
This paper provides a detailed description of the updates made to the 2007 Washington-Idaho Computable General Equilibrium Model created by Holland et al. in order to evaluate the impact of a revenue neutral carbon tax on the Washington State Economy. We modify the Holland et al. (2007) model by incorporating four significant changes which allow us to assess the effect of the revenue-neutral carbon tax policy. First, we impose a $0.14/gal tax and $0.24/gal tax on fossil fuels, in the first two years of the policy, which are equivalent to the $15/ton of carbon and $25/ton of carbon from fossil fuels in all sectors except agriculture. Second, we reduce the sales tax collected from the consumer by 0.5% in the first year and then 1% in the second year. Third, we reduce the business and occupation tax for the manufacturing sector from 0.484% to 0.001%. Finally, we rebate households in the lowest income bracket an amount equal to $157.74 million in the first year and $262.90 million during the second year.

JEL Codes: C68, H23, Q48

Keywords: Computable General Equilibrium Model, Washington State Initiative 732, Double Dividend, Revenue Neutral Carbon Tax

Contents

Introduction:

Washington State has, for the past several years, been attempting to curb their carbon emissions with several proposed bills and expanded use of the Clean Air Rule. Carbon Washington's I-732 was simultaneously trying to design an effective and economic policy that would achieve the same, or similar, environmental outcomes but with the potential second dividend of reduced distortionary taxes that lead to market inefficiencies. The following analysis shows how to implement the I-732 policy in a Computable General Equilibrium (CGE) framework. Using the 2007 Washington-Idaho CGE model created by Holland et al. We analyze a $0.14/gal tax and $0.24/gal tax on fossil fuels, in the first two years of the policy, which are equivalent to the $15/ton of carbon and $25/ton of carbon from fossil fuels in all sectors except agriculture. Second, we reduce the sales tax collected from the consumer by 0.5% in the first year and then 1% in the second year. Third, we reduce the business and occupation tax for the manufacturing sector from 0.484% to 0.001%. Finally, we rebate households in the lowest income bracket an amount equal to $157.74 million in the first year and $262.90 million during the second year.

Section 1: IMPLAN Social Accounting Matrix (SAM)

The IMPLAN SAM has a high degree of flexibility and is already designed to work with the Washington-Idaho Computable General Equilibrium model discussed in the next Chapter. It was for these reasons that we chose to use this data set. Assumptions about the IMPLAN SAM and the way the data is partitioned is discussed in the next three subsections of this chapter.

The IMPLAN SAM data is used to calculate initial values of various parameters and calibrate others once the policy shocks are implemented. It is worth noting that the SAM data is derived from a national SAM that has been regionalized to Washington State. We corroborated gross state product, total state and local government revenues, and industry output levels to ensure the data from IMPLAN aligned with the locally produced data. A comparison of these variables is provided in Appendix 1 at the end of this report.

The SAM is a square matrix composed of A industries (often referred to as activities in the CGE context), C commodities (representing both inputs to and outputs from the activities), F factors of production (labor, capital, and government payments), Institutions (households, federal & local governments, and investments), and foreign and domestic trade (FT and DT). The structure of the SAM is provided in Figure 1 below.

Figure 1: WA-ID CGE Aggregated SAM

		A	C	F	INST	T(FT)	T(DT)
		1	2	3	4	5	6
A	1		MAKE				
C	2	USE			IUSE	CEXPRT	CEXPRT
F	3	FD				FEXPRT	FEXPRT
INST	4		IMAKE	FS	TRNSFR	IEXPRT	IEXPRT
T(FT)	5		CIMPRT	FIMPRT	IIMPRT	TRNSHP	TRNSHP
T(DT)	6		CIMPRT	FIMPRT	IIMPRT	TRNSHP	TRNSHP

Reading down a column will tell you where that column is spending its money. For example, reading down an industry column, such as Agriculture, will show you that the agricultural industry is spending money to buy various commodities that it will use in its production process: fertilizer, seed, accounting services etc. these data are reflected in the "USE" table of the matrix. Reading across a row tells you where that row is receiving its income or whom it is selling its output to. Agricultural commodities may be sold to households, government, exported to foreign and domestic markets, or sold to other industries for use in their production processes.

Sectoral Descriptions

Industries (A)

IMPLAN produces data on approximately 530 distinct industry sectors. These sectors are then aggregated into the 11 distinct sectors for use in the CGE model (Agriculture, Forestry, Mining, Utilities, Fossil fuel, Construction, Processed food, Wholesale and retail trade, Services, Manufacturing, and Miscellaneous). The 11 industries and their associated IMPLAN codes are described in Appendix 2.

These industries use commodities and factors in their production process. The mix of commodities, labor, capital, and payments to government represent the industries production technology. As is the case with all social accounts, the ratio of these inputs are held fixed in the short run, meaning that production technology is held constant. The CGE model does allow for some substitutability between labor and capital, as will be discussed in the next chapter. Fewer input payments for production results in less output being produced.[2]

Commodities (C)

The commodities align almost identically with the industries i.e., agricultural industries produce agricultural commodities. In some cases industries produce byproducts as well e.g., an apple orchard may have a forestry byproduct. The only other major issue with the commodities is that institutions can produce commodities as well. The clearest example of this might be a state owned and operated power plant[3] (e.g., Bonneville Power). This is why the commodities column in the SAM includes not only the Make matrix but the institutional Make matrix, or IMAKE matrix, as well. Unlike the industries, which cannot be traded, commodities can be imported and exported from both foreign and domestic regions. This allows for cross hauling which is prevalent in the data and accounted for in the CGE model using Armington Trade specifications.

Factors (F)

There are three factors of production in the model Labor, Capital, and Payments to government. Labor is represented in IMPLAN as code 5001. Capital has two components: Proprietary Income and Other Property Income, codes 6001 and 7001, respectively. Payments to government are referred to in two ways in the model either as Indirect Business Taxes (INDT), or more traditionally as Taxes on Production and Imports (TOPI), code 8001. Labor and capital are partially substitutable in the CGE model through the use of a Leontief-CES hybrid production function.

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[2] We hardwire the payments to government variable since in the short run public goods are relatively fixed implying that industries could free ride on that portion of their production expenses. This has effects on the calibration of the Walras variable.

[3] Bonneville Power is a state owned and operated power plant. This would be a state government (institution) producing and selling energy as though it were a private industry.

Institutions (INST)

Institutions are represented by, 9 distinct household sectors (broken out by income levels), 3 federal government sectors (defense, non-defense, and Federal investment), 3 state government sectors (education, non-education, and State investments), and a private investment sector (corporate investments, private fixed investments, and inventory additions and deletions).

Household income is derived from payments to labor and capital as well as transfer payments from other households. Since the government acts as a pass-through organization for transfer payments they do not directly appear in the governments budgets. The government does receive income from commodity sales, TOPI, property taxes, sales taxes, and fines or fees levied on households as well as intergovernmental transfers[4]. The investment sector operates quite differently from the other Institutions. Households, governments, and commodities[5] all contribute to or buy investments. Those investments then make annual payments to commodities and institutions.

Trade (FT, DT)

The trade sectors are important from a general equilibrium perspective since domestic and world prices will govern the volumes of imports and exports. As far as this paper is concerned we do not *directly* influence these sectors. Trade will be indirectly influenced through the domestic policy shocks that will have implications on prices, which will in turn have implications on foreign and domestic demand for regionally produced goods. In the context of this report foreign refers to non-U.S. quantities and prices, domestic refers to out-of-region but within the U.S. quantities and prices, and regional refers to Washington state.

