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# Western Economics Forum

A Journal of the
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*Farm & Ranch Management*

*Marketing & Agribusiness*

*Natural Resources & the Environment*

*Policy & Institutions*

*Regional & Community Development*

# Western Economics Forum

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# *The Western Economics Forum*

A peer-reviewed publication from the Western Agricultural Economics Association

Purpose

One of the consequences of regional associations nationalizing their journals is that professional agricultural economists in each region have lost one of their best forums for exchanging ideas unique to their area of the country. The purpose of this publication is to provide a forum for western issues.

Audience

The target audience is professional agricultural economists with a Masters degree, Ph.D. or equivalent understanding of the field that are working on agricultural and resource economic, business or policy issues in the West.

Subject

This publication is specifically targeted at informing professionals in the West about issues, methods, data, or other content addressing the following objectives:

- Summarize knowledge about issues of interest to western professionals
- To convey ideas and analysis techniques to non-academic, professional economists working on agricultural or resource issues
- To demonstrate methods and applications that can be adapted across fields in economics
- To facilitate open debate on western issues

Structure and Distribution

The *Western Economics Forum* is a peer reviewed publication. It usually contains three to five articles per issue, with approximately 2,500 words each (maximum 3,000), and as much diversity as possible across the following areas:

- Farm/ranch management and production
- Marketing and agribusiness
- Natural resources and the environment
- Institutions and policy
- Regional and community development

There are two issues of the *Western Economics Forum* per year (Spring and Fall).

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## Fall 2015 Western Economics Forum offers 4 articles

As editor, I am happy to provide an applied policy analysis concerning a proposed carbon neutral tax for the state of Washington. The authors present two companion pieces and a technical document in which the latter provides methodological documentation.

Regards,
Don McLeod, editor
Western Economics Forum

# A Sectoral Level General Equilibrium Analysis of Washington State Initiative 732 - A Revenue-Neutral Carbon Tax Policy

Washington State Initiative 732 is a proposed revenue-neutral carbon tax policy for the state of Washington, which will be on the November 8, 2016 ballot. The policy proposes a tax on carbon pollution from fossil fuels. The revenues raised from this tax will be used to offset two types of tax payments: a sales tax reduction across all sectors and a business and occupation tax reduction in the manufacturing sector. Some of the revenues will also be used to fund the Working Families Tax Rebate program that aids low-income households.

There are two objectives in the first study which relate to the first two years of the proposed policy. First, we determine the sectors in the economy that will carry the burden of the tax and the sectors that will enjoy the benefits of the policy. We find that three sectors that generate approximately 80% of total carbon revenues are the fossil fuel sector, the household sector and the service sector. Since agriculture is largely exempt, it is the smallest contributor. Benefits from a reduction in the sales tax are relatively more evenly distributed across the different sectors in the economy, with the service sector benefiting the most. The manufacturing sector also enjoys a reduction in the business and occupation tax. Second, we measure the welfare effects of implementing the policy. We estimate Gross Domestic Product (GDP) and Green GDP which is GDP net of pollution damages. GDP and Green GDP both increase after the policy is implemented which indicates that aggregate welfare increases. However, we find that low-income households that do not receive aid through the Working Families Tax Rebate program may incur a decline in welfare. Thus, to increase welfare for all households, the Working Families Tax Rebate program is important.

The second study analyzes the effect of the proposed policy on two important sectors in Washington State: the agricultural and forestry sectors. We find that the value of output in the agricultural and forestry sectors increases by 1.77% and 0.13%, respectively, during the second year of policy implementation. Even though the carbon tax reduces fossil fuel use in both sectors, the influx of labor and capital from the reduction in sales tax offsets this effect leading to a net increase in output value in both sectors. The impact on total exports is small but positive in the agricultural sector with an increase of 1.45%, and exports in the forestry sector see a negligible drop of 0.03%.

The final document in this volume provides a technical detail of the model. This includes the structure of the model, data sources, sectoral components, assumptions and functional forms used in the simulations and calibrations.

The studies summarized in this volume provide important information for voters in Washington State. Also, our study may be of value for other states proposing similar types of carbon-reducing policies, as our model can provide a template for sectoral level analysis and welfare evaluation of a revenue-recycling tax policy.

# Who Pays and Who Benefits from a Revenue Neutral Carbon Tax? The Main Contributors and Beneficiaries from Washington State Initiative 732[1]

**Gregmar I. Galinato, Timothy Nadreau, and Tristan D. Skolrud[2]**

## Introduction

Washington State Initiative 732 (I-732), a citizen-led initiative currently proposed in Washington State, seeks to implement a statewide revenue-neutral carbon tax. The initiative was devised by the lobby group Carbon Washington (CarbonWA)[3]. A revenue-neutral carbon tax taxes commodities that create carbon dioxide during the consumption or production process and uses the revenues to offset an existing tax distortion in the economy by reducing the tax rate in that sector. Here, total additional government revenue from the instrument is zero. Taxing in such a manner can potentially create a double-dividend where the first benefit is a reduction in carbon dioxide emissions and the second benefit is an increase in efficiency in the market where the current distortionary tax exists (Pearce, 1991; Parry, 1995).

The objective of I-732 is to incentivize the adoption of cleaner fuel sources and reduce market inefficiencies by reducing the sales tax across a broad set of sectors and reducing the business and occupation (B&O) tax for the manufacturing sector (CarbonWA, 2015). In particular, I-732 imposes a tax of $25 per metric ton (MT) of carbon dioxide emitted from the use of fossil fuels in the state of Washington. Farm diesel and public transportation are partially exempt from full taxation during the first 40 years of the policy. The revenues are used to fund a 1% reduction in the sales tax, from 6.5% to 5.5%, and a reduction in business and occupation tax in the manufacturing sector from as much as 0.484% to 0.001%. Some revenues from carbon taxes are also used to provide a tax rebate of up to $1,500 per year for low income families (CarbonWA, 2015).

Two studies have estimated whether the policy is truly revenue neutral. CarbonWA (2015) and an independent study by the Washington State House Finance Committee used the Carbon Tax Assessment Model (CTAM) to show that the policy is approximately revenue-neutral (OFM, 2016). CTAM measures the greenhouse gas levels and fiscal impacts of a carbon tax from five sectors: industrial, commercial, residential, electricity and transportation sectors. A variety of fuels can be used within each sector such as natural gas, coal, gasoline, distillate fuel and diesel fuel. The model also allows for changes in output price given a policy shock to determine the effect to changes in consumption and output of fuel within each sector. However, such changes are partial equilibrium in nature, neglecting adjustments in equilibrium supply and demand across sectors. Furthermore, CTAM does not consider the changes from electricity imports and changes to the tax base. Finally, CTAM analyzes the Washington State economy

[1] This research was supported by the Agriculture and Food Research Initiative Competitive Grant No. 2012-67009-19707 from the USDA National Institute of Food and Agriculture. The authors would also like to thank Philip Watson for aid in programming the model as well as Yoram Bauman, Jacob LaRiviere, Jonathan Yoder and two anonymous reviewers for their comments.

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[3] For more information, refer to www.yeson732.org.

as a whole and very few implications are drawn on policy impacts to specific sectors in the economy such as agriculture, forestry and the manufacturing sectors.

This paper uses a general equilibrium approach to measure the effect of I-732 on different sectors in the economy. In particular, we calculate each sector's contribution to total carbon tax revenues and each sector's reduction to total sales and business tax revenues. In addition, we evaluate the policy's potential for achieving revenue neutrality in a general equilibrium context. Unlike the CTAM model, our general equilibrium model allows for spillover effects across sectors as well as changes to electricity imports and changes to the tax base. We also conduct robustness checks on our estimates to determine how slight changes in the policy affect revenue collected. Finally, we assess the welfare effects with and without the policy to determine if it is welfare improving or not. Our analysis focuses solely on the first two years of the project during the gradual phase-in of the sales tax reduction and carbon tax while the agricultural sector is mostly exempt.

## Policy Background

There are four main policy changes proposed by I-732, and each policy change is introduced in different phases. We focus our analysis on the first two years of the policy because it is in those years that our analysis is most reliable given our model and assumptions.

During the first year of the policy, a $15 tax per ton of carbon dioxide will be implemented before rising to $25 per ton in the second year. During the subsequent years, the carbon tax rate rises by 3.5% plus the rate of inflation to account for the predicted carbon tax revenue drop as emissions decline. The carbon tax will be capped at $100/ton in 2016 US dollars which is expected to occur after 40 years (CarbonWA, 2015). The rise of the carbon tax rate in the agricultural sector, or more specifically the use of farm diesel, and the public transportation sector will occur more slowly. These sectors face a rising carbon tax rate that will converge toward the level imposed on the rest of the economy by year 40 (OFM, 2016).

The revenues from the carbon tax are used to finance the reduction in both the business tax in the food and general manufacturing sector and the sales tax across a broad range of sectors. The sales tax will decrease by 1% from 6.5% to 5.5% but it will decline gradually in that the first half-percent reduction occurs in the first year and the second half-percent occurs a year later (CarbonWA, 2015). Unlike the sales tax, the business tax reduction in the manufacturing sector from as much as 0.484% to 0.001% occurs immediately in the first year (CarbonWA, 2015).

In addition to financing decreases in existing taxes, low-income families will also receive a rebate. Revenues from the carbon tax rate will be used to fund the Working Families Tax Rebate, created by state legislators in 2008 but not funded. I-732 will use some of the money earned from carbon taxes to match a portion of the Federal Earned Income Tax Credit. In particular, the policy stipulates a 15% match in the first year and a 25% match in the subsequent years. This is equivalent to about $157 million in the first year and $263 million in the second year (OFM, 2016). The individual household returns will vary depending the number of children and household income, but the maximum level is about $1500.

## Model Description

We modify the Washington-Idaho computable general equilibrium (CGE) model originally developed by Holland et al. (2007). The model contains 530 industries combined into 11 sectors: agriculture, forestry, mining, utilities, fossil fuel, construction, food manufacturing, wholesale and retail trade, services, general manufacturing, and miscellaneous. To show consistency in how we aggregated the sectors, we compared the share of the sectors in the Washington State economy using the IMPLAN data versus data from the Bureau of Economic Analysis in Table 1. The sectoral compositions are very close between the two datasets indicating a reasonable baseline starting point. Some sectors produce output that are used as inputs in other sectors of the economy. For example, agricultural output is an input in the food processing and manufacturing sectors, and the forestry sector output is used as an input in the construction sector. Fossil fuel is a separate sector and is identified as an input in several important sectors such as agriculture, transportation, and utilities.

**Table 1. Comparing the Percentage Share of Each Sector Relative in the Washington State Economy using Data from IMPLAN versus the Bureau of Economic Analysis.**

| Industrial Sectors | Percentage Share of each sector using IMPLAN Data | Percentage Share of each sector using BEA DATA |
|---|---:|---:|
| Agriculture | 2.03 | 1.78 |
| Forestry | 0.16 | 0.00 |
| Construction | 3.99 | 3.82 |
| Utility | 1.32 | 0.86 |
| Fossil Fuel | 0.72 | NA |
| Wholesale and Retail Trade | 11.86 | 12.47 |
| Mining | 0.14 | 0.27 |
| Food Manufacturing | 1.01 | 2.79 |
| General Manufacturing | 11.50 | 10.70 |
| Services | 52.16 | 50.45 |
| Miscellaneous | 15.11 | 16.85 |

NA – not available because no explicit subcategory in BEA

In addition to a subset of the 11 commodity inputs, each sector employs labor and capital, which are substitutable across sectors. All other inputs are assumed to be perfect complements utilized in fixed proportions. The assumption of fixed proportions is a limitation of the model, as sectors are unable to change the ratio of their input uses when responding to policy changes, with the exception of labor and capital inputs. However, such a function is reasonable in the short run when adjustments are not easily made especially if transactions costs are significant when adopting new technology in the long run after the policy is implemented.

