AN ABSTRACT OF THE DISSERTATION OF

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Title: A Regional Computable General Equilibrium Model with Applications for the Pacific Northwest

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Jeffrey J. Reimer

Many important policy problems entail linkages among multiple economic sectors, and require the use of a general equilibrium economic modeling framework. This economic approach is appropriate when the market for any one good or service is linked to numerous other goods and services, and back to fundamental inputs such as labor and capital. In this dissertation, a computable general equilibrium (CGE) model for the Pacific Northwest region is developed. It describes all parts of Pacific Northwest economy simultaneously and how its industries, households, government institutions, and factors of production interact with each other.

The model is used to address two policy issues in the Northwest: development of a new biofuels supply chain, and the impact of future events such as climate change on Pacific Northwest farmers. Before these applications are carried out, a major effort is made to estimate the parameters of the general equilibrium model, and to validate that the model is representative of the regional economy. Techniques from the literature on calibration of macro-economic models are employed, in conjunction with

historical agricultural price and quantity data for the Northwest. These methods allow greater confidence to be placed in the analyses that follow.

Once the model is parameterized and validated, the first application concerns the potential of an oilseed crop, camelina, to be used as a new biofuel for the aviation sector. The aim of this study is to identify conditions and policies under which a supply chain could be developed within the Northwest. Several policy options are examined within the model with regard to meeting stated targets by the aviation sector for using camelina as a biofuel. Model results indicate that a regional supply chain for biofuels is unlikely to develop unless subsidies are targeted to particular activities, including farming and processing. Particular estimates of these subsidies are derived.

The second application of the model concerns how the Pacific Northwest wheat economy will be affected by long-run changes in climate, population growth, input costs, and other phenomena. A series of possible future scenarios, called Representative Agricultural Pathways (RAPs), are developed to describe trends in key drivers at the regional and global scales. These RAPs are quantified and integrated as simulations into the CGE model, the first time this has been done within the literature. In general the health of the Pacific Northwest wheat sector, as represented by wheat prices, exports quantities, and producer economic welfare, appears to be quite viable under a range of alternative future scenarios.

A REGIONAL COMPUTABLE GENERAL EQUILIBRIUM MODEL WITH APPLICATIONS FOR THE PACIFIC NORTHWEST

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APPROVED:

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Head of the Department of Applied Economics

Dean of the Graduate School

I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Xiaojuan Zheng, Author

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Chapter 1. Introduction

Many important topics cut across economic sectors. For example, demand for aviation services, such as commercial airline flights, creates a derived demand for many activities that go into making those flights possible: labor and capital to design and build the aircraft, computers to handle ticket processing and flight control, pilots to fly the plane, and fuel to power its engines. In short, the market for any one good or service is linked to numerous other goods and services, and back to fundamental inputs such as labor and capital. Economists have long developed approaches to deal with the complexity of these economic systems. One comprehensive way to capture multiple economic sectors and linkages is a general equilibrium model. As an important part of economic theory, general equilibrium models link markets for goods, services, inputs, factors of production, households, consumption, and government taxation and spending all into a comprehensive and consistent whole. Market clearing conditions including Walras' Law and budget constraints ensure that everything adds up and is logically consistent. They capture the fact that a change in one part of the economy can affect numerous other parts of the economy, sometimes in large and surprising ways.

Many useful policy insights have been derived using theoretical general equilibrium models. To make them more realistic and problem-driven, however, they must be fitted to data, and the parameters which govern economic behavior must be specified to fit the situation being examined. When general equilibrium models are fitted to particular real-world settings, they are commonly called a Computable General Equilibrium (CGE) model, or applied general equilibrium model.

General equilibrium models have become more widely used in national and regional policy analysis over the past several years. A general equilibrium model attempts to account for all sectors of an economy or a region, and all the interactions that these sectors have with each other.

In this dissertation, a specific type of CGE model will be used: one that applies not to the economy of an entire nation, or the world economy, but to a specific region of the United States. This is a so-called regional CGE model and differs somewhat from a CGE model set up for a nation as a whole. The particular focus of the model developed is on the Pacific Northwest states of Oregon, Washington, and Idaho. The regional aspect of this model means that these three states are treated as a combined unit. The region, then, has interactions with the rest of the United States, and the rest of the world.

Data used to calibrate the general equilibrium model are obtained through the IMPLAN (IMpact Analysis for PLANning) Group. The IMPLAN data are in a standardized dataset of national, state, county and zip code level and distinguish over 500 distinct sectors of the economy. They are used to construct the Social Accounting Matrix (SAM) and parameterize the initial model. The SAM is a series of accounts which describe flows between agents, commodities, factors, and institutions.

One new contribution of this work is to show a new way of validating the general equilibrium model to the particular circumstances of topics being studied. Borrowing techniques from the literature on calibration of real business cycle models, historical data on output and prices are used to parameterize and validate the model. This approach provides an indication of how much price versus quantity typically handles most of the adjustment in this region, for example, to yield shocks arising from year-to-year weather changes.

The validation exercise provides a measure of reliability and assurance by making use of historical price and quantity data to map out historical price responses to historic output shocks. These actual year-to-year price movements will be compared to those which arise from model simulations representing similar, inputted year-to-year output shocks. A comparison of the actual and simulated price adjustments associated from the same output shocks will provide a basis for whether certain regional trade relationships are set up correctly in the model.