The Carbon Sector

The Carbon sector in the model was created by taking the carbon producing industries and grouping them together. Applying a tax on these industries will cause the price of the goods produced by these industries to increase. Such price increases will then be passed on to final consumers of the carbon sector. The rational for modeling the tax in this way was that it would directly influence commodity prices and those increased prices would then be passed through the production process to the end user. This ensured that all carbon consumption, even in the intermediate stages of production would be influenced. Table 1 below outlines which IMPLAN sectors were included in the Fossil-Fuel sector.

[4] Care must be used when calculating total government revenues since intergovernmental transfers may lead to some double counting.

[5] Commodities contribute to the investment sector through additions and deletions from their stock of inventory. For example, excess production of natural gas may be stored, contributing to inventory reserves.

Table 1: Description of the Fossil-Fuel Sector

IMPLAN Code	Industry title
20	Extraction of natural gas and crude petroleum
21	Extraction of natural gas liquids
22	Coal mining
37	Drilling oil and gas wells
38	Support activities for oil and gas operations
156	Petroleum refineries

Prices and Taxes

It is important to note that in the base SAM prices are all normalized to 1 and taxes are embedded in the values of the goods sold. The only initial tax rates calculated by the model then are the indirect business tax rates, and the household income/property tax rates. The SAM by itself would hold these prices and taxes fixed, as supply and demand are assumed by the SAM to be perfectly elastic and inelastic respectively. It is only through the use of the CGE model that these values are able to fluctuate.

In the initial model, sales and commodity taxes are indexed solely on commodities. It was our intention to be able to vary these taxes for each industry and household. Doing this allowed us to change the B&O tax rate for manufacturing only. In the downloadable version of the WA-ID model this would not have been possible since the sales tax was only indexed on commodities. This required us to change the original tb(C) to tb(A,C). This change made it possible for us to change, for example, the tax the agricultural industry paid for their fuel commodity i.e.,

$$tb_2(\text{'}AGR - A\text{'}, \text{'}Fossil - C\text{'}) = \$1/\mathrm{MT}\ C_0 2$$

That is to say farmers, in year two, would pay an additional dollar per metric ton of carbon emissions from their fuel consumption.[6]

Section 2: WA-ID CGE Model

The CGE model developed by economists at University of Idaho and Washington State University was built to work with the IMPLAN Data set and has many attractive attributes. It has a fully specified Armington trade model which is important when modeling states with international air and sea ports and heavily reliant on export markets. It is fairly well commented as far as computer programs go so tracing through various modeling procedures can be done relatively smoothly. Perhaps the most appealing part of the model is that it is open source and does not require one to start building a full CGE model from scratch. It is important to note that since it is produced in GAMS, it has a host of built in solvers that can quickly converge on equilibria, but those solvers are not themselves transparent.

[6] This translates into roughly .38% per gallon of fuel.

Overall the model is broken into 6 primary components: parameters (some of which are calculated from the initial data), variables, the consumer's problem, the producer's problem, the government's balanced budget conditions, and the trade components. In what follows we will explain in technical terms the key components of each of these aspects of the model.[7]

Parameters

The parameters in the CGE model may be assumed at the outset, such as the demand elasticity for capital and labor, or calculated based on the base SAM, such as the intermediate input of a particular commodity per unit of output from a particular industry/activity[8]. Table 2 below shows the initial parameter values as set by the user. Appendix 3 outlines the other parameters that are calculated by the base SAM. The corresponding calculations can be found in the WA-ID CGE documentation but for the sake of brevity are not presented here[9].

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[7] The goal here is to provide the reader with the basic understanding of our modeling approach, what we have altered and why. Complete replication of our results should be possible if the reader were to download and use the 2014 Washington State IMPLAN SAM, the WA-ID CGE model, and follow the procedures outlined in this chapter.

[8] Because we are now discussing the CGE model it is more common to refer to industries as activities. Though these two terms are synonymous it is more traditional to speak of industries when referring to the static SAM and activities when discussing the CGE model.

[9] The WA-ID CGE documentation may be found at http://www.agribusiness-mgmt.wsu.edu/Holland_model/docs/DocumentationR.pdf

Table 2: Initial Prices And Parameters Set by The User

Parameter	Description	Initial Value
XRO(T)	Initial exchange rate	1
PWEO(C,T)	Initial world export price in foreign currency	1
PMO(C)	Initial composite import price in regional currency	1
PEO(C)	Initial composite export price in regional currency	1
PQO(C)	Initial composite commodity price	1
PDO(C)	Initial regional price of regional output	1
PXO(C)	Initial producer price	1
PAO(A)	Initial activity price	1
pwm(T,C)	World import price in foreign currency (exogenous)	1
frisch(C)	Frisch parameter for Stone-Geary utility function	-1
ine(C,H)	Income elasticity	1
xed(C,T)	Elasticity of demand for world export demand function	-50
esubp(A)	Elasticity of substitution for production function	0.99
esubd(C)	Elasticity of substitution between regional output and imports	2
esubs(C)	Elasticity of transformation between regional output and exports	2
esube(C)	Elasticity of transformation between foreign and regional exports	2
esubm(C)	Elasticity of substitution between foreign and regional imports	2
tq(A,C)	Sales tax activity A pays for commodity C	0
tc(H,C)	Consumption tax rate (paid only by households)	0
tqs(C)	Sales tax rate on services not previously taxed	0
tm(T,C)	Import tax rate	0
te(C,T)	Export tax rate	0
efac(FF)	Demand elasticity for factors of production	0.8

Endogenous Variables

There are three types of endogenous variables in the model: prices, quantities, and Accounting variables. These variables are calibrated by the model for a given shock. A negative shock to the consumption tax will simultaneous cause prices, quantities, government revenues and expenditures, household gross and net income, etc. to adjust. Thus, one shock may influence price and quantity variables, and the "accounting" variables such as government revenue or household income will also fluctuate.

These variables are all embedded in the mathematical formulation of the model discussed in the next subsections. It is how these endogenous variables move given a specific shock, or set of shocks, that is critical. The results of the model are all reflective of the changes in these variables. The following three tables list these variables.

Table 3 shows the endogenous price variables that are all initially set to 1. After the shock is implemented these values are recalibrated to their new equilibrium and the change represents the relative price changes caused by the shock. Thus, a price of 1.1 can be interpreted as a 10% increase in the price of that good.

Table 3: Endogonus Price Variables:

Variable	Description
XR	Exchange rate
CPI	Consumer price index
PMR	Regional import price in regional currency
PWE	World export price in foreign currency
PER	Regional export price in regional currency
PM	Composite import price in regional currency
PE	Composite export price in regional c currency
PQ	Composite commodity price
PD	Regional price of regional output
PX	Producer price
PA	Activity price
PVA	Value added price
WF	Average wage or rental rate for factor FF

Table 4 shows the endogenous quantity variables. Recall that in the base case, since prices were set to 1, the initial "quantities" represented both quantity and value i.e., $P \cdot Q = Q = V$. After the prices change these equilibrium quantities adjust as well, requiring us to show quantities of goods produced and the associated value of production separately.

Table 4: Endogonus Quantity Variables:

Variable	Description
QMR	Regional imports
QER	Regional exports
QM	Composite import quantity
QE	Composite export quantity
QQ	Composite quantity supplied to regional demanders
QD	Quantity of regional output supplied to regional demanders
QX	Quantity of regional output
QA	Activity level
QINT	Quantity of intermediate use of commodity C by activity A
IMAKEQ	Institutional make matrix (quantity)
QF	Quantity of factor FF demanded by activity A
QH	Household consumption
QINV	Investment demand
QIINV	Investment demand by institutions
QFS	Factor supply
INDT	Indirect business taxes receipts for each government unit

Lastly, table 5 displays the accounting variables. These variables are in some sense just the names of various equations in the model: Income, expenditure, savings levels etc. These equations are the heart of the model used to calibrate the equilibrium values. The one exception is the Walras dummy variable which insures the model is not under identified.