Domestic and international trade occurs in all sectors. All markets are perfectly competitive and prices and quantities adjust. This general equilibrium model allows us to examine the behavior of supply, demand, and prices in the state economy after allowing for a variety of shocks from the revenue-neutral carbon tax policy. Data from 2014 is used to initialize the model.

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. We impose a $0.14/gal tax and $0.24/gal tax on fossil fuels, in the first two years of the policy, respectively, which are equivalent to the $15/ton of carbon dioxide and $25/ton of carbon dioxide from fossil fuels in all sectors except agriculture.[4] In the agricultural sector, we impose $0.007/gal tax in the first year and a $0.01/gal tax in the second year, which are equivalent to $0.75/ton and $1.25/ton of carbon dioxide, respectively (OFM, 2016). To calculate the total carbon tax revenues generated by each sector, we multiply these tax rates by the amount of fossil fuel used in each sector after all the shocks have occurred.

Second, we reduce the sales tax collected from the consumer by 0.5% in the first year and then 1% in the second year.[5] From this change we are able to determine the aggregate loss in sales tax revenues but we are not able to see how each sector is directly affected by the sales tax rate reduction. To tease out the effect, we calculate the share of output of each sector to the total economy and multiply that share with the total decrease in sales tax revenue collected.

Third, we reduce the business and occupation tax for the manufacturing sector to 0.001%. We are able to determine the output levels before and after all shocks to the economy are implemented and we have approximate measures of the business tax rates in each sector. We calculate the change in business tax revenue collected in each sector given the change in output after the policy is implemented while assuming that the business tax rates stay the same in all sectors except the manufacturing sector.

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 (OFM, 2016). This serves as an income effect for those specific households.

Calibrated parameters remain fixed throughout the simulations, meaning that there is no technology change. While this may be an issue over a longer simulated horizon, we do not expect immediate technological changes over the first two years of the policy. Production functions are Leontief with respect to commodity inputs to production and CES with respect to labor and capital. The composite Leontief-CES functional form can be written a $q_i = \min_{z_{i1},z_{i2},\ldots,z_{i11}} \left\{ \frac{z_{i1}}{a_{i1}}, \frac{z_{i2}}{a_{i2}}, \ldots, \frac{z_{i11}}{a_{i11}} \right\} \times \left( \alpha_K K_i^{\rho} + (1-\alpha_K) L_i^{\rho} \right)^{1/\rho}$, where $q_i$ is the quantity produced by sector *i*, $\{z_{i1}, z_{i2}, \ldots, z_{i11}\}$ represents the input quantities from the eleven sectors employed by sector *i*, $K_i$ and $L_i$ are the respective quantities of capital and labor used in sector *i*, $\{a_{i1}, a_{i2}, \ldots, a_{i11}\}$ are technical coefficients parameterizing the Leontief component, $\alpha_K$ is the share parameter for capital in the CES component, and $\rho$ is a parameter in the elasticity of substitution between capital and labor, defined as $\sigma = 1/(1-\rho)$.

The utility function is Stone-Geary, which assumes a minimum level of expenditure on each good consumed, and results in a linear expenditure system. The functional form is given by $U = \prod_i (q_i - \lambda_i)^{\beta_i}$, where utility *U* is expressed as a function of the consumption of each good *i*, the subsistence level of each good $\lambda_i$, and share parameter $\beta_i$.

[4] To derive this value, we multiply $25/ton by the conversion rate from ton to kilogram (907.185 kg per ton) and multiply it by the amount of carbon emitted per gallon (8.9 kg/gal), i.e. $25/ton x 1 ton/907.185 kg x 8.9 kg/gal = $0.24/gal.

[5] Expenditures exempt from the sales tax reduction are net out proportionally from the service sector.

There are three main assumptions in the model. First, capital is mobile across sectors and aggregate supply of capital is variable. This allows for capital inflow from outside the state when tax rates change and it does not restrict aggregate capital within the state. Second, labor is mobile across sectors and there is no requirement for full employment. Finally, savings is based on the marginal propensity to save and not the autonomous level of consumption. We also allow international trade with a flexible exchange rate.

## Simulation Results

To determine if the model is correctly integrating the effects of the policy, we first examine each policy in isolation and then we examine the simultaneous implementation of all policies. Baseline quantities and prices for the sectors of interest are reported in the second column of Table 2. Columns three through five examine the sales tax reduction, business and occupation tax reduction, and carbon tax imposition in isolation, respectively, and column six examines the joint implementation of all policies. If only a 1% sales tax reduction is implemented, we find that the output in most sectors increase as expected. Three sectors, the forestry, general manufacturing and miscellaneous sectors, realized a slight decline in output. This could happen as the result of a strong substitution effect, wherein an increase in quantity demanded in one sector decreases the demand in either of the three other sectors. The isolated reduction in the business and occupation tax in the food and general manufacturing sectors led to an increase in output in both sectors, as expected. It also increased output in other sectors such as the service sector, and the retail and wholesale trade sector. This illustrates how the tax savings could be passed on to other sectors in the form of lower prices leading to more output. Finally, output generally declines in all sectors when a carbon tax is imposed, with the exemption of agriculture which does not face the full carbon tax rate. In general, sectors that are not dependent on fossil fuel see a rise in output while the more fossil fuel dependent sectors see a decrease in output. The overall price of all sectors rise mainly due to the increase in the price of fossil fuel. Figures 1 and 2 show the percentage changes in quantities and prices resulting from each component of the policy shock.

We summarized the effect of the policy on inflation in Table 3.[6] In year one, the increase in the price level caused just over a quarter of a point increase in the CPI, raising it from 100 to 100.26. In year two the CPI increased to 100.51. Looking at components of the CPI, fossil fuel prices rose the most, from 1 to 1.07 in year 1 and to 1.19 in year two. Utilities, mining, and construction saw the second, third, and forth largest increases in price respectively. In terms of percentage increases in the price level, the policy would likely generate a 0.3% increase in years one and two. Percent increases in the CPI nationally were 1.6% and .1% from 2013 to 2014 and from 2014 to 2015, respectively.[7] Relative to the national inflation, these price increases are minor.

Tables 4, 5, and 6 present sector-level decompositions of changes in tax revenue generation as a result of the simultaneous implementation of all policies pertaining to I-732. In Table 4, we present estimates of carbon tax generation for the first two years of the tax policy, decomposed by sector. Aggregate tax revenues rise from almost $1.2 billion in the first year to almost $2 billion in the second year. The rise is due to the increase in the carbon tax rate from $15/ton of

[6] Our baseline scenario represents our base year of 100. Weights for each commodity consumed by households were calculated as a percentage of total household commodity expenditures.

[7] This data was gathered from the Bureau of Labor Statistics March 2016 “CPI Detailed Report” and can be found in Table 24. http://www.bls.gov/cpi/cpid1603.pdf.

carbon dioxide to $25/ton of carbon dioxide. The fossil fuel sector provides the largest share of carbon revenues with 46% and 43% during the first two years, respectively. The household sector is the second largest contributor at about 20% followed by the service sector at about 15%. Since the household sector is dependent on transportation and the service sector includes transportation services, it is reasonable to find that they are the second and third leading provider of carbon revenues to the State. These three sectors account for almost 80% of carbon revenues. Even though the agricultural sector is a significant consumer of fossil fuel, its contribution to all carbon tax revenues is the smallest among the sectors because of its partial exemption in the beginning stages of the policy.

**Table 2. Output and Price Changes with the Introduction of the WA I-732 During the Second Year of the Policy.**

| Quantity (millions) | Base | Sales Tax Reduction | B&O Tax Reduction | Carbon Tax | Total |
|---|---|---|---|---|---|
| Agriculture | 12,505 | 12,672 | 12,512 | 12,515 | 12,686 |
| Forestry | 1,115 | 1,113 | 1,116 | 1,111 | 1,113 |
| Construction | 37,787 | 39,248 | 37,765 | 36,741 | 38,308 |
| Utility | 16,896 | 17,174 | 16,910 | 16,221 | 16,489 |
| Fossil fuel | 18,126 | 18,351 | 18,120 | 12,379 | 12,573 |
| Wholesale and retail Trade | 74,244 | 75,842 | 74,286 | 73,417 | 75,032 |
| Mining | 1,201 | 1,213 | 1,201 | 1,159 | 1,174 |
| Food manufacturing | 23,236 | 23,777 | 23,242 | 23,088 | 23,618 |
| General manufacturing | 140,029 | 139,674 | 140,173 | 139,316 | 139,333 |
| Services | 385,061 | 391,098 | 385,171 | 381,904 | 387,794 |
| Miscellaneous | 70,891 | 70,735 | 70,495 | 71,409 | 70,851 |
| **Price** | | | | | |
| Agriculture | 1 | 1.006 | 1 | 0.997 | 1.003 |
| Forestry | 1 | 1.005 | 1 | 0.998 | 1.003 |
| Construction | 1 | 1.005 | 1 | 1.001 | 1.006 |
| Utility | 1 | 1.007 | 1 | 1.009 | 1.016 |
| Fossil fuel | 1 | 1.005 | 1 | 1.114 | 1.12 |
| Wholesale and retail Trade | 1 | 1.004 | 1 | 0.997 | 1.002 |
| Mining | 1 | 1.007 | 1 | 1.006 | 1.013 |
| Food manufacturing | 1 | 1.006 | 1 | 0.998 | 1.004 |
| General manufacturing | 1 | 1.006 | 1 | 0.997 | 1.004 |
| Services | 1 | 1.005 | 1 | 0.997 | 1.003 |
| Miscellaneous | 1 | 1.002 | 1 | 0.999 | 1.001 |

Table 5 summarizes the reduction in aggregate sales tax revenues. In the first year with a half-percent reduction in sales tax, total sales tax is reduced by about $700 million. With a full one-percent reduction, the total reduction in sales tax revenue doubles to $1.4 billion. The elasticity of sales tax revenue from a reduction in the sales tax rate is equal to 0.91, which is close to the long-run elasticity of 0.93 for Washington State and well within the short-run elasticity range between 0.15 to 1.41 (Brown, 2002). The service sector is the largest beneficiary at about 18% of total sales tax savings followed by the manufacturing sector at 7% sales tax savings. Given the sizes of the other sectors in the economy, their sales tax savings are relatively small. Thus, we find that unlike the sectors contributing to the carbon tax revenues, the benefits from the sales tax reduction is relatively more evenly distributed across the sectors.