Another contribution of the development of this model is to show, for the first time, how techniques from the calibration of real business cycle theories (e.g., Kydland and Prescott, 1982) can be used to calibrated certain key parts of the CGE model, governing the issues of the flexibility of movement of goods across regions, and how much price versus quantity adjusts when there is a shock to the system. The motivation for the design of the model is to study the following two issues.

The first issue is to study production of biofuels in the Pacific Northwest, namely the potential of a crop called camelina. The general purpose of this study is to offer an economic analysis of the potential development of a regional biofuel system. In particular, an analysis of alternative policies to induce a successful biofuels economy is examined. The policies are evaluated in terms of the amount of growth there will be within the Pacific Northwest region, versus in other regions that are not as much part of the targeted development objectives.

Biofuels have become heavily studied and promoted in the last 15 years in the United States, in many cases because they are viewed as a means of promoting local economic development and regional vitality (Jaeger and Egelkraut, 2011; Diebel and Ball, 1999). A large number of policies have been introduced that serve to promote biofuels. One example is the Renewable Fuel Standard (RFS), which is a federal program that requires transportation fuel sold in the U.S. to contain a minimum percentage of biofuel blends.

The biofuels sector of the Northwest United States, however, has lagged behind that of other regions but is currently undergoing intense study and development (Jaeger et al., 2008; Yoder et al., 2010; Stein, 2012). There is a great deal of commitment among various actors to develop a camelina-based biofuel sector in the Pacific Northwest, but the economics of how this will work are unclear. This is mainly because they have not been studied, at least at the region-wide or economy-wide level. Because of this interest and the development of new policies, it remains necessary to study the economics of camelina-based biofuels.

The major benefits of the general equilibrium model is that it can simultaneously account for a number of different sectors including final demand sectors, oilseed farming sector, oilseed processing sector, livestock sector, competing production sectors, and petroleum sector. The six general sectors identified here are just some of those that will impacted by the emergence of camelina as a biofuel crop in the PNW. These sectors can be thought of as a vertical supply chain. Since this supply chain is not in existence, the task is to facilitate the transmission of signals from end users to raw feedstock producers. The general equilibrium model designed to mimic key stages of the biofuel supply chain and it can account for all sectors in an exhaustive framework. The general equilibrium model recognizes that increased demand for biofuels in certain sectors (military, civilian aviation, surface transportation) creates cascading effects along the vertical supply chain, all the way to farm input suppliers. It allows for firm and consumer substitution in many different markets, spreading the effects of any one shock over a large set of actors.

The second important application of the model is the introduction of Representative Agricultural Pathways (RAPs), which describe narratives and trends in key drivers at a regional or global scale. This has never been done with a CGE model before and there is great interest in this by researchers associated with a USDA-funded research project called Regional Approaches to Climate Change (REACCH).

Three RAPs for the Pacific Northwest region are developed by the DevRAP tool (Valdivia and Antle, 2012) and followed procedures in Antle et al. (2013b). The RAPs concern factors such as population change, trade policy change, productivity (e.g., crop yields or total factor productivity), and the spatial and temporal distribution of these physical outcomes and economic impacts (Antle, 2009). Some of the economic uncertainties such as commodity and input prices, production technology, and policies, as well as increased probability of disturbances associated with a changing climate cannot be modeled, but those that can be, are represented in regional RAPs. Three RAPs are considered, including “Business-as-Usual,” “Dysfunctional World,” and “Optimal Policies (Aggressive Climate Policy).” The connection of RAPs to the computable general equilibrium model is made through a series of hypothetical scenarios, that is, model-specific parameters that are consistent with a pathway. Key economic relations are estimated econometrically using historical data, including a foreign export demand decision model and a Northwest wheat output supply model.

These topics have not been extensively addressed within the economics literature, but it is worthwhile to identify a few studies upon which this study builds and complements. Instead of focusing on the wheat yield issue, Reimer and Li (2009) examine yield variability in staple grains for world as a whole. A noticeable study using CGE approach is done by Valenzuela et al. (2001), which reproduce observed wheat price volatility in agricultural markets with econometrically estimated key parameters and compared them with model predictions by developing a global general equilibrium model. Deschenes and Greenstone (2007) is another study that measures the economic impact of climate change on United State agricultural land. This study is the first one to examine the wheat economy in the Pacific Northwest using a regional general equilibrium framework.

An outline of the remainder of the dissertation is as follows. Chapter 2 introduces the structure and components of the general equilibrium model that developed for the Pacific Northwest region. Model calibration and validation are discussed in detail in Chapter 3. Chapter 4 examines the economic impacts of camelina-based bifofuel in this region using the general equilibrium model. Chapters 5 and 6 discuss the second application of the model, which is to study the economics of wheat in the Pacific Northwest by integrating RAPs to the regional computable general equilibrium model. Chapter 7 summarizes and concludes, and identifies limitations of the existing research, and identifies where future efforts are likely to be most fruitful. Since the dissertation includes a large number of distinct topics, relevant studies are introduced and discussed at different parts of the dissertation, where this information is deemed most relevant.