Table 5: Endogonus Accounting Variables

Variable	Description
YF	Transfer of income to institution I from factor FF
YH	Gross household income
NYH	Net household income
YFG	Federal government income
EFG	Federal government expenditure
YSG	State government revenue
ESG	State government expenditure
FSAVX	Foreign savings (export column)
FSAVM	Foreign savings (import row)
DSAVX	RUS savings (export column)
DSAVM	RUS savings (import row)
WFDIST	Factor price distortion factor
SGADJ	State government spending adjustment factor
SHIFTFF	Factor supply equation shift variable
WALRAS	WALRAS dummy variable (should be 0)

Baseline Results

The baseline results show the beginning values in the model prior to any policy shocks being implemented. All subsequent analysis will be compared relative to these values so that net change in economic values may be observed. This particular section therefore sets the stage and is truly just a representation of the IMPLAN data that currently describes the economy.

Table 6 gives a list of the 11 industrial sectors in column 1, their value added or GRP in column 2, and their business tax payments in column 3. All values are reported in millions of dollars and the "State" row shows total gross state product, and total tax revenues by sector. It is important to note that total state tax revenue from the industries does not equal the total state tax revenue since states derive income from other sources as discussed in the government sub-section of chapter two.

Table 6: Baseline value added and government payments by sector

Industrial Sectors	Baseline GDP	Baseline State Revenues
AGR-A	8,710	120
FOREST-A	685	29
CONST-A	17,124	532
UTIL-A	5,649	1,229
Fossil-A	3,071	96
TRAD-A	50,848	12,203
MIN-A	616	19
FOOD-A	4,337	401
MAN-A	49,271	1,033
SER-A	223,556	15,790
MISC-A	64,761	87
State (Million)	**428,629**	**89,402**

Table 7 outlines the imports and exports of the Washington economy by commodity. As stated before, the goal of this exercise is not to delve into the rigors of the current and capital accounts. This data is simply here as a baseline to see how trade is incorporated in the analysis, a component that is often left out of such policy analyses. It is worth noting here, however, that Washington does import a large amount of crude oil for processing.

Table 7: Value/Quantity of Trade

Industrial Sectors	Imports	Exports
AGR-C	5,273	7,625
FOREST-C	151	472
CONST-C	1,827	132
UTIL-C	4,826	3,888
Fossil-C	20,075	5,644
TRAD-C	4,465	15,399
MIN-C	512	455
FOOD-C	14,563	15,503
MAN-C	126,911	109,721
SER-C	63,800	81,073
MISC-C	12,182	4,780
Total	**254,585**	**244,692**

Other critical baseline values are the amount of each commodity used by each industry in there production process (table 8) and household purchases of commodities (table 9).

Table 8: commodity use by Industry

	AGR-C	FOREST-C	CONST-C	UTIL-C	Fossil-C	TRAD-C	MIN-C	FOOD-C	MAN-C	SER-C	MISC-C
AGR-A	1,303	0	39	63	195	279	14	32	1,161	489	8
FOREST-A	65	134	0	0	17	36	-	-	13	29	1
CONST-A	58	-	17	146	1,405	6,142	338	-	8,686	3,775	95
UTIL-A	-	7	110	5,202	855	42	11	-	54	556	29
Fossil-A	0	0	259	77	14,151	355	3	1	435	714	73
TRAD-A	27	-	234	755	243	1,486	0	17	1,527	18,552	269
MIN-A	0	-	39	41	108	42	84	-	123	139	1
FOOD-A	6,389	7	91	362	96	2,196	-	4,060	2,447	3,047	128
MAN-A	257	644	478	1,919	1,073	6,897	623	573	64,117	17,240	984
SER-A	108	0	4,083	2,718	3,486	5,167	129	1,836	14,764	103,400	3,575
MISC-A	86	-	3,285	229	1,125	401	11	559	1,093	6,614	238

Table 9: Total Household Commodity

Industrial Sectors	HH all
AGR-C	1,608
FOREST-C	-
CONST-C	-
UTIL-C	5,525
Fossil-C	5,268
TRAD-C	35,113
MIN-C	5
FOOD-C	14,346
MAN-C	28,325
SER-C	176,871
MISC-C	16,948
Total	**284,009**

Other baseline values exist, for example, baseline prices are all normalized to 1. These prices will adjust according to the resulting equilibrium but are interpreted as price changes. Similarly, since prices are all 1 in the base case, base case values are the same as base case quantities. When looking at changes in quantity and value after the implementation of the policy shock these must incorporate the new prices.

Consumer Problem

The consumer's problem in this model is represented by the Linear Expenditure System, derived from the Stone-Geary utility function, and the net and gross household income equations.

Gross household income:

Household income may be derived from a variety of sources. The obvious sources are from the households' ownership and payments to their labor and capital, $\sum_F YF_{H,F}$, the value of their investments, $QIINV_H$, and any transfer payments they receive from government, $CPI \cdot \sum_G SAM_{H,G}$. However, households may also receive income through direct interhousehold transfers, $\sum_H \left(trh_{H,H} \cdot \left(1 - \sum_G ty_{G,H}\right) YH_H\right)$, domestically selling commodities they produce, $\sum_C PX_C \cdot IMAKEQ_{H,C}$, or sales made via international and domestic trade, $CPI \cdot \sum_T SAM_{H,T}$.

$$YH_H = \sum_F YF_{H,F} + \sum_C PX_C \cdot IMAKEQ_{H,C} + CPI \cdot \sum_G SAM_{H,G} + QIINV_H + \sum_H \left(trh_{H,H} \cdot \left(1 - \sum_G ty_{G,H}\right) YH_H\right) + CPI \cdot \sum_T SAM_{H,T}$$

Where $YH_H$is gross household income, $YF_{H,F}$ is the households income by factor (labor and capital), PX_C is the price of commodity C received by the institutions (households in this case) and $IMAKEQ_{H,C}$ as the quantity of commodity C produced by each household. The CPI is the consumer price index calibrated by the model given the shocks and $SAM_{H,G}$ represents the value of transfers from governments to households as calculated in the base SAM. $QIINV_H$ is the quantity of investments indexed by households. $trh_{H,H}$ is the inter-household transfer rate and $ty_{G,H}$ is the household effective income tax rate. $SAM_{H,T}$ is simply the household sales to foreign and domestic trade sectors in the base SAM.

Net household income:

To turn the above gross household income to net household income, taxes, transfer payments, etc. must be removed. Net household income, NYH_H, is calculated as

$$NYH_H = YH_H - \sum_H \left(trh_{H,H} \cdot \left(1 - \sum_G ty_{G,H}\right) YH_H \right) - SADJ \cdot mps_H \cdot \left(1 - \sum_G ty_{G,H}\right) YH_H - \sum_G ty_{G,H} \cdot YH_H - CPI \cdot \sum_T SAM_{H,T}$$

Where NYH_H is the net household income. Inter-household transfers, effective income tax rates, gross household income, the CPI and SAM variables are as before. $SADJ$ is a household savings adjustment variable, mps_H is the households marginal propensity to save, and $ty_{G,H}$ is the effective income tax rate[10].