**Figure 1: Percent Change in Output with the Introduction of WA I-732 During the Second Year of the Policy.**

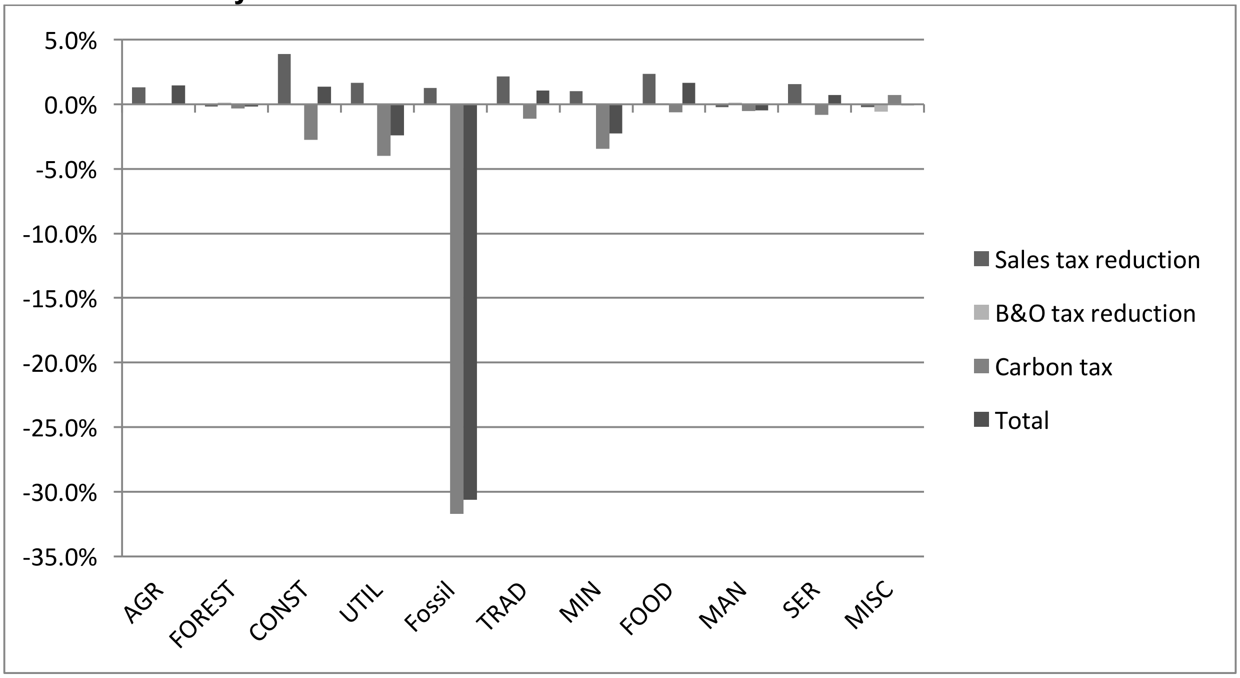


**Figure 2: Percent Change in Prices with the Introduction of WA I-732 During the Second Year of the Policy.**

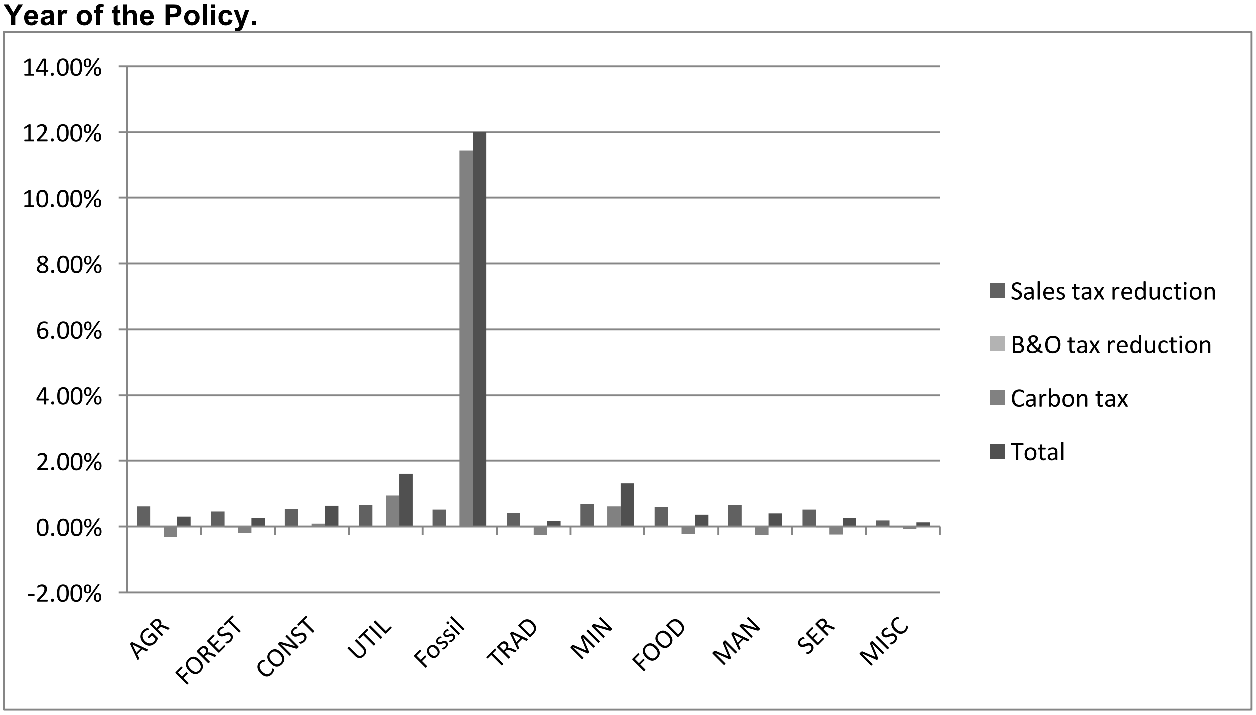

**Table 3. Price Changes, Commodity Weights, and Inflation Due to Policy Change.**

| Sector | Commodity weight | Year 1 | Year 2 |
|---|---|---|---|
| Agriculture | 0.01 | 1.0011 | 1.0030 |
| Forestry | 0.00 | 1.0010 | 1.0026 |
| Construction | 0.00 | 1.0033 | 1.0063 |
| Utility | 0.02 | 1.0090 | 1.0161 |
| Fossil fuel | 0.02 | 1.0719 | 1.1200 |
| Wholesale and retail trade | 0.12 | 1.0005 | 1.0017 |
| Mining | 0.00 | 1.0073 | 1.0132 |
| Food manufacturing | 0.05 | 1.0016 | 1.0036 |
| General manufacturing | 0.10 | 1.0018 | 1.0041 |
| Services | 0.62 | 1.0011 | 1.0027 |
| Miscellaneous | 0.06 | 1.0005 | 1.0012 |
| **Consumer Price Index** | | **100.26** | **100.52** |

**Table 4. Distribution of Carbon Tax Revenues by Sector in Millions of US$ (Base year 2014).**

| Sector | Year 1 | Year 2 |
|---|---|---|
| Agriculture | $0.40 | $0.84 |
| Forestry | $0.85 | $1.47 |
| Construction | $69.05 | $121.29 |
| Utility | $40.94 | $70.47 |
| Fossil fuel | $546.16 | $835.20 |
| Wholesale and retail trade | $11.91 | $20.87 |
| Mining | $5.19 | $8.96 |
| Food manufacturing | $4.71 | $8.27 |
| General manufacturing | $52.45 | $91.10 |
| Services | $170.98 | $299.08 |
| Miscellaneous | $54.88 | $95.72 |
| Household sector | $241.72 | $405.93 |
| **Aggregate carbon tax revenue** | **$1,199.25** | **$1,959.19** |

Note: During the same year (2014), aggregate tax revenue was approximately $17.75 billion. Therefore, during the first two years of the policy, the additional tax revenue translates to a 6.75% and 11.04% increase in tax revenues, respectively.

Table 6 summarizes the effect of the reduction in business and occupation tax in the manufacturing sector across all sectors. The direct effect of the policy is a reduction in the business and occupation tax in the manufacturing sector of approximately $682 million.[8] The amount of business and occupation tax paid by each sector is proportional to the value of its output, so changes in production and/or prices will influence business and occupation tax generation in a proportional manner. Taxes collected in the retail trade and services sectors increase by about $15 million each in the first year and about $35 million each in the second year. Other sectors see a decline in output and a resulting decline in the business and

[8] From our data, the initial B&O tax for the general manufacturing sector is approximately 0.44% while for food manufacturing it is relatively lower at 0.39%. We reduced both general and food manufacturing rates to 0.001%. This would mean that if the data starting points are larger than the amounts in reality, our numbers would be high especially if specific subsectors have B&O rates lower than 0.44%.

occupation tax such as the case of the utility and fossil fuel sectors. The change in business and occupation tax in the non-manufacturing sectors can be attributed to two effects. First, sectors purchasing from the manufacturing sector may see a decrease in cost if the business tax reduction in the manufacturing sector leads to a reduction in price in that sector. Second, the other shocks from the policy such as the sales tax reduction and Working Families Tax Rebate may drive overall demand for goods higher leading to more output and higher business tax revenues. We see a net reduction in tax collections stemming from the business tax reduction in the manufacturing sector of $671 million after accounting for changes in all other sectors.

**Table 5. Distribution of Sales Tax Revenue Savings by Sector in Millions of US$ (Base year 2014).**

| Sector | Year 1 | Year 2 |
|---|---|---|
| Agriculture | -$4.33 | -$8.77 |
| Forestry | -$0.38 | -$0.77 |
| Construction | -$13.05 | -$26.48 |
| Utility | -$5.71 | -$11.40 |
| Fossil fuel | -$4.92 | -$8.69 |
| Wholesale and retail trade | -$25.63 | -$51.87 |
| Mining | -$0.41 | -$0.81 |
| Food manufacturing | -$8.05 | -$16.33 |
| General manufacturing | -$48.04 | -$96.32 |
| Services | -$132.71 | -$268.07 |
| Miscellaneous | -$24.31 | -$48.98 |
| **Reduction in sales tax revenue** | **-$719.61** | **-$1,448.36** |

Note: During the same year (2014), total sales tax revenue was approximately $7.8 billion. Therefore, during the first two year of the policy, the reduction in sales tax revenue translates to a 10.84% and 18.57% drop, respectively.

The overall net effect of the policy is a reduction in revenues of about $349 million in the first year and $380 million in the second year. Note that in our model, a balanced budget constraint is imposed such that aggregate revenues equal aggregate spending. To meet the constraint, consumption spending and investment by the government is immediately reduced so that a deficit does not transpire.

Thus, our results suggest that the policy is not revenue neutral. In the first year of the policy, total carbon tax revenues are equal to $1.2 billion. The tax increase is used to cover a total sales tax reduction of $720 million and $671 million from the reduction in business and occupation tax as well as an allocation of $158 million to fund the Working Families Tax Rebate program. In the second year of the program, the net revenue reduction is similar because even though total carbon taxes reach almost $2 billion, the amount is not enough to cover the loss in sales tax revenue of $1.4 billion, the loss in business and occupation tax of $627 million and funding the Working Families Tax Rebate at $263 million. These shortfalls are covered by reductions in government investment spending.

**Table 6. Effect of Reduction in Business and Occupation Tax in the Manufacturing Sector in Millions of US$ (Base year 2014).**

| Sector | Year 1 | Year 2 |
|---|---|---|
| Agriculture | $0.27 | $0.51 |
| Forestry | $0.01 | $0.00 |
| Construction | $1.03 | $2.49 |
| Utility | -$2.80 | -$3.27 |
| Fossil Fuel | -$3.25 | -$4.72 |
| Wholesale and Retail Trade | $14.57 | $35.24 |
| Mining | -$0.03 | -$0.04 |
| Food Manufacturing | -$68.80 | -$68.56 |
| General Manufacturing | -$614.38 | -$614.38 |
| Services | $15.69 | $38.71 |
| Miscellaneous | $9.76 | $9.82 |
| **Reduction in B&O Revenue** | **-$671.15** | **-$627.66** |

The original estimates from Carbon WA, based on historic data, show a total tax swap of $1.7 billion (CarbonWA, 2015). By their estimates, in the second year of the policy carbon taxes are estimated to be $1.7 billion which are used to cover a $200 million loss in business and occupation tax revenues, a $1.3 billion in sales tax reduction and $263 million to fund the Working Families Tax Rebate program. Given their calculations, it is close to revenue neutral with only a $63 million deficit.

