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Economic and Environmental Impacts of Washington State Biofuel Policy Alternatives

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A computable general equilibrium model is used to analyze the effectiveness of policy alternatives at achieving biofuel-related goals in Washington State. Policy regimes compared include blend mandates, generally funded volumetric and CO_2e (CO_2 equivalent) emissions-based tax/subsidy regimes, and revenue-neutral funded tax/subsidy regimes that use fossil fuel taxes to fund renewable fuel subsidies. Results suggest that a revenue-neutral CO_2e emissions-based tax/subsidy is arguably the most effective single alternative for pursuing the full set of objectives emphasized in recent Washington State legislation.

Key words: biodiesel, biofuel policy, computable general equilibrium, CO_2 equivalent emissions

Introduction

Washington State biofuel policies operate within the context of a substantial set of national biofuel policies and a myriad of state-level policies. The Federal Energy Policy Act of 2005 and The Energy Security and Independence Act of 2007 together mandate that consumption of biofuels increase from 13.2 billion gallons in 2012 to 36 billion gallons by 2022. The corn ethanol contribution to the renewable fuel standard (RFS) is capped at 15 billion gallons per year beginning in 2015, with the remainder being advanced biofuels, such as biomass-based fuels. In the 2008 Farm Bill (H.R. 2419: Food, Conservation, and Energy Act of 2008), tax credits for corn-based ethanol are reduced from 51 cents to 45 cents per gallon (section 15331), while a new tax credit for cellulosic biofuels is established at $1.01 per gallon (section 15321).

To date, the State of Washington biofuel policy includes minor tax incentives for biofuel sales, limited funding for infrastructure development, and a modest RFS that was intended to promote renewable fuel use, but in practice is nonbinding. Although the Washington State RFS target has been reached for ethanol sales, the biodiesel sales target has not been met. Given foreseeable market conditions, agricultural biofuel feedstocks– including oilseeds, sugar beets, and field corn–are likely to account for only a small fraction of Washington's agricultural production and state fuel needs. Washington State does not yet commercially produce any ethanol, though there has been some production in neighboring Oregon. Ethanol processors in Oregon currently import the majority of their corn feedstocks from the Midwest; biodiesel processors in Washington State do the same with Midwest soybeans and canola oil grown in the Pacific Northwest and Canada. Current production of standard biofuel feedstocks in Washington is small, but as federal mandates move away from corn ethanol toward biomass-based biofuel targets, Washington and other Western states with higher densities of woody biomass may see their position improve relative to the Midwest.

The Washington State Governor and Legislature have continued to pursue further biofuel-related legislation. They have focused on five policy goals relating to biofuel markets: 1) increasing in-state

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Table 1: Percentage Change in Commodity World Prices from 2006-2008

Commodity	% Change 2006 - 2008
OILGAS-C	69.54%
GASOLINE-C	50.42%
COMPDIESEL-C	66.72%
DIESEL-C	66.72%
BIODIESEL-C	105.05%
OTHEROIL-C	53.54%
NATGAS-C	-0.16%
GRAIN-C	143.00%
CORN-C	50.00%
POTATO-C	18.25%

production of biofuels, 2) increasing in-state production of biofuel feedstocks, 3) reducing petroleum dependence, 4) reducing carbon emissions, and 5) fostering environmental sustainability.[1]

For this study we use a Computable General Equilibrium (CGE) model to analyze the effectiveness of policy alternatives for achieving these five goals in Washington State.[2] Given the speculative nature of cellulosic biofuel processing technology and the fact that there are no such markets in Washington State, we focus our analysis on the biodiesel industry in the state.[3] A CGE framework is used to make relative comparisons of different policies. We used the IMPLAN (Impact Analysis for Planning) 2006 database for the state of Washington as well as additional detail for sectors related to biofuel production (IMPLAN®, 2010). The model was updated to mid-2008 to account for significant changes in the energy sector during this time period (see table 1).[4] CGE results can be interpreted as economic reactions to policy changes for a small open economy like Washington State under a set of given conditions. This CGE implementation is static, not dynamic; each policy result can be thought of as a short-run "snapshot" of a new economic equilibrium at a particular point in time. This type of analysis is ideally suited to examining relative impacts of different policies, making it an especially valuable tool for policymakers. While there have been a large number of CGE models used to estimate the economic effects of lowering CO_2 equivalent (CO_2e) emissions (see Burniaux, 2002; Hamilton and Cameron, 1994), few have compared the effects of multiple policy types on multiple policy targets.

This research examines the effects that various policy approaches have on the markets for diesel and biodiesel and the state economy as a whole. We model the following policy regimes:

- Feedstock subsidies for oilseed processing (Feed Subsidy);
- Volumetric fossil fuel tax (VFF Tax);
- Volumetric general fund renewable fuel subsidy (GF RF Subsidy);
- Volumetric revenue-neutral renewable fuel subsidy (VFF Tax/RF Subsidy);
- CO_2e equivalent-based fuel tax (CE Tax);
- CO_2e equivalent-based renewable fuel subsidy (CE RF Subsidy);

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[1] See, for example, E2SHB 1303, available at http://apps.leg.wa.gov/billinfo/summary.aspx?year=2007&bill=1303.