Household consumption demand:

We can now use the Linear Expenditure System to calculate the household consumption demand. Traditionally the Stone-Geary utility function, $U = \prod_i (q_i - \lambda_i)^{\beta_i}$, assumes a minimum level of expenditure, λ_i, for each of the i-commodities. If this assumption is removed the Stone-Geary function becomes Cobb-Douglas. The value in using the Stone-Geary utility is that excess income, income remaining after the minimum purchases of the i-commodities are made, is assumed to be spent in constant proportions on each good. The Linear Expenditure System then becomes

$$QH_{C,H} = \lambda_{C,H} + \frac{\beta_{C,H} \cdot \left(NYH_H - \sum_C \left(\lambda_{C,H} \cdot PQ_C \cdot \left(1 + tc_{H,C}\right)\right)\right)}{PQ_C \cdot \left(1 + tc_{H,C}\right)}$$

where $QH_{C,H}$ is the households demand of commodity C, $\lambda_{C,H}$ is the minimum household purchase of commodity C, $\beta_{C,H}$ is the marginal share of the household's budget going to commodity C, PQ_C is the consumer price for commodity C, and $tc_{H,C}$[11] is the consumption tax rate the household pays on commodity C.

Producer Problem

The primary alteration to the production process is that we held industry payments to government fixed in the short run i.e., we held the industries payment to government fixed at the original value of the SAM. The reason for this was that reducing the B&O rate should make production more profitable and result in higher output, but from a strictly Leontief prospective the tax is an input to the production process and reducing it would have made the quantity produced go down. Thus the original Leontief-CES production function, $q_i =$

[10] The income tax rate in Washington is zero, but the effective rate includes federal income tax, fees, fines, and other household payments to government not including consumption tax revenue.
[11] Because this variable differs from the original model the average tax for all households is used.

$\min\left(\frac{z_{i1}}{a_{i1}}, \frac{z_{i2}}{a_{i2}}, \ldots \frac{z_{i11}}{a_{i11}}\right) * (\alpha_i {K_i}^{\rho_i} + (1-\alpha_i){L_i}^{\rho_i})^{\frac{1}{\rho_i}}$, where z_{ij} is quantity of commodity j firm i uses and a_{ij} is the corresponding technical coefficient. The min(·) component of the function represents the Leontief component and the remaining factors represent the standard CES component. This equation takes on a slightly different form in the model, becoming

$$QA_A = \frac{ad_A}{1 - \left(\frac{SAM_{INDT,A}}{SAM_{TOTAL,A}}\right) - \sum_C ica_{C,A}} \left(\sum_F del_{F,A} \times {QF_{F,A}}^{-\rho_A}\right)^{\frac{-1}{\rho_A}}$$

Where QA_A is the output of activity A, ad_A is a production shift parameter, $ica_{C,A}$ is the quantity of commodity C used in producing a unit of activity A's output, $del_{F,A}$ is the share parameter of the production function, $QF_{F,A}$ is the quantity of factor F used in the production process of activity A, and ρ_A reflects an elasticity of substitution between labor and capital for industry A. The values $SAM_{INDT,A}$ and $SAM_{TOTAL,A}$ are the industry payments to government and industry total outlays from the base SAM respectively.

The important thing to note about this production function is that it is CES with respect to the factors of production but Leontief with respect to the other commodities. This Hybrid production function allows for some flexibility in the production form which is an improvement beyond what a multi-regional input-output model could afford.

Government Problem

The state government problem is simply to ensure that the state revenues and state expenditures balance. The balanced budget condition guarantees this by forcing the variables in each equation to adjust until a balance is struck. We do not address the federal government equations in this section since the complexities of the current accounts are not our primary focus. It is important to note that the original CGE model double counted state-intergovernmental transfers and that component of revenues and expenditures needed to be removed from the equations.

State government revenue

In this model government revenue is derived from 10 different sources: income/property tax revenue[12], tariffs, federal transfers to state government, sales of state produced commodities, the asset value of state investments, employment taxes, taxes on production, sales taxes paid by industries, sales taxes paid by consumers, and taxes on services. Because the IMPLAN SAM does not break out government revenues in this way several of

[12] This is a generic reference to payments from households to government that do not include consumption tax revenues.

the assumed initial tax rates are set to zero as shown in the parameters section of the previous chapter. It is important to note that in the original model state intergovernmental transfer were included. This resulted in a double counting of some state dollars. In order to reproduce the results shown in this paper such transfers must be removed from the state government revenue equation.

$$YSG = \sum_{H,SG} ty \cdot YH + CPI \cdot \sum_{T,SG} SAM_{SG,T} + CPI \cdot \sum_{SG,FG} SAM_{SG,FG} + \sum_{C,SG} PX_C \cdot IMAKEQ_{SG,C} + \sum_{SG} QIINV_{SG} + \sum_{SG,F} YF_{SG,F} + \sum_{SG} INDT_{SG} + \sum_{C} (PM_C \cdot QM_C \cdot CM_C + PD_C \cdot QD_C) \cdot tq_{A,C} + \sum_{H,C} PQ_C \cdot QH_{C,H} \cdot tc_{H,C}$$

Where YSG is state government revenue, ty is the effective income tax rate, YH is the households gross income, CPI is the consumer price index, and $SAM_{SG,T}$ is the state's output sold to domestic and foreign markets as calculated by the base SAM. $SAM_{SG,FG}$represents the intergovernmental transfers from the federal government to the state in the bass SAM. PX_C is the producer price of commodity C and $IMAKEQ_{SG,C}$ is the state's output of commodity C. $QIINV_{SG}$, $YF_{SG,F}$, and $INDT_{SG}$ represent the value of state investments, the returns to state government from state owned capital and payments to state employees, and lastly the indirect business taxes industries pay to the state government. PM_C is the composite commodity price of imported goods, QM_C is the quantity of composite commodity imported, and CM_C is a dummy variable that takes on a value of 1 if there are imports of commodity C and 0 otherwise. PD_C and QD_C are the price and quantity of domestically produced and sold goods. The sales tax rate, which may be thought of as the tax industries pay on production is $tq_{A,C}$. The household consumption tax revenue received by the state is captured as the price of commodity C, PQ_C, times the quantity of commodity C sold to household H, $QH_{C,H}$, times the newly introduced consumption tax rate, $tc_{H,C}$.

State government Expenditures

The state government spends money on investments such as state pensions, imports, commodities used in their production processes, and transfers. As in the case of their revenues many of these expenditures are adjusted with the CPI.

$$ESG = CPI \times \sum_{SG,I} SAM_{I,SG} + CPI \times \sum_{SG,T} SAM_{T,SG} + SGADJ \times \sum_{SG,C} PQ_C \cdot qg_{C,SG} - \sum_{H} trans_H - CPI \times sgovbal$$

Where ESG is the states expenditures. The CPI is as it was before and $SAM_{I,SG}$ is state government payments to other institutions as calculated in the base SAM. $SAM_{T,SG}$ is the value of state purchases of imports from U.S. and foreign markets. $SGADJ$ is a state government sales adjustment factor, PQ_C remains the composite commodity price level, and $qg_{C,SG}$ is state government consumption of commodity C. In order to force government budgets down to account for the residual payment to households from the carbon policy $trans_H$ was included directly in the governments expenditures. The $sgovbal$ is simply a balanced budget variable that ensures expenditures match the revenues. Because the household rebate is modeled as a residual payment it actually reduces the government's overall budgets.

Section 3: Modeling the Proposed Policy

The code for the following Shocks to the model can be found in Appendix 4. It should replace the initial shock in the CGE code.

```
" * Set counterfactual
xshift('MAN-C','FT') = 10.0*xshift('MAN-C','FT');"
```

This shock is just a default that allows the model to run a scenario. Effectively it increases the foreign trade of the manufacturing sector in much the way an I-O model would were exogenous final demand to increase by a factor of 10.