Our estimates are larger for all tax changes. Here, we derive about $300 million dollars more in carbon tax revenues but also about $100 million and $427 million more in sales tax reductions and business and occupation tax reductions, respectively. The main difference between our model and the CTAM used by CarbonWA is that in our analysis, we use a general equilibrium model that allows changes in prices and quantities in one sector to affect those in another sector of the economy. In our case we capture direct effects of the policy within a sector as well as spillover effects across sectors. If these spillover effects are significant, they can increase or negate in some instances the direct effects of a policy.

Given the average annual reduction of revenues of about $360 million, we calculated the potential changes in the carbon tax rate, sales tax rate or business and occupation tax rates needed to achieve revenue neutrality for the first two years of the policy and summarized the results in Table 7. In the first year, revenue neutrality can be achieved if a small change in the business and occupation tax is made by cutting it by half of the proposed level at a rate of 0.22% instead of effectively eliminating it altogether. By the second year, it will need to be raised slightly to 0.24% to achieve revenue neutrality. If sales tax is to be adjusted instead of the other policies, it would have to be lowered by 0.22% to only 6.28% instead of 6% in the first year, and in the second year lowered to 5.78% instead of 5.5% to achieve revenue neutrality. Another alternative would be to keep the scheduled changes in the sales and business tax rates but increase the carbon tax. In the first year it would need to be $20/ton instead of $15/ton while in the second year it would need to be $30/ton instead of $25/ton to achieve revenue-neutrality. Finally, one could also adjust the money given to the Working Families Tax Rebate where it would be smaller in lean years and larger in boom years. However, given our simulations, eliminating the Working Families Tax Rebate entirely would not fully achieve revenue neutrality.

**Table 7. Changes in Rates Needed to Achieve Revenue Neutrality.**

| | Carbon Tax | Sales Tax | B&O Tax | Family Tax Rebate |
|---|---|---|---|---|
| Year 1 | $15/ton | 6.000% | 0.220% | $157.74M |
| | $15/ton | 6.280% | 0.001% | $157.74M |
| | $20/ton | 6.000% | 0.001% | $157.74M |
| Year 2 | $25/ton | 5.500% | 0.242% | $262.899M |
| | $25/ton | 5.780% | 0.001% | $262.899M |
| | $30/ton | 5.500% | 0.001% | $262.899M |

Our analysis shows a reduction in government revenues. This is purely an accounting measure that does not give any indication if a policy is welfare improving or not. We calculate Washington State's Gross Domestic Product (GDP) and Green GDP before and after the policy to determine if it is welfare improving as shown in Table 8. Green GDP refers to GDP net of pollution damages from carbon dioxide emissions. Unsurprisingly, Green GDP is higher with the policy than without it. Pollution damages were reduced from $1.38 billion to $955 million. Interestingly, simple GDP also increases with the policy from $443 billion to $447 billion mainly due to growth of various sectors in the economy such as the service sector. Thus, based on these welfare metrics, such a policy is welfare improving as long as a balanced budget is achieved.

**Table 8. GDP and Green GDP Before and After Policy Implementation.**

| | GDP (mill) | Pollution Damages (mill) | Green GDP (mill) |
|---|---|---|---|
| Without policy | $443,391 | $1,376 | $442,015 |
| With policy | $447,268 | $955 | $446,313 |

Note: Calculations for GDP using the income approach.

Lastly we check the effect of the policy on welfare across different household income brackets, with the results shown in Table 9. Based on equivalent variation and utility measures, most income brackets see a rise in welfare. The majority of gains were seen by the lowest and highest income categories. The general rise in welfare can be attributed to the decline in sales tax and increase in purchasing power. Since the high income group consumes the most, this income group receives a relatively high increase in income. The gain by the lowest income bracket can be attributed to the reallocation of some funding from carbon taxes towards the Working Families Tax Rebate. Given their relatively low starting consumption point, the redistribution to the lowest income bracket yields the largest marginal gain. This also illustrates the importance of the Working Families Tax Rebate program in offsetting any negative impacts from the carbon tax. Without such a policy, the lowest income brackets sees a reduction in equivalent variation during the first year.

## Conclusion

This publication examines the effect of a revenue-neutral carbon tax, or Washington State Initiative 732, on different sectors in Washington State using a computable general equilibrium model. The fossil fuel sector, household sector and service sector are the largest contributors to the carbon tax revenues since they contribute, in aggregate, about 80% of total carbon taxes. The benefits from the sales tax reduction are relatively more spread across our sectors with the service sector benefiting the most at 18%. The business and occupation tax reduction in the manufacturing sector also benefits other sectors that use their output in their production process. Finally, we do find a revenue reduction of about $349 million and $380 million in the first two years of the policy respectively.

**Table 9. Household Surplus and Percentage Change in Utility by Year and Income Level.**

| Income Category | Equivalent Variation Year 1 | Equivalent Variation Year 2 | % Change In Utility Year 1 | % Change In Utility Year 2 |
|---|---|---|---|---|
| <$10k | 161.46 | 271.18 | 29.6% | 49.3% |
| $10-$15k | (0.03) | 1.75 | 0.0% | 0.6% |
| $15-$25k | 2.25 | 14.93 | 0.2% | 1.3% |
| $25-$35k | 3.24 | 25.33 | 0.3% | 1.8% |
| $35-$50k | 3.65 | 49.76 | 0.2% | 2.2% |
| $50-$75k | 13.15 | 119.59 | 0.4% | 2.7% |
| $75-$100k | 15.66 | 119.84 | 0.5% | 3.1% |
| $100-$150k | 35.11 | 201.32 | 0.7% | 3.5% |
| >$150k | 46.90 | 228.60 | 0.8% | 3.8% |

Even with a reduction in revenues, we find that GDP net of pollution damages and GDP itself increases with the policy which indicates that the policy is welfare improving based on this metric as long as a balanced budget is achieved. Welfare across most household income brackets increases after the policy but the lowest income brackets are most vulnerable which implies that the Working Families Tax Rebate is critical.

Even though we benefit by using a computable general equilibrium to capture the spillover effects across sectors, our model also has three important limitations. The first limitation is the assumption of perfect complements between non-labor and non-capital inputs. This implies that when we raise the tax on fossil fuel, fossil fuel use, along with all other inputs aside from labor and capital will also decrease proportionally. There is no possibility for substitution towards other fossil fuel substitutes. The Leontief production function could lead to larger decreases in output compared to the case where some substitutability between inputs could occur. This, in turn, could lead to an overestimate of our loss in sales tax revenue and business tax revenue since they are both based on equilibrium output adjustment. Also, we may underestimate the reduction in fossil fuel use if there are alternative substitutes for fossil fuel which implies that our carbon tax revenue estimates may be overestimated.

The second limitation is that we cannot disaggregate the individual business and operating tax for all subsectors of the manufacturing sector. We use the average business and operating tax rate of the sector from our available data. There are some subsectors within manufacturing that face a lower tax rate than our baseline estimate. We may overestimate the lost business tax revenues when reducing the business and operating tax rate for the manufacturing sector.

The third limitation is that all parameters in the model remain fixed which hinders us from conducting any long run analysis. If firms adjust behavior by investing in technology that is less fossil fuel intensive we would expect fossil fuel use to decline in the long run leading to lower carbon tax revenues. If the adoption of less fossil fuel intensive technology is slow, it is likely to lead to revenue-neutrality and even a slight surplus in the medium to long run. However, if there is rapid adoption of less fossil fuel intensive technology, carbon tax revenues may severely drop and lead to a larger reduction in revenues. Without any information regarding future technological progress regarding the substitutes for fossil fuel and the willingness of various sectors to adopt such technology, it is difficult to forecast the long run policy effects. Therefore, there should also be some flexibility in the other aspects of the policy (i.e. re-raising the sales tax or business tax) if shortfalls ever occur.

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# How Does Washington State Initiative 732 Impact the Agriculture and Forestry Sectors?[1]

**Gregmar I. Galinato, Timothy Nadreau, and Tristan D. Skolrud**[2]

## Introduction

Carbon Washington (CarbonWA), a lobby group in Washington State, is currently proposing a revenue-neutral carbon tax called Washington State Initiative 732 (I-732).[3] The objective of the policy is to incentivize adoption of cleaner fuel sources and reduce market inefficiencies that arise through the use of distortionary taxes (CarbonWA, 2015). In general, a revenue-neutral tax instrument has the potential to simultaneously increase aggregate social welfare and boost growth in a renewable fuel industry (Skolrud and Galinato, 2015). The specific revenue-neutral tax policy proposed by CarbonWA is phased into the economy at different rates depending on the sector, leading to differential impacts across sectors, especially in those that can be used as feedstocks in the renewable fuel industry.

The focus of this research is analyzing the impact of the revenue-neutral tax on two sectors with strong significance to the Washington State economy, the agricultural and forestry sectors. The agricultural and forestry sectors are important contributors to Washington State's economy. Combined, they account for over $10 billion in output annually (NASS, 2013; Smith, 2012). They are also important contributors to two related sectors: the general and food manufacturing sectors, which have an annual output of $1.5 billion dollars and account for 100,000 jobs (Brady and Taylor, 2010). These two sectors in Washington State have been identified as significant sources of cellulosic feedstocks, which can be refined to produce advanced biofuels with a much lower carbon footprint than fuel refined from crude oil (Yoder et al. 2010). As the carbon tax increases and the demand for low-carbon fuel increases, we eventually expect an increase in demand for agricultural and forestry output.

This study determines the effect of the proposed revenue-neutral-carbon tax, as outlined in I-732, on output, prices, input use, employment and carbon dioxide emissions in the agricultural and forestry sectors in Washington State during the first two years of policy implementation. We utilize a computable general equilibrium (CGE) model that has 11 primary industrial sectors and allows for endogenous changes in prices and output production. The results of the study not only forecast sector-specific policy effects but may also point to policy prescriptions that may help ameliorate negative effects and enhance positive effects. This study also speaks to the potential effectiveness of such a policy in boosting or shrinking a renewable fuels sector in Washington State currently in its infancy.

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[3] For more information, visit www.yeson732.org.

I-732 has four direct policy effects. The first is a tax of $25 per metric ton (MT) of carbon dioxide emitted from the use of fossil fuels in the state of Washington. Farm diesel and public transportation are exempt from the full amount in the first 40 years of the policy, facing instead a gradually increasing carbon tax schedule. The second policy effect is a 1% reduction in sales tax, from 6.5% to 5.5%. The third effect is a reduction in business and occupation tax in the manufacturing sector from 0.484% to 0.001%, effectively removing the tax in that sector. Finally, the revenues from the carbon tax fund the state's Working Families Tax Rebate policy which allows for a tax rebate of up to $1,500 per year for low-income families (CarbonWA, 2015).

The proposed tax policy is considered revenue neutral because the revenues raised by the carbon tax are used to offset losses from sales and business tax reductions and to fund the tax rebate for low-income families. In requiring less revenue from distortionary taxes such as sales, income and/or business taxes, and gaining more tax revenue from taxes that correct market failure such as carbon taxes, a "double-dividend" may be achieved in the economy (Pearce, 1991; Parry, 1995). The first dividend occurs through the reduction of pollution to an efficient level, and the second dividend results from a reduction in deadweight loss or market inefficiency in a market where an existing distortionary tax is reduced.