Chapter 2. A Computable General Equilibrium Model

2.1 Model Overview

In this chapter a computable general equilibrium model for the Pacific Northwest region is developed, focusing on States of Oregon, Washington, and Idaho.

Computable general equilibrium models have become more widely used in national and regional policy analysis over the past several years. A general equilibrium model attempts to account for all sectors of an economy or a region, and all the interactions that these sectors have with each other. The word "computable" signifies that unlike textbook theory, detailed data are employed and that a model solution can be calculated. The words "general equilibrium" signifies that a shock in one part of the economy, such as a change in government policy, has reverberations throughout the economy, affecting consumers, producers, and businesses that otherwise might seem far removed from the sector that has policy change.

The model developed in this paper is an extension of a model developed at the International Food Policy Research Institute (IFPRI) in the 1990s, as described by Lofgren et al. (2002). It was further adapted for use at the regional level by David Holland and colleagues, as described in Holland, Stodick, and Devadoss (2004). The regional version of the model is different in that it is set up to make full use of

IMPLAN regional trade data. As a result, the regional general equilibrium model is able to distinguish trade with the rest of the U.S. from trade with international markets.

The general equilibrium model is a system of highly non-linear equations that represent demands and supplies resulting from the optimizing behavior of firms and consumers, as well as factor and commodity market clearing conditions. In the following subsections, key equations will be introduced; a full mathematical presentation of the model can be found in the Appendix section.

The model incorporates optimizing households and firms, intermediate input use, inter-household and government transfers, savings and investment, government, and trade with the rest of the world. Regional households receive income from labor, capital, inter-household transfers, federal and state government transfers, and investment income. Households spend money on commodities, inter-household transfers, federal and state government taxes, and investment. Transactions between them are captured quantitatively in a circular flow of income.

2.2 Firms, Households and the Government

The main equations are derived from constrained optimization of the neoclassical production and consumption functions. The behavior of producers and consumers are captured in the specific functional forms as followed. Industries are modeled as representative producers with constant elasticity of substitution (CES) production technologies.

The basic structure of the commodity flows between consumptions and productions in the general equilibrium model is shown in Figure 1. This Figure is developed following the approach of Hosoe et al. (2010). In the first step, biofuel, for example, are produced by the processors (firms) with factor inputs labor and capital. Then, in the step 2, biofuel are shipped to the goods markets, where they are sold to the household for their consumption $X_{biofuel}$. At the household, the goods biofuel and petroleum are consumed and generate utility U. The payments occur in the opposite direction. The factor income is generated by the firms and paid back to the provider of the factors: i.e. the household. In the following paragraphs, household and firm optimization behaviors and the market-clearing conditions are presented.

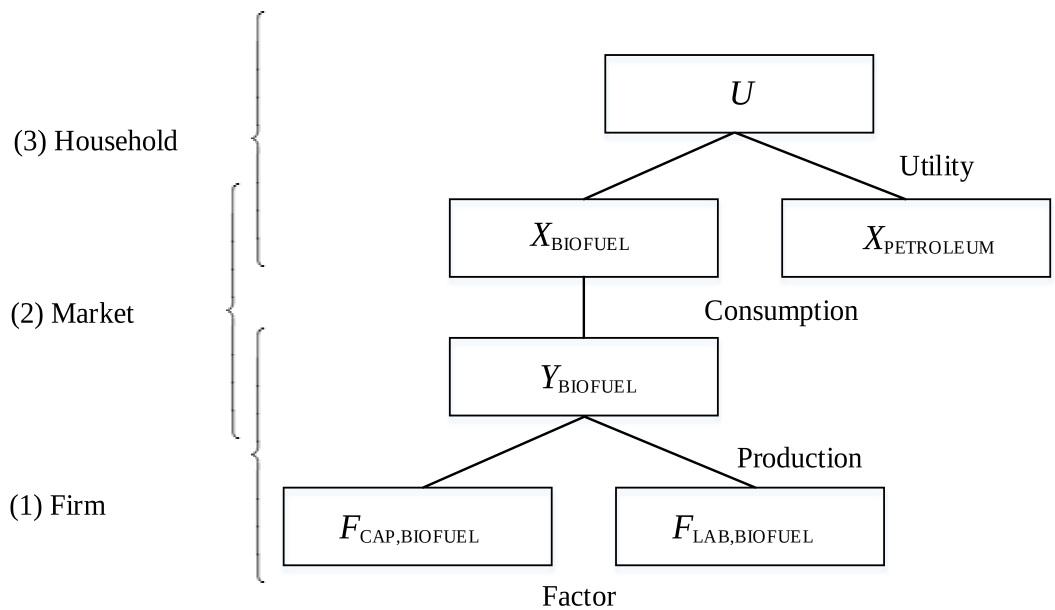

Figure 1. The Basic Structure of General Equilibrium Model

Firms

As shown in equation (5) and Figure 2, the Leontief -cum-CES type production function assume fixed proportions of intermediate inputs, but variable capital/labor substitution for primary factors for a given industry (Ghosh et al., 2005).