[2] See (Espinola-Arredondo, Wandschneider, and Yoder, 2009) for a related discussion of achieving multiple goals through policy.

[3] Yoder et al. (2009) provide a broader analysis of biofuel markets that includes cellulosic biofuels and other possible alternatives.

[4] While continued volatility in this sector and the recent change in economic stability date this research to some extent, the results can be used as quantitative support for the relative impact of different fuel-related policies.

- CO_2e equivalent-based revenue-neutral renewable fuel subsidy (CE Tax/CE RF Subsidy);
- Blend mandates for biodiesel (Standard).

We examine the impact of each of these policy types on multiple sets of economic indicators, including:

- Changes in fuel production and price, in terms of percentage change from the baseline;
- Changes in net lifecycle CO_2e emissions from in-state consumption of fuels, in terms of percentage change from the baseline;
- Changes in the state Gross Domestic Product (GDP), in millions of dollars, calculated from both the expenditure and income side. The expenditure side represents the value of production sold to final consumers in millions of dollars, including government, households, and exported less imported goods. The income side represents the wage and capital bill (i.e., household and government income from the factors of production, plus indirect business taxes);
- Changes in equivalent variation (EV), in millions of dollars, representing the net welfare impact of a policy change on households. EV will be roughly equal to net change in household income if there are no changes in composite prices. We focus on the sum of EV over all income categories.

The qualitative results of the CGE analysis are largely consistent with basic economic theory. We find that subsidies increase EV through increased household incomes as well as decreased prices, while taxes decrease EV and increase state revenue. Renewable fuel subsidies also lead to an increase in CO_2e emissions due to an increase in consumption of all fuels. Emission directed taxes are most effective, outside of renewable fuel standards, at reducing CO_2e emissions. One somewhat surprising finding is that our results suggest that GDP will increase with an increase in a standard Pigouvian tax on carbon. We discuss the reasons for this result below. Due to the nature of CGE models in general and the rapidity with which renewable energy markets are changing, among other issues, these results should not be interpreted as nominal forecasts of likely market outcomes for these policies. Importantly, the quantitative results of the CGE modeling should be interpreted as relative comparisons of the different policies and their ability to achieve specified goals.

The primary contribution of this paper is a comparison of policy alternatives for progressing toward the state's five goals. None of the alternatives are ideal for any one goal, but as might be expected, we find that some policies dominate others. For example, were the only policy objective a reduction in carbon emissions, a more standard carbon tax or renewable fuel standard shows itself to be a strong alternative, but other types of policy instruments perform better for addressing alternative policy goals.

Model

CGE modeling framework provides a foundation for comparing the impacts of different policy alternatives on the Washington State biofuel and feedstock markets and the Washington State economy as a whole. CGE models are multi-sector models of the economy comprising a set of calibrated input/output supply and demand equations and are based on Walrasian general equilibrium concepts of market clearing in product and factor markets. CGE models have been used primarily to analyze tax and trade policies (Rickman and Snead, 2007), but have also been used to examine the economic impact of energy price shocks at the national and state level (Holland, Stodick, and Painter, 2007) and for modeling the impacts of environmental policy and carbon sequestration (Beauséjour, Lenjosek, and Smart, 1995; Burniaux, 2002). As in standard (neoclassical) economic models, producers are assumed to be profit maximizers, and in typical CGE applications they can sell their output either on the domestic market or on the export market, based on market prices. Households are assumed to maximize utility by consuming a mix of domestic and imported goods subject to an income constraint (for an in-depth review of CGE modeling, see Wing, 2004).

In the Washington CGE model used for this analysis, households are modeled as representative agents for nine different income levels, and industries are modeled as representative producers. Industries are represented by fifty-five sectors consisting of thirty-one agricultural-related sectors, fourteen fuels-related sectors, five transportation sectors, and aggregated services and manufacturing sectors. Given the agricultural nature of biofuel production, agricultural industries have a greater degree of disaggregation in order to analyze potential policy impacts.

Specific functional forms are used to capture the behavior of economic agents. The parameters of these functions are obtained by calibration to a dataset for a given year.[5] State level equilibrium commodity and factor prices are endogenously determined such that all product and factor markets are cleared (excess demand is zero in each market).

The Washington CGE model allows for imperfect substitution between state-produced goods, goods from the rest of the United States, and goods from the rest of the world. An Armington function is used to capture the substitution possibilities between state-produced goods and imported goods for both firms and households. Because this is a regional model, we formulate the Armington function at two levels. In the first stage we allow for substitution between domestic goods (produced in Washington) and imported goods; in the second stage we differentiate between domestic imports (imports from rest of the United States) and foreign imports (imports from rest of the world) and allow substitution to occur between them. Prices of foreign goods and imports from the rest of the United States are assumed to be exogenous and fixed, which is equivalent to assuming that Washington State is a "small" economy that does not affect import or export prices. The consumer price index is the numeraire.