We examine the effect of the policy on the agricultural and forestry sectors directly after the two-year initial phase-in period, when the carbon tax reaches a level of $25/ton of emitted carbon and the agricultural sector is still exempt from paying the majority of the carbon tax. Based on the specific targets of I-732, we hypothesize three direct effects in the agricultural and forest sectors from each policy change. In the second year of the policy, the partial exemption results in the agricultural sector paying just 5% of the tax borne by other sectors. We anticipate a negative impact on the value of output due to the increase in the price of fossil fuel from the carbon tax alone but it will affect the forest sector more than the agricultural sector because it is not exempt. The sales tax reduction may lead to a marginal change in the consumption mix of consumers away from products that rely heavily on fossil fuel towards other goods. Because the agricultural sector faces a comparatively lower tax rate, we expect a smaller change in the output price of agricultural goods compared to goods from other sectors, which may precipitate a shift towards agricultural good consumption. From the farmer's perspective, there may also be an increase in capital investment given this reduction in sales tax. A business tax reduction in the manufacturing sector does not directly affect the agricultural and forest sector but there might be an indirect impact. For example, equipment manufacturers may pass on their reduced cost of production to firms in the agricultural and forest sector. Finally, transfers to low-income families may increase welfare for eligible employees in the agricultural and forest sector. We turn to a CGE model for Washington State to measure all the welfare effects and test the hypotheses of the impacts of the carbon revenue-neutral tax.

## Timeline and Policy Specifics of I-732

The impact of the policies outlined in I-732 are not immediate but come in various phases as outlined in Table 1. We focus our analysis during the first two years of the proposal. The carbon tax will be $15 per ton in the first year before rising to $25 per ton in the second year. After the second year, the carbon tax rate rises by 3.5% plus the rate of inflation. This is to account for the predicted carbon tax revenue drop as fossil fuel related emissions decline. The carbon tax will be capped at $100/ton which is expected to occur after more than 40 years (CarbonWA, 2015). Farm diesel and public transportation are partially exempt during the first 40 years of the policy which means they do not face the full carbon tax value. Instead, they face a rising carbon tax rate that will converge toward the level imposed on the rest of the economy by year 40 (OFM, 2016). Table 2 summarizes the exemption rates for farm diesel and public transportation.

**Table 1. Stages During the Implementation of I-732.**

| Timeline | Phase – in and adjustments | Exemption |
|---|---|---|
| Year 1 | Carbon Tax: $15/ton,<br>Sales Tax: 0.5% reduction to 6%<br>Business tax in the manufacturing sectors: 0.439% reduction to 0.001% | Farm Diesel and Public transportation |
| Year 2 | Carbon Tax: $25/ton year<br>Sales Tax: 1% reduction to 5.5%<br>Business tax in the manufacturing sectors: 0.439% reduction to 0.001% | Farm Diesel and Public transportation |
| Year 3 - 40 | Increase in carbon tax by 3.5% annually plus inflation rate | Farm Diesel and Public transportation |
| After year 40 | Increase in carbon tax by 3.5% annually plus inflation rate until $100/ton is reached | None |

The full implementation of the sales tax reduction occurs in the second year of the policy. The sales tax will reduce by 0.5% in the first year leading to a 6% sales tax rate. During the second year of the proposal, the sales tax rate will be reduced again by 0.5% leading to a 5.5% sales tax rate which will be implemented in the succeeding years. On the other hand, the business tax reduction from approximately 0.484% to 0.001% in the manufacturing sector occurs immediately in the first year (CarbonWA, 2015).

Funding the Working Families Tax Rebate is based on a proposed schedule by the lobby group CarbonWA. In the first year of the policy, when the carbon tax rate is only $15/ton, the total funds from the carbon revenues allotted to the Working Families Tax Rebate is $157.74 million. Once the carbon tax rate is $25/ton, total funds allotted to the Working Families Tax Rebate is $262.90 million. During the subsequent years, annual funding will be in the range of $279 million to $296 million (OFM, 2016).

## Model

We modify the Washington-Idaho CGE model originally developed by Holland et al. (2007). The model allows us to examine the behavior of producers and consumers given a variety of shocks related to the revenue-neutral carbon tax policy to determine output and price changes in various sectors of the economy.

We use 2014 data from IMPLAN. It contains approximately 530 industry categories. These categories are then aggregated into 11 distinct industries: Agriculture, Forestry, Mining, Utilities, Fossil fuel, Construction, Food manufacturing, Wholesale and retail trade, Services, General Manufacturing, and Miscellaneous. We primarily focus on agriculture and forestry but to allow for a general equilibrium relationship, we include all other sectors in the state economy. Some sectors produce output that are used as inputs in other sectors of the economy. For example, agricultural output is an input in the food manufacturing and general manufacturing sectors, and the forestry sector output is used as an input in the construction sector. We allow for domestic and international trade in all sectors. Fossil fuel is identified as an input in several important sectors such as agriculture, transportation, and energy. All markets are perfectly competitive and prices and quantities adjust. The model also contains sales and business tax rates.

In addition to the 11 commodity inputs each sector employs labor and capital, which are substitutable across sectors. Labor and capital are substitutable but all other inputs are assumed to be perfect complements utilized in fixed proportions. The assumption of fixed proportions is a limitation of our model, as sectors are unable to change the ratio of their input uses when responding to policy changes, with the exception of labor and capital inputs. Unfortunately, this assumption is required for our computations to be tractable.

**Table 2. Carbon Tax Rates in the Agricultural Sector During the Exemption Period.**

| Year | General Carbon Tax Constant 2016 Dollars | Agricultural, and Public Transit Carbon Tax % of General | Agricultural, and Public Transit Carbon Tax Constant 2016 Dollars | Year | General Carbon Tax Constant 2016 Dollars | Agricultural, and Public Transit Carbon Tax % of General | Agricultural, and Public Transit Carbon Tax Constant 2016 Dollars |
|---|---|---|---|---|---|---|---|
| 1 | $ - | - | $ - | 21 | $46 | 50% | $23 |
| 2 | $15 | 5% | $0.75 | 22 | $48 | 55% | $26 |
| 3 | $25 | 5% | $1.25 | 23 | $50 | 55% | $27 |
| 4 | $26 | 10% | $3 | 24 | $51 | 60% | $31 |
| 5 | $27 | 10% | $3 | 25 | $53 | 60% | $32 |
| 6 | $28 | 15% | $4 | 26 | $55 | 65% | $36 |
| 7 | $29 | 15% | $4 | 27 | $57 | 65% | $37 |
| 8 | $30 | 20% | $6 | 28 | $59 | 70% | $41 |
| 9 | $31 | 20% | $6 | 29 | $61 | 70% | $43 |
| 10 | $32 | 25% | $8 | 30 | $63 | 75% | $47 |
| 11 | $33 | 25% | $8 | 31 | $66 | 75% | $49 |
| 12 | $34 | 30% | $10 | 32 | $68 | 80% | $54 |
| 13 | $35 | 30% | $11 | 33 | $70 | 80% | $56 |
| 14 | $36 | 35% | $13 | 34 | $73 | 85% | $62 |
| 15 | $38 | 35% | $13 | 35 | $75 | 85% | $64 |
| 16 | $39 | 40% | $16 | 36 | $78 | 90% | $70 |
| 17 | $40 | 40% | $16 | 37 | $81 | 90% | $72 |
| 18 | $42 | 45% | $19 | 38 | $83 | 95% | $79 |
| 19 | $43 | 45% | $20 | 39 | $86 | 95% | $82 |
| 20 | $45 | 50% | $22 | 40 | $89 | 100% | $89 |

Source: OFM (2016)

We incorporate four significant changes to the original Holland et al. (2007) model to assess the effect of the revenue-neutral carbon tax policy during the first two years of the policy. First, we impose a $0.24/gal tax on fossil fuels, which is equivalent to the $25/ton of carbon from fossil fuels, in all sectors that use the input except agriculture.[4] In the first year of the policy when the carbon tax is $15/ton, we impose a $0.14/gal tax on fossil fuels. In the agricultural sector, we instead impose a $0.01/gal tax which is equivalent to the $1.25/ton of carbon in the second year. Second, we reduce the sales tax by half a percent in the first year and 1% in the second year. Third, we reduce the business tax for the manufacturing sector from 0.484% to 0.001% in

[4] To derive this value, we multiply $25/ton by the conversion rate from ton to kilogram (907.185 kg per ton) and multiply it by the amount of carbon emitted per gallon (8.9 kg/gal), i.e. $25/ton x 1 ton/907.185 kg x 8.9 kg/gal = $0.24/gal,

both years. Finally, we treat the expenditures that fund the Working Families Tax Rebate program as a lump sum payment to the lowest income bracket.

There are three main assumptions in the model. First, given the open economy nature of the model, capital is mobile across sectors and aggregate supply of capital is variable. This allows for capital inflow from outside the state when tax rates change and it does not restrict aggregate capital within the state. Second, labor is mobile across sectors and there is no requirement for full employment. Finally, savings is based on the marginal propensity to save and not the autonomous level of consumption. Note that we also allow international trade in the model to examine how the policy affects agricultural exports and assume a flexible exchange rate.

## Results

To test the validity of the model, we introduce each shock separately and examine if the direction of changes to the agricultural and forestry sectors are as predicted. Then, we introduce all shocks simultaneously to analyze the net effect.

Table 3 shows the effect of each individual shock (sales tax reduction, business tax reduction, and carbon tax imposition) along with the simultaneous effect of all shocks in the agricultural sector during the first two years of the policy. Figures 1 and 2 show the percentage changes in output, exports and fossil fuel use in each year. We find that the value of agricultural output increases by 0.94% after the first year and 1.77% in the second year. The impact of just the carbon tax in the agricultural sector leads to a reduction in value by 0.08% and 0.24% in the first two years of the policy, respectively. This is mainly due to a decrease in fossil fuel expenditures by 32%. However, this negative impact is offset by the reduction in sales tax which increases the value of agricultural output by almost 2% in the second year. This may be due to an influx in both labor and capital into the agricultural sector since the cost of these inputs decline from a reduction in sales tax.

During the second year of the policy, the value of output increases because of a rise in domestic output by 1.44% and an increase in price by 0.30%. Not all output is consumed in-state because approximately 61% is exported. The net effect of the policy is a minimal increase in exports by 1.45%. Since world prices are not affected by the policy and the value of domestic production increases by only 1.77%, we expect such a small positive impact on exports.

The direction of change in the agricultural sector is similar to the forestry sector but the net effects are not as large as shown in Table 4 and Figures 3 and 4. The aggregate value of output increases by 0.19% in the first year and 0.13% in the second year due to the price rising in the sector. The increase is primarily driven by the inflow of labor and capital into the sector due to the reduction in sales tax. The overall growth in the sector after the policy is smaller compared to the agricultural sector because the forestry sector is not exempt from the fossil fuel tax. The fossil fuel tax alone reduces the value of output in the forestry sector by 0.26% in the first year which is three times larger in reduction compared to the agricultural sector during the same time period. In the second year, the fossil fuel tax alone reduces the value of output by 0.55% which is more than double the case of agriculture during the second year.