$$(1)\ \ ica_{C,A} = \frac{QINTO_{C,A}}{QAO_A}$$

$$(2)\ \ del_{FF,A} = \frac{WFDIST_{FF,A} * WFO_{FF} * QFO_{FF,A}^{\ rho_A + 1}}{\sum_{FFF} WFDIST_{FFF,A} * WFO_{FFF} * QFO_{FFF,A}^{\ rho_A + 1}}$$

$$(3)\ \ ad_A = \frac{QAO_A * (1\text{-}tb_A - \sum_{C} ica_{C,A})}{(\sum_{FF} del_{FF,A} * QFO_{FF,A}^{\ -rho_A})^{\frac{-1}{rho_A}}}$$

$$(4)\ \ rho_A = \frac{1}{esubp_A} - 1$$

$$(5)\ \ QA_A = \frac{ad_A}{1\text{-}tb_A - \sum_{C} ica_{C,A}} * (\sum_{FF} del_{FF,A} * QF_{FF,A}^{\ -rho_A})^{\frac{-1}{rho_A}}$$

Where QA indicates the level of activity A, ad is the production shift parameter, tb_A is the indirect business tax rate of activity A. The production function assumes fixed proportions of intermediate inputs (denoted as $ica_{C,A}$) along with flexible use of labor and capital. Producers choose their level of operation to maximize profits or minimize costs using constant returns to scale production technology. Production factors, denoted as FF, include labor, capital, and intermediate inputs, and are paid according to their respective marginal productivities. This flexibility is modeled using a constant elasticity of substitution (CES) production technology. Parameter `rho(A)` indicates the CES production function exponent.

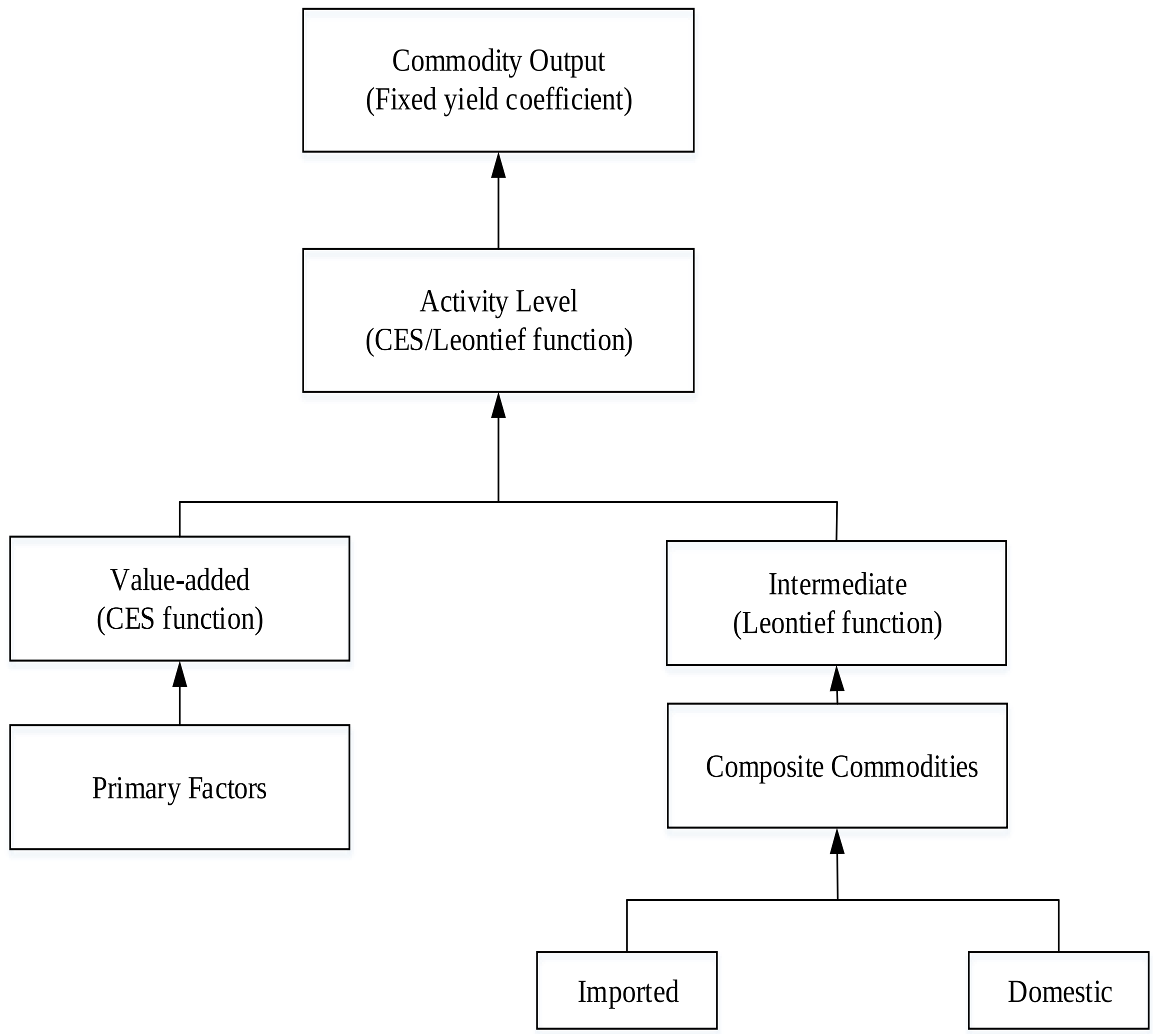

Figure 2. Production Technology

Households

Consumers are assumed to choose their purchases to maximize their utility subject to budget constraints. Consumers are modeled as a representative agent with Stone-Geary preferences, as shown in equation (8):