Most of the parameters of the model are calibrated from an IMPLAN-based SAM for Washington State. However, the Armington elasticities, the transformation (CET) elasticities (counterparts of the Armington elasticities on the export side), the elasticity of capital/labor substitution in production, and the household income elasticity are all free parameters to be specified by the model user and based on the literature (Rickman and Snead, 2007). State government revenues are determined as part of the solution to the equilibrium problem (i.e., they are endogenously determined) and in the model act to support state government expenditures.[6]

Constructing the Washington State SAM and Baseline Analysis

At the time of this study, in-state commercial capacity of biodiesel production was a little over 100 million gallons per year.[7] Given that the 100MG/Y Imperium Renewables plant in Gray's Harbor represented nearly 90% of in-state biodiesel production capacity, the biodiesel producing activity in the SAM (and Washington CGE model) is representative of a 100MG/Y production process (Ellis). This accounts for approximately 50% of total in-state consumption of biodiesel. We replicate the current commodity distribution of diesel to allocate biodiesel to the other industries in the state as well as exportation levels. The budget used is a scaled version of that published in Shumaker et al. (2007), with additional consulting with Dr. Shumaker (personal communication June, 2008). The biodiesel baseline price of $4.96/gal was obtained from OPIS as an average of wholesale rack prices

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[5] The dataset used is usually a Social Accounting Matrix (SAM), which is a matrix showing income and expenditure flows in the Washington economy.

[6] GAMS (General Algebraic Modeling System) software (using the PATH solver) is used to construct and solve the Washington model. The GAMS code and model documentation representing the model equations are available at http://www.agribusiness-mgmt.wsu.edu/Holland_model/index.htm.

[7] Since then, the largest producer of biodiesel in Washington State ceased operations due to changes in the export market for biodiesel and the price of biodiesel feedstocks relative to the price of diesel (Young, 2009).

for Soy Methyl Esters B100 blend biodiesel in Seattle and Vancouver on May 15, 2008 (Oil Price Information Service).

The biodiesel production process and output commodity have been incorporated into the previously-designed regional CGE model by Holland, Stodick, and Devadoss (2005) as follows. The commodity biodiesel (Biodiesel-C) can be introduced into the Washington economy in three ways: (1) in-state production, (2) domestic importation, or (3) international importation.[8] For each run of the CGE model, in-state production of commodity Biodiesel-C is produced from oilseed processing, which has inputs from canola, soybeans, safflower, and mustard. The activity Oilsdproc-A can be thought of as an independent crushing industry that produces and sells seed oil (Oilsdproc-C) as a single commodity to various production processes, including Biodiesel-A.

The degree of flexibility between imported biodiesel and in-state produced biodiesel is dependent on an imposed Armington trade elasticity. In this model biodiesel is assumed to have an Armington trade elasticity of 2. This is consistent with previous research and represents a moderate degree of commodity substitution (Holland, Stodick, and Painter, 2007).

SAM Structure for Mandate Policies

The commodity Biodiesel-C is combined with the commodity Diesel-C to make the composite fuel Compdiesel-C ("Comp[osite]diesel-C") that is bought by consumers and used as an intermediate good, either exported or used domestically. Compdiesel-C is defined by the linear aggregation equation:

$$\text{(1)} \qquad \textit{Compdiesel-C} = (\alpha)(\textit{Diesel-C}) + (1-\alpha)(\textit{Biodiesel-C}),$$

where the share α is set exogenously, as would be the case for a binding biofuel blend mandate.

SAM Structure for Taxes/Subsidies Policies

Policy comparisons are also made between different tax/subsidy regimes intended to stimulate growth in both biofuel feedstock production and biofuel production. Unlike the mandate policy regime, in the CGE model different fuels are treated as separate and entirely independent activities and commodities to be produced, imported/exported, and consumed. While the form does not allow for the complex demand interaction of different marketed blends of diesel and biodiesel, it provides insights into the general behavior of the state economy under the different policy regimes and is less computationally burdensome than the mandate regime.

SAM Structure for Carbon-Based Policies

CGE models are often used to estimate economic effects of pollution, such as the economic impact of meeting carbon emission targets (Hamilton and Cameron, 1994). While the majority of the carbon policy models focus on the impact of lowering greenhouse gas (GHG) emissions in high emitting sectors, we focus on the impact from creating new, low emitting (sequestering) sectors such as biodiesel. Policy instruments assessed in the carbon emissions literature include fossil fuel taxes, carbon taxes, and emission standards. We also include these policy instruments in our study.

We incorporate lifecycle CO_2e GHGs in the biofuels sectors by adjusting the mandate and tax/subsidy policy regimes discussed above by the respective per-gallon lifecycle CO_2e emissions for each motor fuel Biodiesel-C and Diesel-C. Net carbon emissions for each fuel type are an unweighted average of existing lifecycle CO_2e emissions estimates from 2006 onward. Our approach to GHGs accounts for differences in the energy content of fuels and provides emissions

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[8] The suffix "-C" denotes a variable as a distinct Commodity, while the suffix "-A" denotes a variable as a distinct commodity-producing Activity.