Sales Tax Reduction

For the purposes of our model the reduction in "Sales" tax is a reduction in the consumption tax rate paid by households. Currently that rate is 6.5%. It is quite true that food is not taxed in Washington and Alcohol and Tabaco are taxed at higher rates. Because our model is not capturing the entirety of the Washington State tax code these nuances are ignored. However, there are several issues with the underlying SAM that require us to adjust some measures of the sales tax in both years of our analysis. The first and largest issue is how housing is handled in the SAM this sector in the model falls under services and is known as Owner Occupied Dwellings. What is standard in both input-output and SAMs is to allow this vector to operate as though the owner of a home is paying rent to himself. Clearly this element and others like it need to be exempted from the tax rates, which are why different rates are applied to the service sector and all other household consumption.

Because the consumption tax rate is initially set at zero and all changes are modeled as a percentage reduction i.e., a -.01 would represent a 1% reduction in the current rate. For the service sector rate the same methodology applies but only to the percentage of services effected by the consumption tax reduction e.g. -.01*30%.

Business and Operations Tax Reduction

The B&O tax reduction only applies to the manufacturing sector and we have ignored some of the intricacies of how semi-conductor manufacturing, for example, may be affected differently from other manufacturing sectors. Essentially we calculate the portion of TOPI reflective of B&O, and reduce that portion of the TOPI rate originally at .4%[13] to .001%. This portion of the code stays constant in both years of the model since it is fully implemented in the first year and does not change.

Carbon Tax

The Carbon tax payment, as stated previously is a tax we place on the fossil fuel sector itself. Again, this tax was originally set at 0 and we need to turn the annual $25 per metric ton of CO2 into a percentage tax rate. From various source we estimated 8.9kg of CO2 per unit of output from the fossil fuel sector, 907.185kg equals a metric ton. So a $25 per metric ton rate became a 7.6% price increase when the estimated price per unit of output from the fossil fuel sector was $3.23. Thus, in the second year the increased sales tax for non-exempt industries was 7.6% and for the agricultural sector it was 0.38%.

Transfer Payment

The transfer payments came directly from the lobby group Carbon Washington at $157.74 million in the first year and $262.9 in the second year. Because the total state budgets were declining absent the transfer this money was withdrawn from the states investment funds, as can be seen in the following results.

[13] Even though the official rate was .484% the original SAM was producing a .4% in the base case. This may have been a result of other manufacturing sectors, such as semiconductor manufacturing, bringing the sector average down slightly.

Appendix 1: Validation of Base IMPLAN Data for Washington

There is always a need to externally verify the data used in these models so we did several preliminary checks to ensure the numbers we were working with resembled the published data from various government sources. The first and easiest check was to ensure that the Gross State product matched that reported by IMPLAN. IMPLAN reported this number at $428.6 billion and the BEA[14] reported it at $422.8 billion. This represented only a 1.3% difference, which I we were comfortable with. Initial state government revenues including operating and non-operating budgets were reported by IMPLAN at $89.4 billion and by the 2012 Census of Governments[15] at $88.5 billion.

The last check we did was to see how total regional output by industry lined up with the BEA's measures. Table A.1 shows a relatively close match, usually within 1-2% of one another.

Table A.1: Percentage of regional output by sector

Industrial Sectors	IMPLAN Data	BEA DATA
AGR-A	2%	2%
FOREST-A	0%	0%
CONST-A	4%	4%
UTIL-A	1%	1%
Fossil-A	1%	0%
TRAD-A	12%	12%
MIN-A	0%	0%
FOOD-A	1%	3%
MAN-A	11%	11%
SER-A	52%	50%
MISC-A	15%	17%

[14] See the BEA's regional GDP by state in millions of current dollars http://www.bea.gov/iTable/iTable.cfm?reqid=70&step=1&isuri=1&acrdn=2#reqid=70&step=10&isuri=1&7003=200&7035=-1&7004=naics&7005=1&7006=53000&7036=-1&7001=1200&7002=1&7090=70&7007=2014&7093=levels

[15] This data is obtained by summing the State and Local government revenues together (columns 3 and 4) in order to match the IMPLAN figures. This data may be downloaded at https://www.census.gov/govs/local/

Appendix 2: Description of the 11 Industrial Sectors

Three sectors: Processed foods, Services, and Manufacturing

Table A.2: Sector Descriptions

IMPLAN Code	Agriculture
1	Oilseed farming
2	Grain farming
3	Vegetable and melon farming
4	Fruit farming
5	Tree nut farming
6	Greenhouse nursery production
7	Tobacco farming
8	Cotton farming
9	Sugarcane and sugar beet farming
10	All other crop farming
11	Beef cattle ranching
12	Dairy cattle and milk production
13	Poultry and egg production
14	Other animal production
17	Commercial fishing
18	Commercial hunting and trapping
19	Support activities for agriculture

IMPLAN Code	Mining
23	Iron ore mining
24	Gold ore mining
25	Silver ore mining
26	Lead and zinc ore mining
27	Copper ore mining
28	Uranium-radium-vanadium ore mining
29	Other metal ore mining
30	Stone mining and quarrying
31	Sand and gravel mining
32	Other clay ceramic refractory minerals mining
33	Potash soda and borate mineral mining
34	Phosphate rock mining
35	Other chemical and fertilizer mineral mining
36	Other nonmetallic minerals
39	Metal mining services
40	Other nonmetallic minerals services

IMPLAN Code	Miscellaneous
513	Religious organizations
514	Grantmaking giving and social advocacy organizations
516	Labor and civic organizations
517	Private households
520	Other federal government enterprises
521	State government passenger transit
523	Other state government enterprises
524	Local government passenger transit
526	Other local government enterprises
501	Owner-occupied dwellings
527	Not an industry (Used and secondhand goods)
528	Not an industry (Scrap)
529	Not an industry (Rest of world adjustment)
530	Not an industry (Noncomparable foreign imports)
531	Employment and payroll of state govt non-education
532	Employment and payroll of state govt education
533	Employment and payroll of local govt non-education
534	Employment and payroll of local govt education
535	Employment and payroll of federal govt non-military
536	Employment and payroll of federal govt military

IMPLAN Code	Utilities
41	Electric power generation - Hydroelectric
42	Electric power generation - Fossil fuel
43	Electric power generation - Nuclear
44	Electric power generation - Solar
45	Electric power generation - Wind
46	Electric power generation - Geothermal
47	Electric power generation - Biomass
48	Electric power generation - All other
49	Electric power transmission and distribution
50	Natural gas distribution
51	Water sewage and other systems
519	Federal electric utilities
522	State government electric utilities
525	Local government electric utilities

IMPLAN Code	Fossil-Fuel
20	Extraction of natural gas and crude petroleum
21	Extraction of natural gas liquids
22	Coal mining
37	Drilling oil and gas wells
38	Support activities for oil and gas operations
156	Petroleum refineries

IMPLAN Code	Construction
52	Construction of new health care structures
53	Construction of new manufacturing structures
54	Construction of new power and communication structures
55	Construction of new educational and vocational structures
56	Construction of new highways and streets
57	Construction of new commercial structures including farm structures
58	Construction of other new nonresidential structures
59	Construction of new single-family residential structures
60	Construction of new multifamily residential structures
61	Construction of other new residential structures
62	Maintenance and repair construction of nonresidential structures
63	Maintenance and repair construction of residential structures
64	Maintenance and repair construction of highways streets bridges and tunnels