$$(6)\ \ lambda_{C,H} = \frac{QHO_{C,H} * PQO_C + \dfrac{beta_{C,H} * NYHO_H}{frisch_C}}{PQO_C}$$

$$(7)\ \ beta_{C,H} = \frac{QHO_{C,H} * PQO_C * ine_{C,H}}{NYHO_H}$$

(8)

$$QH_{C,H} = lambda_{C,H} + beta_{C,H} * (NYH_H - \sum_{CC} lambda_{CC,H} * (1+tc_{CC}) * PQ_{CC}) / ((1+tc_C) * PQ_C)$$

In equation (8), $QH_{C,H}$ denotes household consumption level. Households are aggregated into one category, and their consumption is allocated across different commodities (both market and home commodities) according to linear expenditure system (LES) demand function, derived from maximization of a Stone-Geary utility function (Lofgren et al., 2002). Equation (6) shows how the parameters `lambda` and `beta` are calculated. Where `lambda(C, H)` is the subsistence level parameter and `beta(C,H)` is the marginal budget share parameter. The full list of equations involve in this CGE model are reported in Appendix A.

The Government

The government is one of the components of institutions. The government collects taxes and receives transfers from other institutions. In the basic CGE model version, all taxes are at fixed ad valorem rates. This income for the government can be used to purchase commodities for its consumption and for transfers to other institution.

The model solution provides a set of prices that clears all commodity and factor markets and makes all the individual agent optimizations feasible and mutually consistent. Region-level commodity prices and factor prices are endogenously determined, i.e., solved by the model. Federal government expenditure and investment are exogenous to the model. State government revenues are determined endogenously as part of the solution to the equilibrium problem.

2.3 Regional Aggregation

Sales of output occur either within the Pacific Northwest or outside the region, based on market prices. The model allows for imperfect substitution between region-produced goods, and goods from the rest of the U.S. and the rest of the world. This is done by way of an Armington function, which captures the substitution possibilities between region-produced goods and imported goods for both firms and households. The Armington function is of the constant-elasticity-of-substitution type; the higher the value of the assumed elasticity, the easier substitution occurs between region-produced and imported goods. Specified elasticities are listed in Table 1.

Table 1. Specified Elasticities

Parameter	Specified value
Elasticity of demand for world export function	xed(C,T) = -50;
Elasticity of substitution for production	esubp(A) = 0.99;
Elasticity of substitution (armington) between regional output and imports	esubd(C) = 2;
Elasticity of substitution (transformation) between domestic (regional) and foreign demand	esubs(C) = 2;
Elasticity of substitution (transformation) between ROW and RUS for exports	esube(C) = 2;
Elasticity of substitution (armington) between ROW imports and RUS imports	esubm(C) = 2;
Income elasticity	ine(C,H) = 1;
Consumption flexibility--determines minimum subsistence level of consumption -1 implies zero minimum	frisch(C) = -1;
Demand elasticity for capital and labor	efac(FF) = 0.8;

The export supply function is derived from a constant elasticity of transformation (CET) function. It specifies the value of exports as a function of the ratio of region-level and U.S./international export prices under a fixed exchange rate. The CET function defines the production possibilities available to a given industry, assuming exported products are differentiated from region-marketed products (the Armington assumption). The export composite is a function of the price of exports to the rest of the U.S. and foreign sources.

2.4 Model Closure

Model closure classifies variables into endogenous (solved within the model) and exogenous (predetermined outside the model). Closure rules are specified for labor markets, capital markets, foreign trade markets, savings and investment, and foreign savings. Closures chosen in this study are as follows: capital is mobile and supply is fixed; labor is mobile and supply is fixed; both foreign and the rest U.S. savings are flexible. A full list of all available closure options are in Table 2.

Table 2. List of Closure Options

1. Capital closure (determined by setting the scalar CAPCLOS)
CAPCLOS = 1. Capital is mobile and supply is fixed.
CAPCLOS = 2. Capital is mobile and supply is variable
CAPCLOS = 3. Capital is activity specific and fixed.
2. Labor closure (determined by setting the scalar LABCLOS)
LABCLOS = 1. Labor is mobile and supply is fixed.
LABCLOS = 2. Labor is mobile and supply is variable.
LABCLOS = 3. Labor is mobile. Unemployment is possible.
3. Savings and investment closure (determined by setting the scalar SICLOS)
SICLOS = 1. Savings is investment driven.
SICLOS = 2. Investment is savings driven.
SICLOS = 3. CPI varies allowing prices to adjust to achieve equilibrium.
4. ROW current account closure (determined by setting the scalar ROWCLOS)
ROWCLOS = 1. Foreign exchange rate is variable.
ROWCLOS = 2. foreign savings (export - FSAVX) is variable.
ROWCLOS = 3. foreign savings (import - FSAVM) is variable.
5. RUS current account closure (determined by setting the scalar RUSCLOS)
RUSCLOS = 1. RUS exchange rate is variable.
RUSCLOS = 2. RUS savings (export - DSAVX) is variable.
RUSCLOS = 3. RUS savings (import - DSAVM) is variable.