Table 2: Estimates of CO_2e Emissions for Various Fuel Types

Commodity	Lifecycle Net Carbon Emissions	Energy Content	Total Carbon Emissions/Gallon
Diesel			
Hill et al, 2006	82.3 g CO_2e/MJ		11.35
BFIN		130500 Btu/G = 36.4 MJ/liter = 137.9 MJ/G	
Biodiesel			
National Biodiesel Board, 2005		118296 Btu/G = 33 MJ/liter = 125 MJ/G	6.13
Hill et al, 2006	49 g CO_2e /MJ	91% of diesel's energy content $\sim$ 125 MJ/G	
BFIN		33.3 - 35.7 MJ/liter	
Gasoline			
Sims et al. (2006)	72 g CO_2e /MJ		10.75
Hill et al. (2006)	96.9 g CO_2e /MJ		
Babcock and Feng (2007)	94 g CO_2e /MJ	121/G	
BFIN		132 MJ/G	

ranking per gallon, as shown in table 2. These emission estimates are then multiplied by the estimates of fuel usage by type to calculate the net CO_2 equivalent emissions impact for each policy.[9]

2008 SAM–Adjusting for Energy Price Shocks

The most recent baseline data obtained from IMPLAN is representative of the Washington State economy in 2006. In subsequent years we have seen substantial worldwide increases in prices of both petroleum products and agricultural commodities such as wheat and corn. Accounting for the economic impact of these changes in prices allows for our subsequent analysis to be more representative of today's economy. Table 1 lists the price changes implemented to adjust the Washington CGE model to 2008 energy and agricultural prices. We are assuming the Washington economy has adjusted to these price shocks, and this becomes our new baseline economy. A counterfactual CGE analysis is run with price shocks, and the counterfactual equilibrium solution is taken as the new baseline for which policy comparisons will be made. Estimates of changes in petroleum prices are based upon 2008 averages from January 1 through May 21 as reported by the Energy Information Administration (2009). Prices of composite diesel products are assumed to be equal to diesel in the baseline and will only be enacted in the mandate-structured model.

Conversion of the 2006 baseline to a new 2008 replica baseline allows for the price difference between diesel and biodiesel to be more appropriately represented. In 2006 the average price per gallon of biodiesel was lower than the price of diesel, but in 2008 biodiesel cost roughly a dollar more than diesel. While this modified 2006 Washington State baseline is still somewhat dated, this modification is more representative of the current fuel industries.

Factor and commodity markets follow typical neoclassical behavior. Capital and labor are free to move across sectors, but the endowment of each factor is fixed at the state level with market-clearing capital rental and wage rates. This assumption implies that if an industry is forced to scale

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[9] It should be noted that life-cycle CO_2e emissions estimates are highly contentious, especially for biofuels generally, and this uncertainty exists at both the micro-level and the aggregate level (see Marland, Hamal, and Jonas, 2009, for a general discussion).

back production and release capital and labor, rental and wage rates will adjust accordingly, assuring the market for each factor will clear.

Policy Comparisons

We consider several tax/subsidy policies, each under several economic environments. We examine feedstock subsidies and taxes for the production of biofuels and then consider CO_2e-based subsidies, taxes, and an integrated tax/subsidy program similar to that examined in detail in Galinato and Yoder (2009). Finally, we consider the economic impact of imposing blend mandates on fuel markets and follow with a brief sensitivity analysis.

Volume-Based Taxes/Subsidies

Feedstock input costs for in-state biofuels producers are lowered using a state subsidy; that is, biofuel activity is assumed to receive a subsidy for the cost of feedstock. This policy is applied for oilseed processing to biodiesel. The feedstock subsidies are set equal to either a 5% or a 20% reduction in the price (producer cost) of the input in the biofuel production activity.

The next set of policies is a mixture of renewable fuel subsidies and fossil fuel taxes. The volume-based subsidies for renewable fuels (i.e., Biodiesel-C) are assumed to be funded through the state's general fund; they are again set at 5% and 20%. Fossil fuel taxes on Diesel-C are of a much smaller percentage tax rate due to the extreme impact fossil fuels have on the state economy: 0.1% and 0.73%. The amount of state revenue generated from a 0.1% fossil fuel tax is roughly \$17.34 million, nearly three times that needed to fund a 5% renewable fuels subsidy.

The revenue neutral tax-subsidy policy regime is strictly revenue neutral in the baseline and defined by the following equation, where $QD()$ is domestic quantity output for domestic consumption (see Galinato and Yoder, 2009, for a discussion of this type of policy).

$$Tax_{(Diesel)} = \left(\frac{QD_{(Biodiesel)}}{QD_{(Diesel)}}\right)(Subsidy_{(Biodiesel)}). \tag{2}$$

The amount of the fossil fuel tax is defined by the subsidy rates provided to renewable fuels with rates equal to 5% and 20%. While the policy regime is revenue neutral in state government revenues from diesel taxes and biofuel subsidies, it is not revenue neutral regarding total state government revenues and expenditures due to feedback effects on other sources (taxes) of state government revenues.