IMPLAN Code	Wholesale and retail trade
395	Wholesale trade
396	Retail - Motor vehicle and parts dealers
397	Retail - Furniture and home furnishings stores
398	Retail - Electronics and appliance stores
399	Retail - Building material and garden equipment and supplies stores
400	Retail - Food and beverage stores
401	Retail - Health and personal care stores
402	Retail - Gasoline stores
403	Retail - Clothing and clothing accessories stores
404	Retail - Sporting goods hobby musical instrument and book stores
405	Retail - General merchandise stores
406	Retail - Miscellaneious store retailers
407	Retail - Nonstore retailers

IMPLAN Code	Forestry
15	Forestry products and timber production
16	Commercial logging

Table A.2 (Cont.): Sector Descriptions

IMPLAN Code	Services	IMPLAN Code	Manufactures
441	Owner-occupied dwellings	65	Dog and cat food manufacturing
482	Hospitals	66	Other animal food manufacturing
440	Real estate	112	Fiber yarn and thread mills
475	Offices of physicians	113	Broadwoven fabric mills
502	Limited-service restaurants	114	Narrow fabric mills and schiffli machine embroidery
428	Wireless telecommunications carriers (except satellite)	115	Nonwoven fabric mills
437	Insurance carriers	116	Knit fabric mills
483	Nursing and community care facilities	117	Textile and fabric finishing mills
433	Monetary authorities and depository credit intermediation	118	Fabric coating mills
478	Outpatient care centers	119	Carpet and rug mills
476	Offices of dentists	120	Curtain and linen mills
477	Offices of other health practitioners	121	Textile bag and canvas mills
436	Other financial investment activities	122	Rope cordage twine tire cord and tire fabric mills
485	Individual and family services	123	Other textile product mills
503	All other food and drinking places	124	Hosiery and sock mills
408	Air transportation	125	Other apparel knitting mills
447	Legal services	126	Cut and sew apparel contractors
427	Wired telecommunications carriers	127	Mens and boys cut and sew apparel manufacturing
411	Truck transportation	128	Womens and girls cut and sew apparel manufacturing
509	Personal care services	129	Other cut and sew apparel manufacturing
495	Gambling industries (except casino hotels)	130	Apparel accessories and other apparel manufacturing
422	Software publishers	131	Leather and hide tanning and finishing
474	Other educational services	132	Footwear manufacturing
487	Child day care services	133	Other leather and allied product manufacturing
480	Home health care services	134	Sawmills
512	Other personal services	135	Wood preservation
459	Veterinary services	136	Veneer and plywood manufacturing
472	Elementary and secondary schools	137	Engineered wood member and truss manufacturing
442	Automotive equipment rental and leasing	138	Reconstituted wood product manufacturing
496	Other amusement and recreation industries	139	Wood windows and door manufacturing
435	Securities and commodity contracts intermediation and brokerage	140	Cut stock resawing lumber and planing
481	Other ambulatory health care services	141	Other millwork including flooring
497	Fitness and recreational sports centers	142	Wood container and pallet manufacturing
488	Performing arts companies	143	Manufactured home (mobile home) manufacturing
479	Medical and diagnostic laboratories	144	Prefabricated wood building manufacturing
434	Nondepository credit intermediation and related activities	145	All other miscellaneous wood product manufacturing
471	Waste management and remediation services	146	Pulp mills
412	Transit and ground passenger transportation	147	Paper mills
466	Travel arrangement and reservation services	148	Paperboard mills
508	Personal and household goods repair and maintenance	149	Paperboard container manufacturing
515	Business and professional associations	150	Paper bag and coated and treated paper manufacturing
410	Water transportation	151	Stationery product manufacturing
489	Commercial Sports Except Racing	152	Sanitary paper product manufacturing
423	Motion picture and video industries	153	All other converted paper product manufacturing
432	Internet publishing and broadcasting and web search portals	154	Printing
443	General and consumer goods rental except video tapes and discs	155	Support activities for printing
491	Promoters of performing arts and sports and agents for public figures	157	Asphalt paving mixture and block manufacturing
505	Car washes	158	Asphalt shingle and coating materials manufacturing
469	Landscape and horticultural services	159	Petroleum lubricating oil and grease manufacturing
414	Scenic and sightseeing transportation and support activities for transportation	160	All other petroleum and coal products manufacturing
458	Photographic services	161	Petrochemical manufacturing
510	Death care services	162	Industrial gas manufacturing
511	Dry-cleaning and laundry services	163	Synthetic dye and pigment manufacturing
419	Book publishers	164	Other basic inorganic chemical manufacturing
409	Rail transportation	165	Other basic organic chemical manufacturing
468	Services to buildings	166	Plastics material and resin manufacturing
418	Periodical publishers	167	Synthetic rubber manufacturing
518	Postal service	168	Artificial and synthetic fibers and filaments manufacturing
417	Newspaper publishers	169	Nitrogenous fertilizer manufacturing
467	Investigation and security services	170	Phosphatic fertilizer manufacturing
498	Bowling centers	171	Fertilizer mixing
424	Sound recording industries	172	Pesticide and other agricultural chemical manufacturing
450	Specialized design services	173	Medicinal and botanical manufacturing
506	Electronic and precision equipment repair and maintenance	174	Pharmaceutical preparation manufacturing
465	Business support services	175	In-vitro diagnostic substance manufacturing
444	Video tape and disc rental	176	Biological product (except diagnostic) manufacturing
494	Amusement parks and arcades	177	Paint and coating manufacturing
425	Radio and television broadcasting	178	Adhesive manufacturing
415	Couriers and messengers	179	Soap and other detergent manufacturing
464	Employment services	180	Polish and other sanitation good manufacturing
490	Racing and Track Operation	181	Surface active agent manufacturing
500	Other accommodations	182	Toilet preparation manufacturing
445	Commercial and industrial machinery and equipment rental and leasing	183	Printing ink manufacturing
470	Other support services	184	Explosives manufacturing
416	Warehousing and storage	185	Custom compounding of purchased resins
421	Greeting card publishing	186	Photographic film and chemical manufacturing
462	Office administrative services	187	Other miscellaneous chemical product manufacturing
426	Cable and other subscription programming	188	Plastics packaging materials and unlaminated film and sheet manufacturing
463	Facilities support services	189	Unlaminated plastics profile shape manufacturing
454	Management consulting services	190	Plastics pipe and pipe fitting manufacturing
413	Pipeline transportation	191	Laminated plastics plate sheet (except packaging) and shape manufacturing
420	Directory mailing list and other publishers	192	Polystyrene foam product manufacturing
429	Satellite telecommunications resellers and all other telecommunications	193	Urethane and other foam product (except polystyrene) manufacturing
430	Data processing hosting and related services	194	Plastics bottle manufacturing
431	News syndicates libraries archives and all other information services	195	Other plastics product manufacturing
438	Insurance agencies brokerages and related activities	196	Tire manufacturing
439	Funds trusts and other financial vehicles	197	Rubber and plastics hoses and belting manufacturing
446	Lessors of nonfinancial intangible assets	198	Other rubber product manufacturing
448	Accounting tax preparation bookkeeping and payroll services	199	Pottery ceramics and plumbing fixture manufacturing
449	Architectural engineering and related services	200	Brick tile and other structural clay product manufacturing
451	Custom computer programming services	201	Flat glass manufacturing
452	Computer systems design services	202	Other pressed and blown glass and glassware manufacturing
453	Other computer related services including facilities management	203	Glass container manufacturing
455	Environmental and other technical consulting services	204	Glass product manufacturing made of purchased glass
456	Scientific research and development services	205	Cement manufacturing
457	Advertising public relations and related services	206	Ready-mix concrete manufacturing
460	Marketing research and all other miscellaneous professional scientific and technical services	207	Concrete block and brick manufacturing
461	Management of companies and enterprises	208	Concrete pipe manufacturing
473	Junior colleges colleges universities and professional schools	209	Other concrete product manufacturing
484	Residential mental retardation mental health substance abuse and other facilities	210	Lime manufacturing
486	Community food housing and other relief services including rehabilitation services	211	Gypsum product manufacturing
492	Independent artists writers and performers	212	Abrasive product manufacturing
493	Museums historical sites zoos and parks	213	Cut stone and stone product manufacturing
499	Hotels and motels including casino hotels	214	Ground or treated mineral and earth manufacturing
504	Automotive repair and maintenance except car washes	215	Mineral wool manufacturing
507	Commercial and industrial machinery and equipment repair and maintenance	216	Miscellaneous nonmetallic mineral products manufacturing