2.5 Calibration of Model

Data used to calibrate the developed general equilibrium model are obtained through the IMPLAN (IMpact analysis for PLANning) Group (IMPLAN, 2012). These data have a long history in multi-sector regional economic analysis, and are ideally suited for the analysis of vertical supply chains in this study. The IMPLAN data are in a standardized dataset of national, state, county and zip code level and distinguish over 500 distinct sectors of the economy. IMPLAN provides the most complete economic data that can be customized to any specific industry and region for economic impact analysis. For this study the year 2011 data on three states is used to construct the Social Accounting Matrix (SAM) and parameterize the initial model. Details on SAM and calibration of model will be introduced in Chapter 3.

2.6 Counterfactual Scenarios and Policy Parameters

As mentioned in the above section, once parameterized to replicate a baseline year of data, the model can be used to trace a shock in one part of the economy, such as a change in government policy, to consumers, producers, and businesses that otherwise might seem far removed from the sector that has the initial change. To mimic the changes hypothesized by final demanders and policymakers, the counterfactual scenarios will be designed for each study. In this section a few key policy parameters are introduced.

The parameter representing the quantity of commodity C used as an intermediate input per unit of activity A is labeled `ica` (C, A), which is defined specifically as follows:

(9)

$$ica_{OILSDPROC,TRANS} = \frac{QINTO_{OILSDPROC,TRANS}}{QAO_{TRANS}} = \frac{\text{Initial quantity of intermediate use of OILSDPROC by activity TRANS}}{\text{Initial activity TRANS level}}$$

Where:

(10)

$$QINTO_{OILSDPROC,TRANS} = \frac{SAM_{OILSDPROC,TRANS}}{PQO_{OILSDPROC}} = \frac{\text{Quantity of Oilseed Processing used in production of TRANS}}{\text{Initial Oilseed Processing Price}}$$

(11) $$QAO_{TRANS} = \frac{SAM_{TOTAL,TRANS}}{PAO_{TRANS}} = \frac{\text{Total Value of TRANS activity}}{\text{Initial TRANS Activity Price}}$$

The main counterfactual scenarios designed in this paper are to reflect the changes in the camelina-based biofuels used in the transportation sector. The parameter `ica` (C, A) is used. To meet the desired level of oilseed-based biofuels to be used in the future, for example, there will be an increase in the transportation sector's use of oilseed-based biofuels, and also an increased use of the oilseed processing sector for oilseeds. There may also be increased use of camelina meal, for example, in the animal feeding sector. Chapter 3 will show how model parameters are calibrated and validated with details.

Chapter 3. Calibration and Validation of Parameters

3.1 The Social Accounting Matrix

A Social Accounting Matrix is a series of accounts which describe flows between agents, commodities, factors, and institutions. It describes transactions by agents and is written in a matrix-form table (Hosoe et al., 2010). More technically, a SAM is a square matrix in which each account is represented by a row and a column (Lofgren et al., 2002).

As seen from Table 3, each cell shows the payment from the account of its column to the account of its row. Thus, the incomes of an account appear along its row and its expenditures along its column. The underlying principle of double-entry accounting requires that, for each account in the SAM, total revenue (row total) equals total expenditure (column total) (Lofgren et al, 2002). The Social Accounting Matrix is the empirical basis of the general equilibrium model. The SAM can include any number of industries and commodities desired by the user.

The “Make” matrix is the commodity output. The “Use” matrix is the intermediate use of commodity in activity. Table 4 is the Social Accounting Matrix for biofuel sectors aggregation (in millions of 2011 dollars).

Table 3. The Social Accounting Matrix

	Activity	Commodity	Factors	Institutions	Enterprises	Capital	Trade	Total
Activity		Make					Exports	
Commodity	Use			Consumption		Consumption		
Factors	Value Added							
Institutions		Sales	Transfers	Transfers	Transfers	Transfers	Exports	Income
Enterprises								
Capital						Transfers	Exports	
Trade	Imports		Factor Trade	Imports		Transfers	Exports	
Total				Expenditures				

Table 4. The SAM for Biofuel Sectors (in millions of 2011 dollars)

	OILSEED	OILSPROC	OIL	MANUF	TRANS	LIVESTOCK	OTHAGR	FOOD	CONSUTILM	WRTRADE	SERVICES
OILSEED-C	1.9			86.5		0.2	1.9	17.4	419.0		
OILSPROC-C		867.8		15.0	70.1			81.8		15.5	326.8
OIL-C		91.2	46.0	1226.4	44.1		3.6	466.6	117.2	24.2	225.4
MANUF-C	6.3	3804.5	947.9	267117.1	16682.2	1682.5	6784.8	8779.8	21304.2	8864.8	23201.3
TRANS-C	0.0	0.2	0.0	131.3	85.9	3.1	44.1	0.1	5.3	30.2	150.27
LIVESTOCK-C	0.0	34.3		4.6	1.2	1189.4	30.4	3131.3	1.9	0.0	3.3
OTHAGR-C	0.6	1995.6		2915.6	6.0	971.8	1235.1	4134.3	995.8	21.0	218.6
FOOD-C		1401.2	1.1	930.4	545.8	12.5	52.1	3567.9	155.0	222.5	2356.4
CONSUTILM-C	1.5	650.3	36.5	27968.8	890.9	1404.5	2651.1	1517.7	4800.8	747.7	4064.1
WRTRADE-C	0.0	29.4	5.1	4216.1	1165.6	2.9	9.3	102.6	123.2	1617.5	658.8
SERVICES-C	0.1	82.6	11.9	16771.4	1072.4	20.7	58.3	327.5	716.0	912.5	1742.0