CO_2e Based Taxes/Subsidies

The CO_2e based tax, subsidy, and revenue neutral tax-subsidy policy regimes are analyzed in a similar fashion to the volumetric policies. The CO_2e based tax policy taxes all fuels depending on their CO_2e emissions based on the following formula:

$$Tax_{(Fuel)} = \frac{TCE_{(Fuel)}}{\eta}, \tag{3}$$

for η = 2000 and 5000, where *TCE* is Total CO_2 equivalent emissions measured in kilograms (see table 2 for the list of total CO_2 equivalent emissions per gallon). Subsidies provided to renewable fuels (RF) are functions of their net CO_2e emission reductions from fossil fuels (FF):

$$Subsidy_{(RF)} = \frac{TCE_{(FF)}}{\omega} - \frac{TCE_{(RF)}}{\omega} \tag{4}$$

for $\omega = 104.4$ and 26.1. For ease of comparison, the scaling factors for these policies, η and ω, are chosen to yield effects of similar relative sizes to that of the volumetric policies. The revenue neutral

Table 3: Various Policies Analyzed by the Regional CGE Model

	Fuel Type		**Feedstock**
Policy Regime	**Biodiesel**	**Diesel**	**Oilseed**
Feedstock			
Feed Subsidy 1			5%
Feed Subsidy 2			20%
Volumetric			
VFF Tax 1		0.10%	
VFF Tax 2		0.73%	
GF RF Subsidy 1	5%		
GF RF Subsidy 2	20%		
RF Subsidy/VFF Tax 1	5%	0.05%	
RF Subsidy/VFF Tax 2	20%	0.21%	
Carbon Based			
CE Tax 1	0.12%	0.23%	
CE Tax 2	0.31%	0.57%	
CE RF Subsidy 1	5%		
CE RF Subsidy 2	20%		
CE RF Subsidy/CE Tax 1	5%	0.054%	
CE RF Subsidy/CE Tax 2	20%	0.215%	
Standards			
Standard 1	5%	95%	
Standard 2	20%	80%	

CO_2e based policy scenario is calculated in the same manner as the volumetric revenue neutral regime. Table 3 lists the policies for which all thirty-six counterfactuals were calibrated.

Blend Mandates

Content standards equal to 5% and 20% for biodiesel in diesel are simulated using the linear aggregation equation described above in the SAM Structure for Mandate Policies section. Contents are set exogenously, representing a state mandated content standard, and market prices are assumed to adjust quantities of fossil fuel and biofuel commodities to meet the standard. The blend mandates for diesel are analyzed separately from the tax/subsidy policies due to the various modeling constraints associated with the SAM structure.

Results and Discussion

This CGE analysis is focused on the comparison of different policy regimes that coincide with at least one of the five following objectives: in-state production of biofuels and their feedstocks, reduction in petroleum dependence, reduction in CO_2e emissions, and environmental sustainability.[10] Selected results are presented in table 4 and table 5. Results for prices, output, and total carbon emissions are published in percent changes from baseline values. GDP, state government

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[10] The amount of information obtained through the various counterfactual runs is substantial. The complete set of counterfactuals may be obtained from the author.

Table 4: CGE Counterfactual Price and Quantity Results Under Various Policy Regimes

Policy Level	Biodiesel Price (% Change)	Biodiesel Quantity (% Change)	Diesel Price (% Change)	Diesel Quantity (% Change)
Feed Subsidy				
5%	−1.76	7.15	−0.00	0.01
20%	−7.05	37.25	−0.00	0.03
VFF Tax				
0.10%	0.01	−0.05	0.01	−0.05
0.73%	0.04	−0.36	0.07	−0.40
GF RF Subsidy				
5%	0.12	21.66	−0.00	0.03
20%	0.31	186.10	−0.02	0.16
RF Subsidy / VFF Tax				
5%/0.05%	0.12	21.64	−0.00	0.01
20%/0.21%	0.31	185.80	−0.01	0.08
CE Tax				
0.12%/0.23%	0.01	−0.13	0.02	−0.12
0.31%/0.57%	0.03	−0.31	0.06	−0.30
CE RF Subsidy				
5%	0.12	21.64	−0.00	0.03
20%	0.31	186.15	−0.02	0.18
CE RF Subsidy / CE Tax				
5%/0.054%	0.12	21.65	−0.00	0.01
20%/0.215%	0.31	185.97	−0.01	0.11
Standard				
5%	0.27	105.14	0.00	−2.70
20%	0.37	715.58	0.00	−18.34

revenue, and EV are reported as nominal changes from baseline values. Results are only relevant as a comparison of policy impacts on the Washington State economy.

Feedstock Subsidies

Oilseed processing subsidies create identical increases in derived demand for each oilseed input type, because biodiesel production is modeled as fixed proportion technology for input use. If the inputs to oilseed processing were not held constant we would expect the cheapest oilseed crop to exhibit the largest increase in production. For a 5% subsidy level, the increase in biodiesel output is just 7.15%. The price of regular diesel decreases slightly, resulting in a 0.01% increase in usage. State GDP declines by \$1.19 million. EV for this policy increases by \$0.20 million and CO_2e emissions increase by 0.01% due to increased fuel usage.