**Table 3. Effect of I-732 on the Agricultural Sector.**

| | Base (Year 0) | Sales tax reduction | B&O tax reduction | Carbon tax | Total | Total difference from base |
|---|---|---|---|---|---|---|
| Year 1 | | | | | | |
| Value of output (mill) | $12,505 | $12,629 | $12,511 | $12,495 | $12,623 | $117 |
| Quantity of domestic output | $12,505 | $12,589 | $12,511 | $12,519 | $12,607 | $101 |
| Quantity of exports | $7,625 | $7,668 | $7,630 | $7,643 | $7,690 | $65 |
| Output price | $1 | $1 | $1 | $1 | $1 | $0 |
| Fossil fuel expenditures (mill) | $195 | $196 | $195 | $195 | $197 | $2 |
| Year 2 | | | | | | |
| Value of output (mill) | $12,505 | $12,753 | $12,512 | $12,475 | $12,727 | $222 |
| Quantity of domestic output | $12,505 | $12,672 | $12,512 | $12,515 | $12,686 | $180 |
| Quantity of exports | $7,625 | $7,711 | $7,630 | $7,646 | $7,736 | $111 |
| Output price | $1 | $1 | $1 | $1 | $1 | $0 |
| Fossil fuel expenditures (mill) | $195 | $198 | $195 | $195 | $198 | $3 |

***Figure 1. Year 1 Percent Changes in Agricultural Measures Relative to the Base Year.***

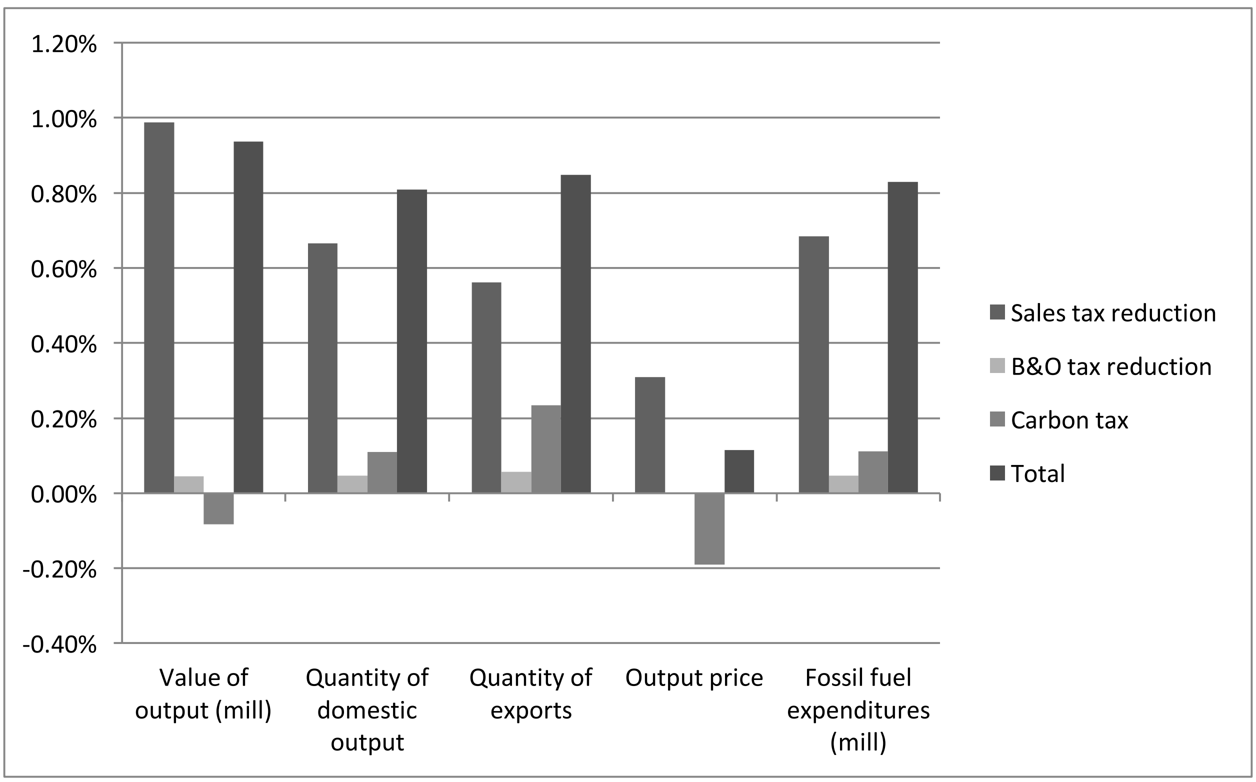
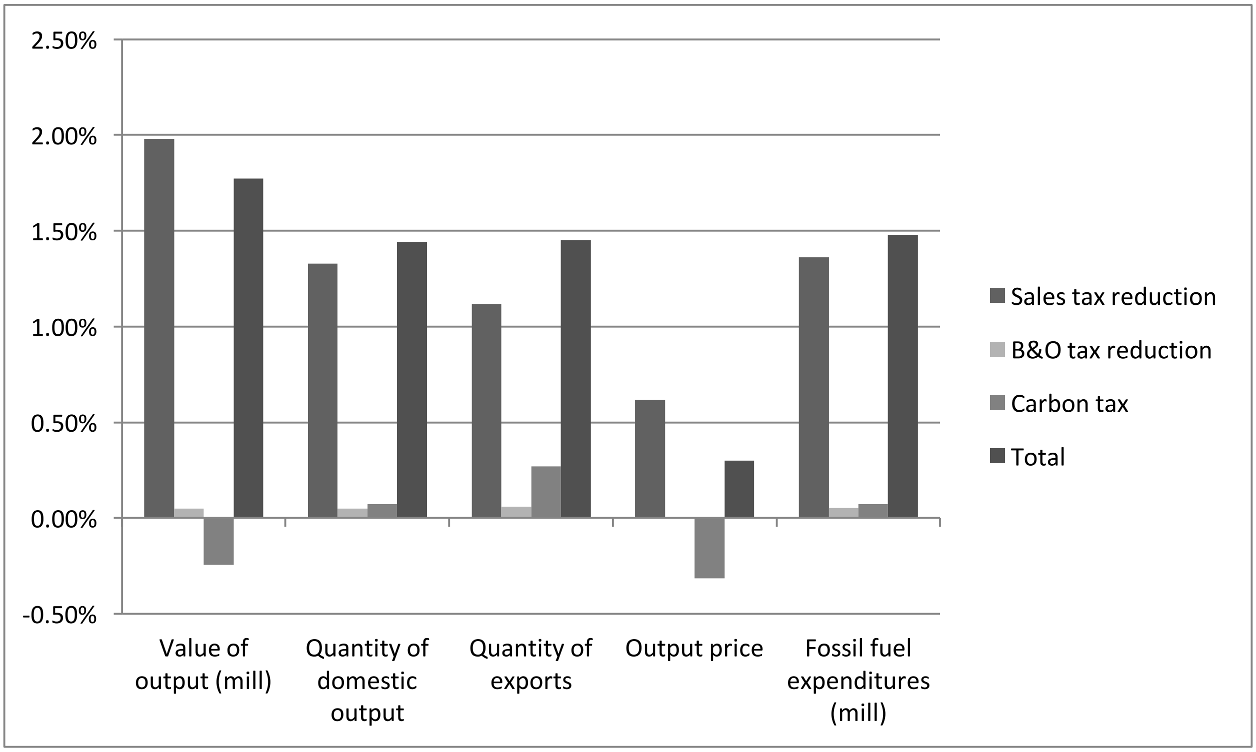


***Figure 2. Year 2 Percent Changes in Agricultural Measures Relative to the Base Year.***




Approximately 42% of products from the forestry sector are exported. During the first year of the policy, forestry exports increased by 0.14%. However, by the second year of the policy, exports decline by 0.03% which is primarily due to a 0.19% decline in domestic output. The decline in output during the second year occurs because the forestry sector faces the full $25/ton of carbon unlike the agricultural sector. Therefore, we find that sectors in the economy can grow after the full policy is implemented even if they are not exempt from the carbon tax. These sectors that benefit from the revenue-neutral tax policy are likely labor and capital intensive and have relatively little fossil fuel expenditures compared to other inputs in production.

Even with the carbon tax exemption, the agricultural sector does see a reduction in fuel use after the implementation of the policy as shown in Table 5. This corresponds to a 9% drop in carbon dioxide emissions from that sector. Since the forestry sector faces the full carbon tax rate, the percentage drop in fuel and reduction in carbon dioxide emission level is higher at 11%.

**Table 4. Effect of I-732 on the Forestry Sector.**

| | Base (Year 0) | Sales tax reduction | B&O tax reduction | Carbon tax | Total | Total difference from base |
|---|---|---|---|---|---|---|
| Year 1 | | | | | | |
| Value of output (mill) | $1,115 | $1,117 | $1,116 | $1,112 | $1,117 | $2 |
| Quantity of domestic output | $1,115 | $1,114 | $1,116 | $1,113 | $1,115 | $1 |
| Quantity of exports | $472 | $472 | $473 | $471 | $473 | $1 |
| Output price | $1 | $1 | $1 | $1 | $1 | $0 |
| Fossil fuel expenditures (mill) | $17 | $17 | $17 | $17 | $17 | $0 |
| Year 2 | | | | | | |
| Value of output (mill) | $1,115 | $1,119 | $1,116 | $1,108 | $1,116 | $1 |
| Quantity of domestic output | $1,115 | $1,113 | $1,116 | $1,111 | $1,113 | -$2 |
| Quantity of exports | $472 | $472 | $473 | $470 | $472 | $0 |
| Output price | $1 | $1 | $1 | $1 | $1 | $0 |
| Fossil fuel expenditures (mill) | $17 | $17 | $17 | $17 | $17 | $0 |