3.2 Model Calibration

For this study the year 2011 data on three states is used to construct the Social Accounting Matrix and parameterize the initial model. The three states are Oregon, Washington, and Idaho. The database used to calibrate the PNW CGE model are obtained through the IMPLAN (IMpacts for PLANning) Group. The IMPLAN data distinguish 509 distinct sectors of the economy. An aggregated 11-sector Northwest general equilibrium model is calibrated in this study.

The model is a simultaneous system of non-linear equations written with the General Algebraic Modeling System (GAMS). The joint equilibrium value of the endogenous variables is calculated using a non-linear solver (Path) within GAMS, and the model is initially solved for all endogenous variables to replicate the base year (2011) SAM. The SAM is used to calibrate a number of model parameters, e.g., the production function shift and share parameters for each sector. During calibration, all prices are set to unity and the base year factor levels and SAM flows are substituted into the model as equilibrium values of model variables. The process is similar to maximum likelihood estimation with one observation. In this case the baseline year is 2011.

The model also contains a number of free parameters set by the user. Many of the parameters are set to values commonly employed in the literature (e.g., Lofgren et al., 2002; Holland, Stodick, Devadoss, 2004; Yoder et al., 2010). For example, the elasticity of substitution between capital and labor in the production function (`esupb`) is set at 2. The rest-of-world export elasticity of demand for oilseeds is set to -1.175, an estimate made in Reimer et al. (2012). Values of `esubd` and `esubs`, which were introduced above, are from Bilgic et al. (2002). Based on their estimates, they are set at 1.447 and 1.339 for unprocessed and processed oilseeds, respectively. Values of `esube` and `esubm`, also introduced above, are from Hertel et al. (2002), and are set at 4.9 and 5.2 for unprocessed and processed oilseeds, respectively.

Once baseline is established through the processes, then model is shocked, such that new values of endogenous variables are found that replicate a new hypothetical scenario in a consistent way (obeying all resource constraints, behavioral constraints, technological constraints). It will be possible to look at multiple parameters at the same time to illustrate the widespread effects of the change. Results will be in percentage changes or level changes, showing the difference between the baseline and an alternative future state (i.e., with and without the shock).

3.3 Model Validation

Once the model was parameterized as described above, a validation exercise was undertaken to give a sense of how well the model replicates the historical data for the region with special focus on the wheat and oilseed sectors. The validation exercise has precedents in the work of macroeconomists who study the real business cycle, such as Kydland and Prescott (1996). The approach is to map out the model's response functions for relevant shocks in time series data. This is important to the regional focus of the study, as it provides an indication of how much price versus quantity typically handles most of the adjustment in this region.

With Oilseed Historical Data

The approach makes use of 1991-2011 oilseed price and quantity data from the United States of Department Agriculture (USDA), National Agricultural Statistics Service *Crop Production, Grain Stocks, and Crop Values* and USDA, Foreign Agricultural Service, *Global Agricultural Trade System*. This is done for canola, since this has the longest historical record in the Northwest, and since it comprises much of the production considered as ‘oilseeds’ within the SAM.

The process of calibration can be explained by first examining Figures 3 and 4, which report actual canola output and prices for the U.S. from 1991-2011. There are trends in both of these, related to factors such as technology change or general inflation in the economy. Abstracting from these trends, the associated year-to-year volatility can provide information about the extent that prices adjust to output shocks, which are mostly caused by weather (Valenzuela et al., 2007).

It is worth asking why it is important to study the relationship between prices and quantities when there is a shock to output. The idea is that if the model can do a good job replicating historical price-quantity relationships, then it should do a good job of representing a shock to final demand with respect to new biojet demand.