Table A.2 (Cont.): Sector Descriptions

IMPLAN Code	Processed food
67	Flour milling
68	Rice milling
69	Malt manufacturing
70	Wet corn milling
71	Soybean and other oilseed processing
72	Fats and oils refining and blending
73	Breakfast cereal manufacturing
74	Beet sugar manufacturing
75	Sugar cane mills and refining
76	Nonchocolate confectionery manufacturing
77	Chocolate and confectionery manufacturing from cacao beans
78	Confectionery manufacturing from purchased chocolate
79	Frozen fruits juices and vegetables manufacturing
80	Frozen specialties manufacturing
81	Canned fruits and vegetables manufacturing
82	Canned specialties
83	Dehydrated food products manufacturing
84	Fluid milk manufacturing
85	Creamery butter manufacturing
86	Cheese manufacturing
87	Dry condensed and evaporated dairy product manufacturing
88	Ice cream and frozen dessert manufacturing
89	Animal except poultry slaughtering
90	Meat processed from carcasses
91	Rendering and meat byproduct processing
92	Poultry processing
93	Seafood product preparation and packaging
94	Bread and bakery product except frozen manufacturing
95	Frozen cakes and other pastries manufacturing
96	Cookie and cracker manufacturing
97	Dry pasta mixes and dough manufacturing
98	Tortilla manufacturing
99	Roasted nuts and peanut butter manufacturing
100	Other snack food manufacturing
101	Coffee and tea manufacturing
102	Flavoring syrup and concentrate manufacturing
103	Mayonnaise dressing and sauce manufacturing
104	Spice and extract manufacturing
105	All other food manufacturing
106	Bottled and canned soft drinks & water
107	Manufactured ice
108	Breweries
109	Wineries
110	Distilleries
111	Tobacco product manufacturing

IMPLAN Code	Manufactures (Cont.)
217	Iron and steel mills and ferroalloy manufacturing
218	Iron steel pipe and tube manufacturing from purchased steel
219	Rolled steel shape manufacturing
220	Steel wire drawing
221	Alumina refining and primary aluminum production
222	Secondary smelting and alloying of aluminum
223	Aluminum sheet plate and foil manufacturing
224	Other aluminum rolling drawing and extruding
225	Nonferrous metal (exc aluminum) smelting and refining
226	Copper rolling drawing extruding and alloying
227	Nonferrous metal except copper and aluminum shaping
228	Secondary processing of other nonferrous metals
229	Ferrous metal foundries
230	Nonferrous metal foundries
231	Iron and steel forging
232	Nonferrous forging
233	Custom roll forming
234	Crown and closure manufacturing and metal stamping
235	Cutlery utensil pot and pan manufacturing
236	Handtool manufacturing
237	Prefabricated metal buildings and components manufacturing
238	Fabricated structural metal manufacturing
239	Plate work manufacturing
240	Metal window and door manufacturing
241	Sheet metal work manufacturing
242	Ornamental and architectural metal work manufacturing
243	Power boiler and heat exchanger manufacturing
244	Metal tank (heavy gauge) manufacturing
245	Metal cans manufacturing
246	Metal barrels drums and pails manufacturing
247	Hardware manufacturing
248	Spring and wire product manufacturing
249	Machine shops
250	Turned product and screw nut and bolt manufacturing
251	Metal heat treating
252	Metal coating and nonprecious engraving
253	Electroplating anodizing and coloring metal
254	Valve and fittings other than plumbing manufacturing
255	Plumbing fixture fitting and trim manufacturing
256	Ball and roller bearing manufacturing
257	Small arms ammunition manufacturing
258	Ammunition except for small arms manufacturing
259	Small arms ordnance and accessories manufacturing
260	Fabricated pipe and pipe fitting manufacturing
261	Other fabricated metal manufacturing
262	Farm machinery and equipment manufacturing
263	Lawn and garden equipment manufacturing
264	Construction machinery manufacturing
265	Mining machinery and equipment manufacturing
266	Oil and gas field machinery and equipment manufacturing
267	Food product machinery manufacturing
268	Semiconductor machinery manufacturing
269	Sawmill woodworking and paper machinery
270	Printing machinery and equipment manufacturing
271	All other industrial machinery manufacturing
272	Optical instrument and lens manufacturing
273	Photographic and photocopying equipment manufacturing
274	Other commercial service industry machinery manufacturing
275	Air purification and ventilation equipment manufacturing
276	Heating equipment (except warm air furnaces) manufacturing
277	Air conditioning refrigeration and warm air heating equipment manufacturing
278	Industrial mold manufacturing
279	Special tool die jig and fixture manufacturing
280	Cutting tool and machine tool accessory manufacturing
281	Machine tool manufacturing