***Figure 3. Year 1 Percent Changes in Forestry Measures Relative to the Base Year.***

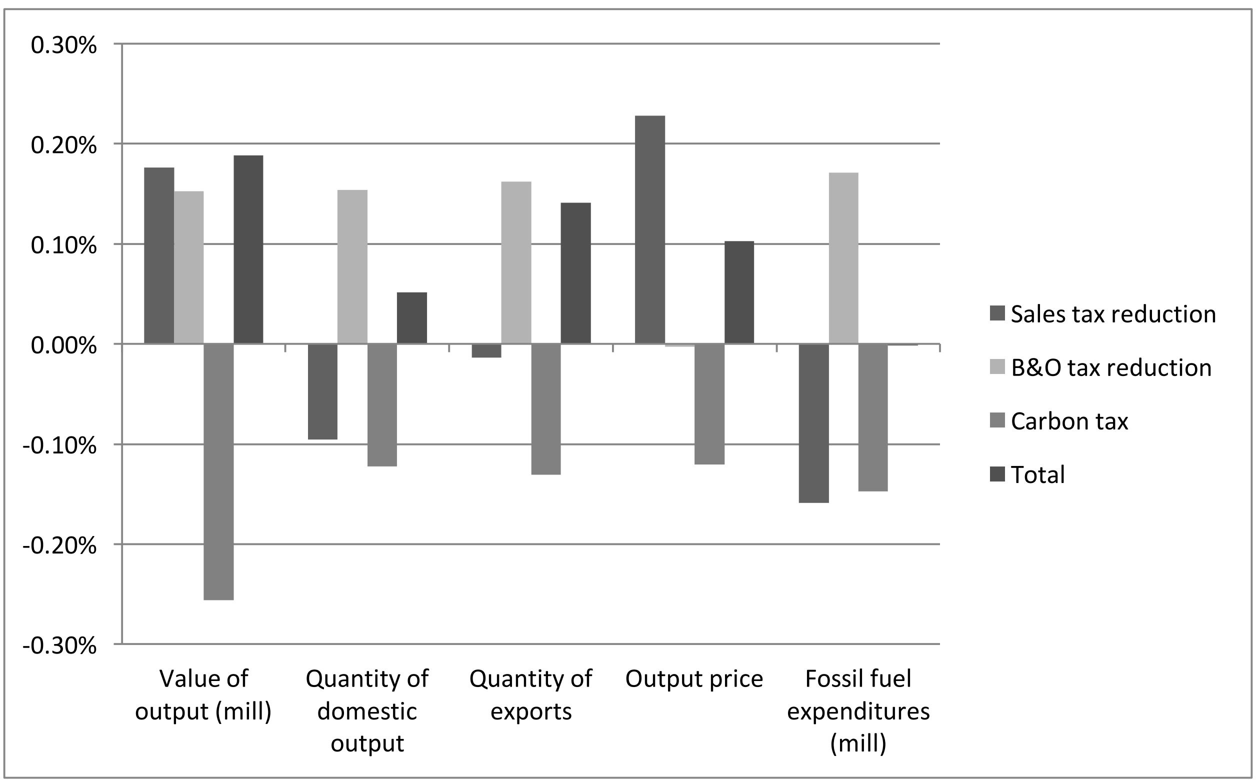
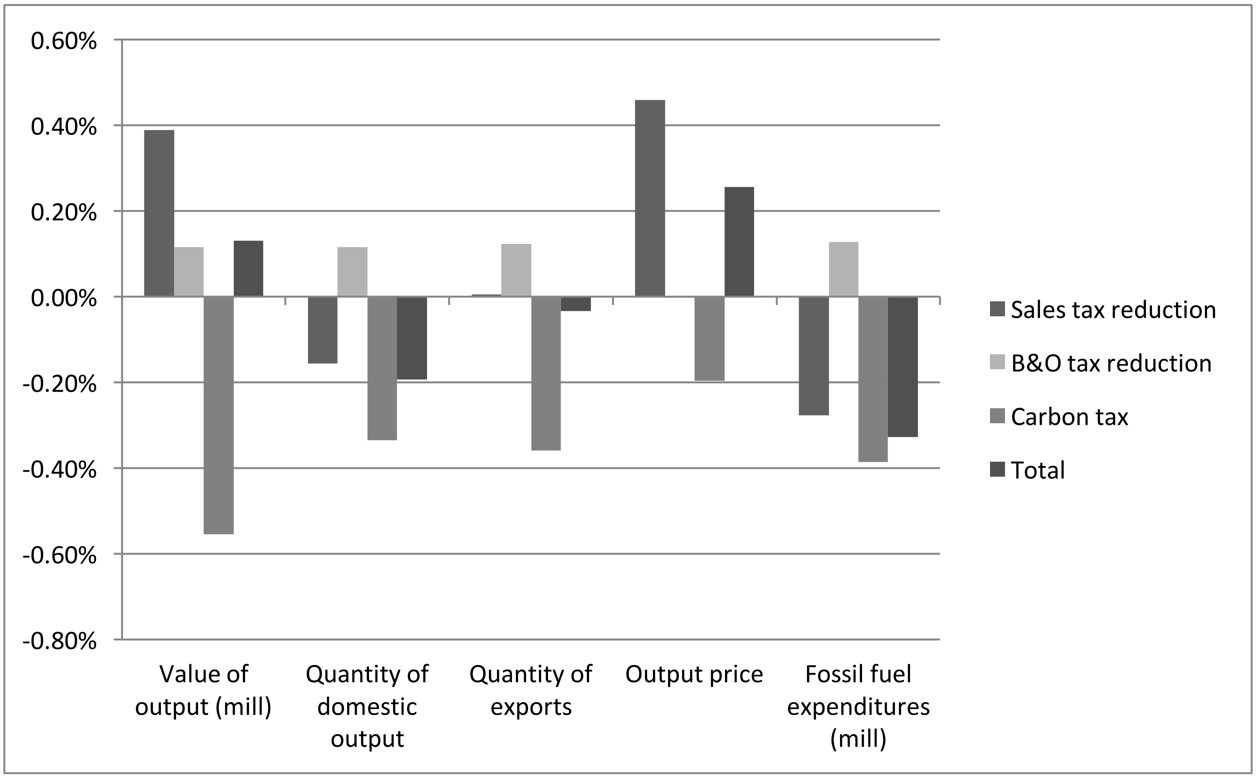


***Figure 4. Year 2 Percent Changes in Forestry Measures Relative to the Base Year***




We also find differential effects of agricultural product consumption across household income brackets as shown in Table 6.[5] The biggest gains in consumption based on output levels are from the higher income brackets. As we go to the lower income brackets, the consumption gains become smaller but as we reach the lowest income bracket, the consumption of agricultural production actually rises. We attribute this increase in consumption by the lowest income households to the state subsidies received by these households from the Working Families Tax Rebate program. The lowest income bracket sees the largest percentage increase in agricultural consumption. It has resulted in an increase in agricultural consumption by 2.6% and 4.5% in the first two years respectively. For all other income brackets, the increase in agricultural consumption is 0.4% in the first year and 0.8% to 1% in the second year.

**Table 5. Change in Fossil Fuel Use and Carbon Dioxide Emissions.**

| | Fossil fuels (gallons) | | Emissions (MT) | |
|---|---|---|---|---|
| | Before | After | Before | After |
| Agriculture | 60,454,193 | 54,714,528 | 593,090 | 536,781 |
| Forestry | 5,373,854 | 4,784,914 | 52,721 | 46,943 |

[5] We do not show this data for the forestry sector because households in the IMPLAN data do not directly purchase from this sector. Instead, they are used in inputs for other items consumed by households such as the construction sector or agricultural sector.

**Table 6. Household Agricultural ($ million) Consumption by Income Category and Year**

| Income Level | Baseline | Year 1 | Year 2 |
|---|---|---|---|
| <$10k | $45.03 | $46.22 | $47.06 |
| $10-$15k | $30.18 | $30.30 | $30.41 |
| $15-$25k | $83.70 | $84.04 | $84.38 |
| $25-$35k | $97.70 | $98.11 | $98.54 |
| $35-$50k | $160.00 | $160.68 | $161.48 |
| $50-$75k | $282.97 | $284.20 | $285.77 |
| $75-$100k | $249.49 | $250.58 | $252.01 |
| $100-$150k | $339.70 | $341.18 | $343.18 |
| $150k+ | $319.25 | $320.58 | $322.44 |

## Discussion and Summary

This study analyzed the effect of the revenue-neutral carbon tax suggested by I–732 on the agricultural and forestry sectors of Washington State. We find that the value of output in the agricultural and forestry sectors rise by 1.77% and 0.13%, respectively, during the second year of the policy. Our simulations are constructed to evaluate the effects of I–732 during the first two years of the policy, when the carbon tax reaches $25/ton, the sales and business taxes are reduced, and the agricultural sector is subjected to a partial exemption from the carbon tax. Exports rise by 1.45% in the agricultural sector while the forestry sector show a decrease by 0.03%. Average household consumption of agricultural products increases, with the high income and lowest income households seeing the largest increases in consumption. We find that as long as a sector does not have a large expenditure share of fossil fuel in their production of a good, they may see an increase in growth after the implementation of the policy even without any exemptions as shown in the case of the forestry sector.

Overall, the agricultural sector will see a modest gain in year 2. As the fossil fuel tax rises over time, the increase in value of output will be lower, holding all other factors such as technological development constant. When the carbon tax is fully implemented in the agricultural sector, its impact will vary greatly depending on the extent to which the sector substitutes to technologies that requires less carbon. In this regard, the agricultural sector has a significant advantage compared to the other sectors in the economy, which will have to substitute to less carbon-intensive technologies while continuing to pay the full-amount of the carbon tax.

The effect of the carbon tax on the value of output in the forestry sector is slightly more significant than the agricultural sector, mainly due to the sector's lack of a partial carbon tax exemption. This has interesting repercussions to the cellulosic biofuel sector currently in its infancy. As carbon-intensive inputs become more expensive across the state, the demand for low-carbon energy alternatives, such as advanced biofuels sourced from agricultural and forestry sectors, will likely increase. Our analysis indicates that the initial impact from the revenue-neutral carbon tax will be minimal on these sectors, and may eventually lead to expansions as cellulosic feedstock refining technology improves.

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# WSU CGE Analysis of Carbon WA: Technical Documentation[1]

**Timothy P. Nadreau**[2]

## 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. Washington State Initiative 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.

## 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 section. 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.

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.

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

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***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 determines 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 indicates 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, which implies 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 section. Fewer input payments for production results in less output being produced.[3]

**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[4] (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.

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[3] We hold fixed 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.

[4] 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.

**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.

**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[5]. The investment sector operates quite differently from the other Institutions. Households, governments, and commodities[6] 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.In this model, 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.

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

[6] 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 in the agricultural industry paid for their fuel commodity i.e.,

$$tb_2(\text{`}AGR - A\text{'}, \text{'}Fossil - C\text{'}) = \$1/\text{MT } C0_2$$

That is to say farmers, in year two, would pay an additional dollar per metric ton of carbon emissions from their fuel consumption.[7]

## 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.

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

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

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.[8]

***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[9]. 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[10].

**Table 2: 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(C) | Sales tax rate | 0 |
| tc(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 |

[8] 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.

[9] 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.

[10] The WA-ID CGE documentation may be found at

http://www.agribusiness-mgmt.wsu.edu/Holland_model/docs/DocumentationR.pdf

| | | |
|---|---|---|
| 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: Endogenous 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: Endogenous 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: Endogenous 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 section 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. This data identifies 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 household purchases of commodities (table 8) and the volume of each commodity used by each industry in there production process (table 9).

**Table 8: 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, $CPI \cdot \sum_T SAM_{H,T}$ . Gross household income is,

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

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, and transfer payments, 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[11].

**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, $\lambda_i$, 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 $tc_{H,C}$[12] 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

[11] 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.

[12] Because this variable differs from the original model the average tax for all households is used.

go down. Thus the Leontief-CES production function is $q_i = \min\left(\frac{z_{i1}}{a_{i1}}, \frac{z_{i2}}{a_{i2}}, \ldots \frac{z_{i11}}{a_{i11}}\right) * (\alpha_i {K_i}^{\rho_i} + (1-\alpha_i){L_i}^{\rho_i})^{\frac{1}{\rho_i}}$, where $z_{ij}$ is quantity of commodity j firm i uses and $a_{ij}$ is the corresponding technical coefficient. The $\min(\cdot)$ 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 $\rho_A$ 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.

**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 | 0 | 0 | 13 | 29 | 1 |
| Const-A | 58 | 0 | 17 | 146 | 1,405 | 6,142 | 338 | 0 | 8,686 | 3,775 | 95 |
| Util-A | 0 | 7 | 110 | 5,202 | 855 | 42 | 11 | 0 | 54 | 556 | 29 |
| Fossil-A | 0 | 0 | 259 | 77 | 14,151 | 355 | 3 | 1 | 435 | 714 | 73 |
| Trad-A | 27 | 0 | 234 | 755 | 243 | 1,486 | 0 | 17 | 1,527 | 18,552 | 269 |
| Min-A | 0 | 0 | 39 | 41 | 108 | 42 | 84 | 0 | 123 | 139 | 1 |
| Food-A | 6,389 | 7 | 91 | 362 | 96 | 2,196 | 0 | 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 | 0 | 3,285 | 229 | 1,125 | 401 | 11 | 559 | 1,093 | 6,614 | 238 |

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[13], 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 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 were removed from the state government revenue equation. State government revenue is,

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

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. State government expenditure is,

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

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

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 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.