Table 5: CGE Counterfactual Environmental and Economic Results Under Various Policy Regimes

Policy Level	CO_2 emissions (% Change)	State GDP	Equivalent Variation	State Revenue
Feed Subsidy				
5%	0.01	−1.19	0.20	−2.35
20%	0.02	−6.05	0.68	−11.75
VFF Tax				
0.10%	−0.05	5.88	−6.07	17.34
0.73%	−0.34	42.43	−44.62	126.18
GF RF Subsidy				
5%	0.03	−5.90	1.10	−5.68
20%	0.15	−40.40	0.75	−35.87
RF Subsidy / VFF Tax				
5%/0.05%	0.00	−3.98	−0.79	−0.12
20%/0.21%	0.09	−32.66	−6.76	−13.60
CE Tax				
0.12%/0.23%	−0.11	13.01	−13.47	38.39
0.31%/0.57%	−0.26	32.32	−33.79	95.81
CE RF Subsidy				
5%	0.03	−6.18	1.60	−6.07
20%	0.17	−42.25	3.18	−38.17
CE RF Subsidy / CE Tax				
5%/0.054%	0.02	−5.03	0.55	−2.82
20%/0.215%	0.13	−37.60	−0.99	−25.16
Standard				
5%	−0.40	−9.98	−4.06	−10.09
20%	−2.73	−71.48	−28.49	−68.86

Notes: Monetary values are in millions $ change

Volumetric Fossil Fuel Taxes & Renewable Fuel Subsidies

Imposing taxes on fossil fuels increases the producer price. A volumetric fossil fuel tax of 0.10% results in a 0.05% decline in diesel output and a 0.05% decrease in CO_2e emissions (see tables 4 and 5). The fossil fuel tax also results in a 0.05% decline in biodiesel output. This result may seem counterintuitive at first, but biodiesel is used in fixed proportion to diesel in the CGE model. Therefore, when diesel consumption falls so does biodiesel.

Government revenue and expenditures increase by $17.34 million, EV falls by $6.07 million, and State GDP increases by $5.88 million. This last result is surprising, because taxes tend to reduce GDP as a result of the impact of cost increases on economic activity and primary factor income. However, given the significance and structure of electricity production in Washington State, the fuel excise tax is accompanied by an increase in indirect business taxes (IBT) and thus state

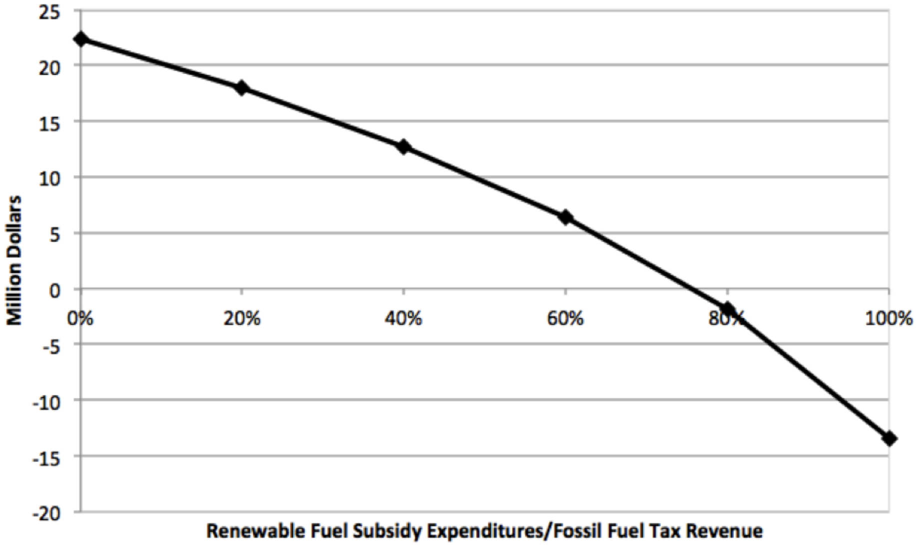

Figure 1: Impact on State Revenue of Various Levels of Biodiesel Subsidy Expenditures Funded by a 0.2% Diesel Tax

revenue/expenditures. The fuel taxes cause a shift in the production of electricity from the public to the private sector, where IBT are much higher. This movement is primarily due to the ease of capital and labor mobility within the private electricity sector, which generates a sink for unused capital and labor (a function of the fixed endowment of each in the model). This in turn results in an increase in GDP even with declining factor incomes. When the volumetric fossil fuel tax is increased from 0.10% to 0.73% (the largest computationally allowable tax) all results increase proportionally.

Results from volumetric subsidies with no offsetting fuel tax increase are summarized in tables 4 and 5. At a 5% subsidy the biodiesel industry increases output by 21.66%. The ability of the biodiesel industries to capitalize on the subsidies stems from its relatively efficient production function and the shift in industry factor demand curves resulting from the subsidy. In-state supply of biofuels does not change much. Indeed, EV increases slightly with the subsidy, due to increased labor demand and lower prices.

The revenue-neutral volumetric renewable fuel subsidy yields results similar to the subsidy-only policy, with some important differences. Changes in producer price and output quantities for all sectors differ by less than 1%. The resulting changes in the economy are almost the same. However, reductions in state government revenue decrease from $5.68 million with a general fund subsidy to $122,000 with the 5% subsidy. The magnitude of difference is greatly exacerbated when the subsidy is increased to 20%. Households still experience decreases in EV but on a much smaller scale than with the volumetric fossil fuel tax. The tax on diesel to generate the subsidy is so small in proportion to the subsidy that its negative effects on the economy are relatively negligible. In other words, government revenue is greatly reduced but households are only slightly worse off with the revenue-neutral volumetric renewable fuel subsidies. However, this is a short-run outcome in terms of household well-being; large reductions in government revenue will eventually impact households in the form of reductions in government services.