IMPLAN Code	Manufactures (Cont.)
282	Rolling mill and other metalworking machinery manufacturing
283	Turbine and turbine generator set units manufacturing
284	Speed changer industrial high-speed drive and gear manufacturing
285	Mechanical power transmission equipment manufacturing
286	Other engine equipment manufacturing
287	Pump and pumping equipment manufacturing
288	Air and gas compressor manufacturing
289	Measuring and dispensing pump manufacturing
290	Elevator and moving stairway manufacturing
291	Conveyor and conveying equipment manufacturing
292	Overhead cranes hoists and monorail systems manufacturing
293	Industrial truck trailer and stacker manufacturing
294	Power-driven handtool manufacturing
295	Welding and soldering equipment manufacturing
296	Packaging machinery manufacturing
297	Industrial process furnace and oven manufacturing
298	Fluid power cylinder and actuator manufacturing
299	Fluid power pump and motor manufacturing
300	Scales balances and miscellaneous general purpose machinery manufacturing
301	Electronic computer manufacturing
302	Computer storage device manufacturing
303	Computer terminals and other computer peripheral equipment manufacturing
304	Telephone apparatus manufacturing
305	Broadcast and wireless communications equipment manufacturing
306	Other communications equipment manufacturing
307	Audio and video equipment manufacturing
308	Bare printed circuit board manufacturing
309	Semiconductor and related device manufacturing
310	Capacitor resistor coil transformer and other inductor manufacturing
311	Electronic connector manufacturing
312	Printed circuit assembly (electronic assembly) manufacturing
313	Other electronic component manufacturing
314	Electromedical and electrotherapeutic apparatus manufacturing
315	Search detection and navigation instruments manufacturing
316	Automatic environmental control manufacturing
317	Industrial process variable instruments manufacturing
318	Totalizing fluid meter and counting device manufacturing
319	Electricity and signal testing instruments manufacturing
320	Analytical laboratory instrument manufacturing
321	Irradiation apparatus manufacturing
322	Watch clock and other measuring and controlling device manufacturing
323	Blank magnetic and optical recording media manufacturing
324	Software and other prerecorded and record reproducing
325	Electric lamp bulb and part manufacturing
326	Lighting fixture manufacturing
327	Small electrical appliance manufacturing
328	Household cooking appliance manufacturing
329	Household refrigerator and home freezer manufacturing
330	Household laundry equipment manufacturing
331	Other major household appliance manufacturing
332	Power distribution and specialty transformer manufacturing
333	Motor and generator manufacturing
334	Switchgear and switchboard apparatus manufacturing
335	Relay and industrial control manufacturing
336	Storage battery manufacturing
337	Primary battery manufacturing
338	Fiber optic cable manufacturing
339	Other communication and energy wire manufacturing
340	Wiring device manufacturing
341	Carbon and graphite product manufacturing
342	All other miscellaneous electrical equipment and component manufacturing
343	Automobile manufacturing
344	Light truck and utility vehicle manufacturing
345	Heavy duty truck manufacturing
346	Motor vehicle body manufacturing
347	Truck trailer manufacturing
348	Motor home manufacturing
349	Travel trailer and camper manufacturing
350	Motor vehicle gasoline engine and engine parts manufacturing
351	Motor vehicle electrical and electronic equipment manufacturing
352	Motor vehicle steering suspension component (except spring) and brake systems manufacturing
353	Motor vehicle transmission and power train parts manufacturing
354	Motor vehicle seating and interior trim manufacturing
355	Motor vehicle metal stamping
356	Other motor vehicle parts manufacturing
357	Aircraft manufacturing
358	Aircraft engine and engine parts manufacturing
359	Other aircraft parts and auxiliary equipment manufacturing
360	Guided missile and space vehicle manufacturing
361	Propulsion units and parts for space vehicles and guided missiles manufacturing
362	Railroad rolling stock manufacturing
363	Ship building and repairing
364	Boat building
365	Motorcycle bicycle and parts manufacturing
366	Military armored vehicle tank and tank component manufacturing
367	All other transportation equipment manufacturing
368	Wood kitchen cabinet and countertop manufacturing
369	Upholstered household furniture manufacturing
370	Nonupholstered wood household furniture manufacturing
371	Other household nonupholstered furniture manufacturing
372	Institutional furniture manufacturing
373	Wood office furniture manufacturing
374	Custom architectural woodwork and millwork
375	Office furniture except wood manufacturing
376	Showcase partition shelving and locker manufacturing
377	Mattress manufacturing
378	Blind and shade manufacturing
379	Surgical and medical instrument manufacturing
380	Surgical appliance and supplies manufacturing
381	Dental equipment and supplies manufacturing
382	Ophthalmic goods manufacturing
383	Dental laboratories
384	Jewelry and silverware manufacturing
385	Sporting and athletic goods manufacturing
386	Doll toy and game manufacturing
387	Office supplies (except paper) manufacturing
388	Sign manufacturing
389	Gasket packing and sealing device manufacturing
390	Musical instrument manufacturing
391	Fasteners buttons needles and pins manufacturing
392	Broom brush and mop manufacturing
393	Burial casket manufacturing
394	All other miscellaneous manufacturing

Appendix 3: Parameters Initially calculated from the SAM

Table A.3: Quantities and Parameters Calculated from Base SAM

Parameter	Description
QMRO(T,C)	Initial regional imports
QERO(C,T)	Initial regional exports
QMO(C)	Initial composite import quantity
QEO(C)	Initial composite export quantity
QQ(C)	Initial composite quantity supplied to regional demanders
QDO(C)	Initial quantity of regional output supplied to regional demanders
QXO(C)	Initial quantity of regional output
QAO(A)	Initial activity level
QINTO(C,A)	Initial quantity of intermediate use of commodity C by activity A
IMAKEQO(I,C)	Initial institutional make matrix (quantity)
QFO(FF,A)	Initial quantity of factor FF demanded by activity A
QHO(C,H)	Initial household consumption
QINVO(C)	Initial investment demand
QIINVO(I)	Initial institutional investment demand
QFSO(FF)	Initial factor supply
INDTO(G)	Initial indirect business taxes receipts for each government unit
EMPLOY(A)	Employment data (actual number of jobs in each sector)
YFO(I,FF)	Initial transfer of income to institution I from factor FF
YHO(H)	Initial gross household income
NYHO(H)	Initial net household income
YFGO	Initial federal government income
EFGO	Initial federal government spending
YSGO	Initial state government income
ESGO	Initial state government spending
FSAVXO	Initial foreign savings (export column)
FSAVMO	Initial foreign savings (import row)
DSAVXO	Initial savings for RUS (export column)
DSAVMO	Initial savings for RUS (import row)
CPIO	Initial consumer price index
WFDISTO(FF,A)	Initial factor price distortion factor
IADJO	Initial investment adjustment factor
SADJO	Initial savings adjustment factor
SGADJO	Initial state government spending adjustment factor
SHIFTFFO(FF)	Initial shift variable for factor supply equation
theta(A,C)	Yield of output C per unit of activity A
ica(C,A)	Quantity of C as intermediate input per unit of activity A
tb(A)	Indirect business tax rate
ty(G,H)	Household income tax rate
trh(H,HH)	Inter-household transfers
mps(H)	Marginal propensity to save
cwts(C)	Weight of commodity C in the consumer price index
wfa(FF,A)	Price for factor FF in activity A
xshift(C,T)	Shift parameter for world export demand function
lambda(C,H)	Subsistence level parameter for Stone-Geary utility function
beta(C,H)	Marginal budget share parameter for Stone-Geary utility function
engelwt(H)	Engel aggregation weight
qg(C,G)	Government consumption
shry(I,FF)	Institutional share of factor income
tbshr(G)	Government unit share of indirect business taxes
sgovbal	Initial state government budget balance
ad(A)	Shift parameter for production function
del(F,A)	Share parameter for production function
rho(A)	Exponent for production function
aq(C)	Shift parameter for armington demand function
adel(C)	Share parameter for armington demand function
arho(C)	Exponent for armington demand function
as(C)	Shift parameter for supply transformation function
sdel(C)	Share parameter for supply transformation function
srho(C)	Exponent for supply transformation function
ae(C)	Shift parameter for export transformation function
edel(C)	Share parameter for export transformation function
erho(C)	Exponent for export transformation function
am(C)	Shift parameter for armington import function
mdel(C)	Share parameter for armington import function
mrho(C)	Exponent parameter for armington import function

Appendix 4: Code for Modeling Economic Shocks

```
* Set counterfactual

* YEAR 1 SCENARIOS
* (Iteration 1) this counterfactual is a 0.5% reduction in the sales tax paid by all sectors
tc(H,NSER) = -.005;
tc(H,'SER-C') = -.0015;

* (Iteration 2) this counterfactual reduces the IBT for manufacturing
tb('MAN-A') = .00158;

* (Iteration 3) this counterfactual adds a commodity fuel tax
tq(NAG,'FOSSIL-C')= .04561;
tq('AGR-A','FOSSIL-C')= .0019;

*(Iteration 4) this is the low income transfer payment
trans('HHD1')= 157.74



* YEAR 2 SCENARIOS
* (Iteration 1) this counterfactual is a 1% reduction in the sales tax paid by all sectors
tc(H,NSER) = -.01;
tc(H,'SER-C') = -.003;

* (Iteration 2) this counterfactual reduces the IBT for manufacturing *
tb('MAN-A') = .00158;

* (Iteration 3) this counterfactual adds a commodity fuel tax
tq(NAG,'FOSSIL-C')= .076;
tq('AGR-A','FOSSIL-C')= .0038;

*(Iteration 4) this is how we built in the low income carbon transfer payment
trans('HHD1')= 262.899
```