**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 state rate is 6.5%. It is true that food is not taxed in Washington and Alcohol and Tobacco 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 affected 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%[14] 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 already declining prior to the paying of the transfer payment this money was withdrawn from the states investment funds.

[14] 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[15] reported it at $422.8 billion. This represented only a 1.3% difference, which 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[16] at $88.5 billion.

The last check we conducted 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 | 2.0% | 1.8% |
| FOREST-A | 0.2% | 0.0% |
| CONST-A | 4.0% | 3.8% |
| UTIL-A | 1.3% | 0.9% |
| Fossil-A | 0.7% | 0.0% |
| TRAD-A | 11.9% | 12.5% |
| MIN-A | 0.1% | 0.3% |
| FOOD-A | 1.0% | 2.8% |
| MAN-A | 11.5% | 10.7% |
| SER-A | 52.2% | 50.5% |
| MISC-A | 15.1% | 16.9% |

[15] 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

[16] 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

**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 | Forestry |
|---|---|
| 15 | Forestry products and timber production |
| 16 | Commercial logging |

| 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 | 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** | **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** | **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** | **Food Manufacturing** |
|---|---|
| 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** | **General Manufacturing** |
|---|---|
| 65 | Dog and cat food manufacturing |
| 66 | Other animal food manufacturing |
| 112 | Fiber yarn and thread mills |
| 113 | Broadwoven fabric mills |
| 114 | Narrow fabric mills and schiffli machine embroidery |
| 115 | Nonwoven fabric mills |
| 116 | Knit fabric mills |
| 117 | Textile and fabric finishing mills |
| 118 | Fabric coating mills |
| 119 | Carpet and rug mills |
| 120 | Curtain and linen mills |
| 121 | Textile bag and canvas mills |
| 122 | Rope cordage twine tire cord and tire fabric mills |
| 123 | Other textile product mills |
| 124 | Hosiery and sock mills |
| 125 | Other apparel knitting mills |
| 126 | Cut and sew apparel contractors |
| 127 | Mens and boys cut and sew apparel manufacturing |
| 128 | Womens and girls cut and sew apparel manufacturing |
| 129 | Other cut and sew apparel manufacturing |
| 130 | Apparel accessories and other apparel manufacturing |
| 131 | Leather and hide tanning and finishing |
| 132 | Footwear manufacturing |
| 133 | Other leather and allied product manufacturing |
| 134 | Sawmills |
| 135 | Wood preservation |
| 136 | Veneer and plywood manufacturing |
| 137 | Engineered wood member and truss manufacturing |
| 138 | Reconstituted wood product manufacturing |

| | |
|---|---|
| 139 | Wood windows and door manufacturing |
| 140 | Cut stock resawing lumber and planing |
| 141 | Other millwork including flooring |
| 142 | Wood container and pallet manufacturing |
| 143 | Manufactured home (mobile home) manufacturing |
| 144 | Prefabricated wood building manufacturing |
| 145 | All other miscellaneous wood product manufacturing |
| 146 | Pulp mills |
| 147 | Paper mills |
| 148 | Paperboard mills |
| 149 | Paperboard container manufacturing |
| 150 | Paper bag and coated and treated paper manufacturing |
| 151 | Stationery product manufacturing |
| 152 | Sanitary paper product manufacturing |
| 153 | All other converted paper product manufacturing |
| 154 | Printing |
| 155 | Support activities for printing |
| 157 | Asphalt paving mixture and block manufacturing |
| 158 | Asphalt shingle and coating materials manufacturing |
| 159 | Petroleum lubricating oil and grease manufacturing |
| 160 | All other petroleum and coal products manufacturing |
| 161 | Petrochemical manufacturing |
| 162 | Industrial gas manufacturing |
| 163 | Synthetic dye and pigment manufacturing |
| 164 | Other basic inorganic chemical manufacturing |
| 165 | Other basic organic chemical manufacturing |
| 166 | Plastics material and resin manufacturing |
| 167 | Synthetic rubber manufacturing |
| 168 | Artificial and synthetic fibers and filaments manufacturing |
| 169 | Nitrogenous fertilizer manufacturing |
| 170 | Phosphatic fertilizer manufacturing |
| 171 | Fertilizer mixing |
| 172 | Pesticide and other agricultural chemical manufacturing |
| 173 | Medicinal and botanical manufacturing |
| 174 | Pharmaceutical preparation manufacturing |
| 175 | In-vitro diagnostic substance manufacturing |
| 176 | Biological product (except diagnostic) manufacturing |
| 177 | Paint and coating manufacturing |
| 178 | Adhesive manufacturing |
| 179 | Soap and other detergent manufacturing |
| 180 | Polish and other sanitation good manufacturing |
| 181 | Surface active agent manufacturing |
| 182 | Toilet preparation manufacturing |
| 183 | Printing ink manufacturing |
| 184 | Explosives manufacturing |
| 185 | Custom compounding of purchased resins |

| | |
|---|---|
| 186 | Photographic film and chemical manufacturing |
| 187 | Other miscellaneous chemical product manufacturing |
| 188 | Plastics packaging materials and unlaminated film and sheet manufacturing |
| 189 | Unlaminated plastics profile shape manufacturing |
| 190 | Plastics pipe and pipe fitting manufacturing |
| 191 | Laminated plastics plate sheet (except packaging) and shape manufacturing |
| 192 | Polystyrene foam product manufacturing |
| 193 | Urethane and other foam product (except polystyrene) manufacturing |
| 194 | Plastics bottle manufacturing |
| 195 | Other plastics product manufacturing |
| 196 | Tire manufacturing |
| 197 | Rubber and plastics hoses and belting manufacturing |
| 198 | Other rubber product manufacturing |
| 199 | Pottery ceramics and plumbing fixture manufacturing |
| 200 | Brick tile and other structural clay product manufacturing |
| 201 | Flat glass manufacturing |
| 202 | Other pressed and blown glass and glassware manufacturing |
| 203 | Glass container manufacturing |
| 204 | Glass product manufacturing made of purchased glass |
| 205 | Cement manufacturing |
| 206 | Ready-mix concrete manufacturing |
| 207 | Concrete block and brick manufacturing |
| 208 | Concrete pipe manufacturing |
| 209 | Other concrete product manufacturing |
| 210 | Lime manufacturing |
| 211 | Gypsum product manufacturing |
| 212 | Abrasive product manufacturing |
| 213 | Cut stone and stone product manufacturing |
| 214 | Ground or treated mineral and earth manufacturing |
| 215 | Mineral wool manufacturing |
| 216 | Miscellaneous nonmetallic mineral products manufacturing |
| 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 |
| 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 |

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|---|---|
| 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 |

| **IMPLAN Code** | **Services** |
|---|---|
| 441 | Owner-occupied dwellings |
| 482 | Hospitals |
| 440 | Real estate |
| 475 | Offices of physicians |
| 502 | Limited-service restaurants |
| 428 | Wireless telecommunications carriers (except satellite) |
| 437 | Insurance carriers |
| 483 | Nursing and community care facilities |
| 433 | Monetary authorities and depository credit intermediation |
| 478 | Outpatient care centers |

| | |
|---|---|
| 476 | Offices of dentists |
| 477 | Offices of other health practitioners |
| 436 | Other financial investment activities |
| 485 | Individual and family services |
| 503 | All other food and drinking places |
| 408 | Air transportation |
| 447 | Legal services |
| 427 | Wired telecommunications carriers |
| 411 | Truck transportation |
| 509 | Personal care services |
| 495 | Gambling industries (except casino hotels) |
| 422 | Software publishers |
| 474 | Other educational services |
| 487 | Child day care services |
| 480 | Home health care services |
| 512 | Other personal services |
| 459 | Veterinary services |
| 472 | Elementary and secondary schools |
| 442 | Automotive equipment rental and leasing |
| 496 | Other amusement and recreation industries |
| 435 | Securities and commodity contracts intermediation and brokerage |
| 481 | Other ambulatory health care services |
| 497 | Fitness and recreational sports centers |
| 488 | Performing arts companies |
| 479 | Medical and diagnostic laboratories |
| 434 | Nondepository credit intermediation and related activities |
| 471 | Waste management and remediation services |
| 412 | Transit and ground passenger transportation |
| 466 | Travel arrangement and reservation services |
| 508 | Personal and household goods repair and maintenance |
| 515 | Business and professional associations |
| 410 | Water transportation |
| 489 | Commercial Sports Except Racing |
| 423 | Motion picture and video industries |
| 432 | Internet publishing and broadcasting and web search portals |
| 443 | General and consumer goods rental except video tapes and discs |
| 491 | Promoters of performing arts and sports and agents for public figures |
| 505 | Car washes |
| 469 | Landscape and horticultural services |
| 414 | Scenic and sightseeing transportation and support activities for transportation |
| 458 | Photographic services |
| 510 | Death care services |
| 511 | Dry-cleaning and laundry services |
| 419 | Book publishers |
| 409 | Rail transportation |
| 468 | Services to buildings |

| | |
|---|---|
| 418 | Periodical publishers |
| 518 | Postal service |
| 417 | Newspaper publishers |
| 467 | Investigation and security services |
| 498 | Bowling centers |
| 424 | Sound recording industries |
| 450 | Specialized design services |
| 506 | Electronic and precision equipment repair and maintenance |
| 465 | Business support services |
| 444 | Video tape and disc rental |
| 494 | Amusement parks and arcades |
| 425 | Radio and television broadcasting |
| 415 | Couriers and messengers |
| 464 | Employment services |
| 490 | Racing and Track Operation |
| 500 | Other accommodations |
| 445 | Commercial and industrial machinery and equipment rental and leasing |
| 470 | Other support services |
| 416 | Warehousing and storage |
| 421 | Greeting card publishing |
| 462 | Office administrative services |
| 426 | Cable and other subscription programming |
| 463 | Facilities support services |
| 454 | Management consulting services |
| 413 | Pipeline transportation |
| 420 | Directory mailing list and other publishers |
| 429 | Satellite telecommunications resellers and all other telecommunications |
| 430 | Data processing hosting and related services |
| 431 | News syndicates libraries archives and all other information services |
| 438 | Insurance agencies brokerages and related activities |
| 439 | Funds trusts and other financial vehicles |
| 446 | Lessors of nonfinancial intangible assets |
| 448 | Accounting tax preparation bookkeeping and payroll services |
| 449 | Architectural engineering and related services |
| 451 | Custom computer programming services |
| 452 | Computer systems design services |
| 453 | Other computer related services including facilities management |
| 455 | Environmental and other technical consulting services |
| 456 | Scientific research and development services |
| 457 | Advertising public relations and related services |
| 460 | Marketing research and all other miscellaneous professional scientific and technical services |
| 461 | Management of companies and enterprises |
| 473 | Junior colleges colleges universities and professional schools |
| 484 | Residential mental retardation mental health substance abuse and other facilities |

| | |
|---|---|
| 486 | Community food housing and other relief services including rehabilitation services |
| 492 | Independent artists writers and performers |
| 493 | Museums historical sites zoos and parks |
| 499 | Hotels and motels including casino hotels |
| 504 | Automotive repair and maintenance except car washes |
| 507 | Commercial and industrial machinery and equipment repair and maintenance |

| **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 |

## 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
```

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