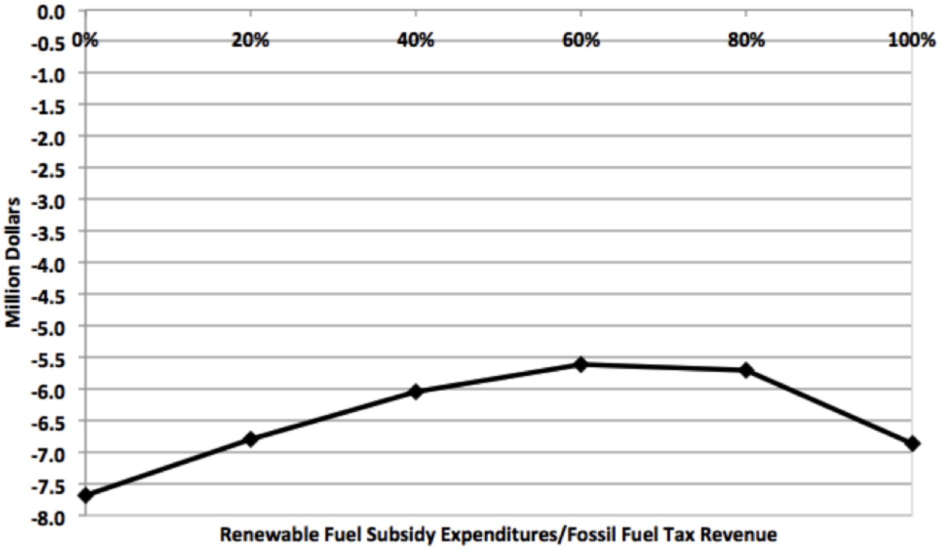

Figure 2: Nominal Change in Equivalent Variation from a Range of Biodiesel Subsidy Expenditures Funded by a 0.2% Diesel Tax

CO_2 Equivalent Taxes and Subsidies

Under a carbon-based tax, total CO_2e emissions are reduced and the state earns a sizable increase in revenue. However, households are worse off in terms of market outcomes, with decreased net income and thus a decrease in EV. Production of all fuels, both fossil and renewable, is predicted to decline under this carbon-based tax. Since the diesel market is much larger than the renewable fuel market, an equivalent percentage decline in production or consumption in the diesel market constitutes a much greater quantity change compared to an equivalent percentage change in the biodiesel market. As in the renewable fuels subsidy scenario, in which all fuel usage increases due to the reduction in fuel prices, the carbon-based tax decreases quantity demand for all fuels because of increased fuel prices.

Since the CO_2e emission reduction subsidies were set to achieve the same relative subsidy size as the volume-based subsidies, the outcome is nearly identical (tables 4 and 5). The advantage of the carbon-based subsidy is that it creates incentives for advances in emissions-reducing biofuels, whereas the volumetric subsidy does not. Not surprisingly, when incentives are tied to the reduction of greenhouse gases, the industry with the lower level of CO_2e emissions will be favored.

The first level of CO_2e-based subsidies (5%) causes the output of biodiesel to increase by 21.64%. EV increases by \$1.60 million and state GDP declines by \$6.18 million. CO_2e emissions go up by 0.03%, due to the overall decline in fuel prices, which increases consumption. The revenue-neutral CO_2e policy regime yields very similar outcomes as the CO_2e reduction subsidies but with nearly half the decrease in state government revenue and smaller decreases in GDP. Total CO_2e emissions increase slightly for the revenue-neutral CO_2e policies although not as much as for the general fund CO_2e reduction subsidies. Requiring a transfer of funds from higher emitting industries to lower emitting industries accomplishes two goals: for a set amount of fuel consumed, CO_2e emissions decrease and the balance of trade increases in Washington's favor.

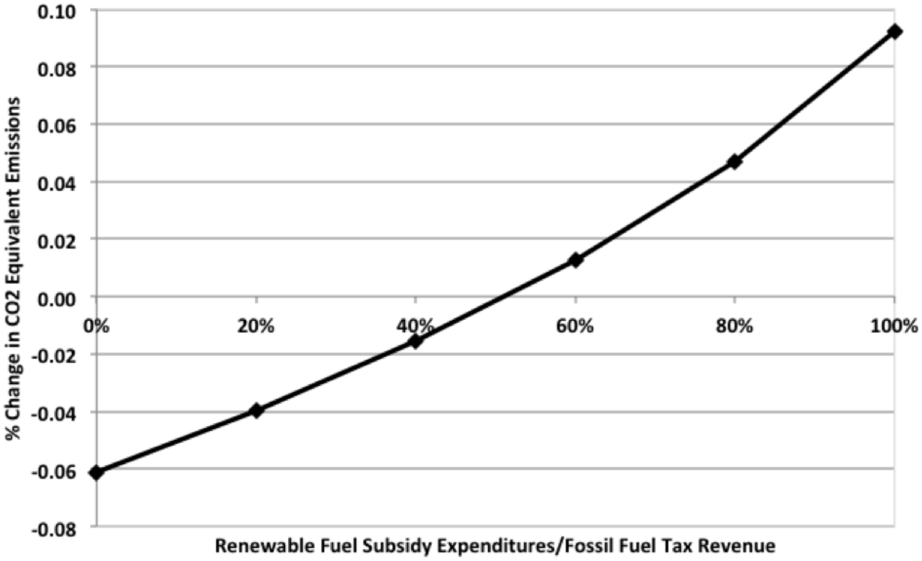

Figure 3: Impact on Lifecycle CO_2 Equivalent Emissions from a Range of Biodiesel Subsidy Expenditures Funded by a 0.2% Diesel Tax

Blend Mandates

Assuming a renewable fuel standard for biodiesel of 20% leads to a 715.58% increase in biodiesel production, production of regular diesel declines by 18.34%. Because of the substitution towards cleaner burning biodiesel, CO_2e emissions from fuels decline by nearly 2.73%. However, state GDP declines by $71.48 million and EV decreases by $28.49 million. Thus, fossil fuel consumption and the correlated CO_2e emissions both decline, as in the renewable fuel subsidy scenario, with a smaller negative impact on state GDP and a similar impact on EV. Both of these policies effectively reduce fossil fuel usage and thus CO_2e emissions, but there are large negative impacts on state GDP and EV. Although mandatory standards can be effective for targeting and implementing a blend mandate, they are costly.

CGE Sensitivity Analysis

A sensitivity analysis is conducted to measure the impact of various levels of renewable fuel subsidies on state GDP and state revenues. A fossil fuel tax of 0.2% on diesel is used to fund renewable fuel subsidies for biodiesel of 4%, 8%, 12%, 16%, and 20%. The fossil fuel tax is sufficient to fund the 20% subsidy level. At the highest level of subsidization, state revenue declines by nearly $13.4 million, figure 1. EV also declines by $6.86 million (figure 2). Without the renewable fuel subsidies, revenue from the fossil fuel taxes increases state government revenue by $22.39 million and EV declines by $7.69 million in this case.

Using 60% of the tax for a 12% renewable fuel subsidy increases state revenue by $6.39 million. This particular policy level has the smallest impact on EV, which declines by $5.61 million, indicating that the optimal level for a revenue neutral tax/subsidy may in fact be at some quasi-revenue neutral level. As the renewable fuel subsidy is increased we see a steady increase in biodiesel prices from 0.01% to 0.31% and a decrease in diesel prices from 0.01% to -0.01%, resulting in an increase in consumption and therefore an increase in net CO_2e emissions (figure 3).

Table 6: Average CGE Counterfactual Policy Impact on State GDP per 1% Change in Policy Objective

Policy	Millions \$ per 1% Increase in Biodiesel Quantity	Millions \$ per 1% Decrease in CO_2 Emissions	Millions \$ per 1% Increase in Equivalent Variation
Feed Subsidy	0.16	−210.75	7.42
VFF Tax	−117.73	−121.20	0.96
GF RF Subsidy	0.24	−233.00	29.62
VFF Tax / RF Subsidy	0.18	−844.78	−4.93
CE Tax	−102.17	−121.29	0.96
CE RF Subsidy	0.26	−227.26	8.57
CE Tax / CE RF Subsidy	0.22	−270.37	−14.42
Standard	0.10	25.57	−2.48

Conclusion

Some distinct patterns emerge from modeling these various policy scenarios for Washington State. Only blend mandates and fossil fuel taxes reduce net CO_2e emissions as a result of decreased fuel consumption and the substitution of lower emission biodiesel. Biofuel subsidies reduce the overall price of fuel, which increases the quantity demanded of fuel and hence CO_2e emissions. Even if more biofuels are used, the net effect of lowered fuel prices is an increase in consumption of all fuels. In general, subsidies reduce fuel prices and thus were the only policies that increase EV. With the exception of the two fuel tax policies, all of the policies in this study reduce GDP, due to the structure of the electricity market. Research has shown that when an increase in state revenue is passed directly to the consumer, there is a positive increase in general welfare (Bento et al., 2009).

Given these results, the choice of policies will depend on the priorities of the five policy targets: 1) increasing in-state production of biofuels, 2) increasing in-state production of biofuel feedstocks, 3) reducing petroleum dependence, 4) reducing carbon emissions, and 5) fostering environmental sustainability. In order to compare the relative impact of the different policies on Washington State, table 6 converts the CGE counterfactual results into a net impact on State GDP by the percentage change in measureable policy objects. If reducing carbon emissions were the most important goal then blend mandates and taxes–carbon-based fuel taxes in particular–would be most cost-effective. If consumer wellbeing based solely on market outcomes were of the highest importance, then the choice would be among the subsidies tested in this study. If increased production of biofuels and their feedstocks were the most important consideration, results indicate that blend mandates, feedstock subsidies, and the revenue neutral subsidy policy, respectively, are most cost effective. However, the CGE model does not account for specific comparative advantages that Washington State and the Northwest may have in producing alternate types of biofuels and their feedstocks. Research into technologies that exploit these advantages could prove to be both cost-effective and welfare-improving in the long run. Trade-offs are inherent in the use of each policy, and no single policy effectively addresses all the pre-stated specific targets.

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