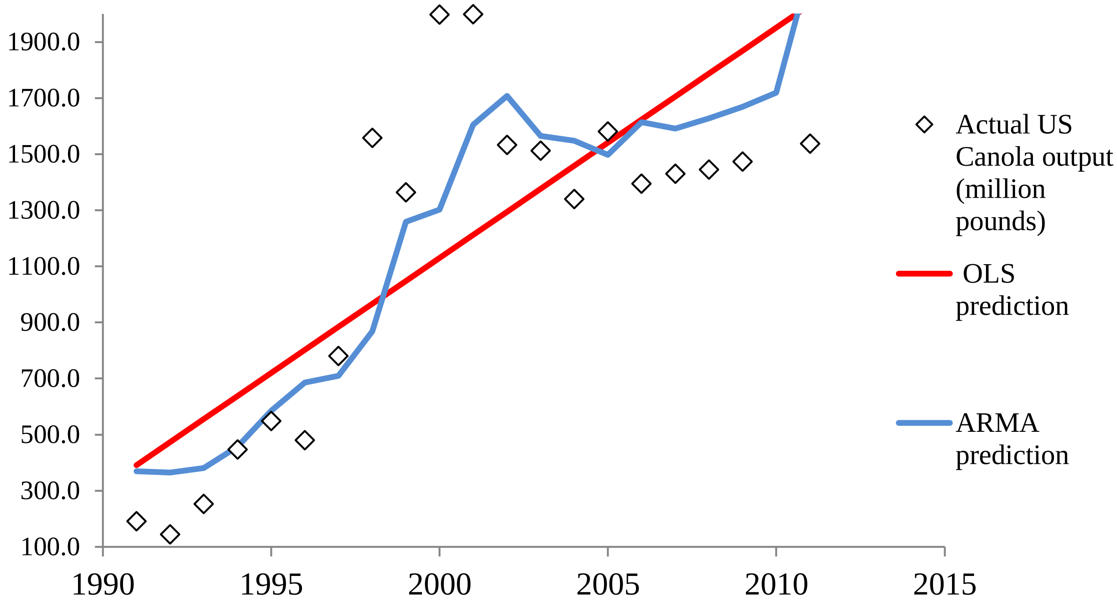

Figure 3. Actual versus Predicted U.S. Canola Output (million pounds)

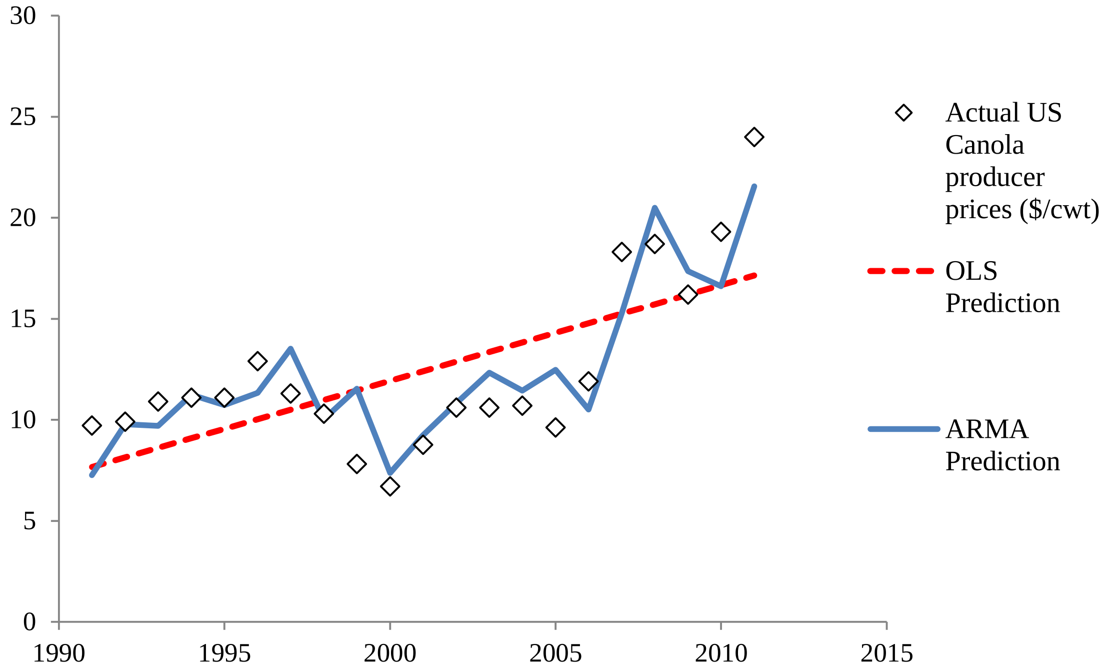

Figure 4. Actual versus Predicted U.S. Canola Price ($/cwt)

The first task is to detrend the time series. Two alternative ways of detrending the time series are used: a simple ordinary least squares (OLS) approach (in which only the year of an observation, and an intercept, are included on the right hand side of the model) and an autoregressive moving average (ARMA) model. Fitted models are presented visually in Figures 3 and 4.

Residuals from the output regression (Figure 3) are used to calculate percentage changes in output by year. These percentage changes are plugged into the CGE model. It then reports the associated price change. If output was well below trend (such as in 2009 and 2010), then we would expect the supply curve to shift to the left, and price would rise, for example. On the other hand, when output was above trend for a year (such as in 2002 and 2003), then we would expect the supply curve to shift to the right, and price would fall. The extent to which price change is an empirical question, however, ultimately depending on price elasticities of demand in other regions (who can absorb extra supply, for example) as well as the ease of trading oilseeds across regions (which is influenced by barriers such as transport costs and tariffs). If the model is calibrated correctly, then we would expect the magnitude of the simulated price changes to match the magnitude observed in the historical record.

The magnitude of historical price changes can be characterized by the second moment of the residuals from the regressions in Figure 4. The standard deviation of residuals from the simple trend line regression of actual canola prices is 15.4 under the ARMA approach, and 25.1 under the OLS approach (Table 5). The latter predicts higher volatility since it forces a linear relationship, and thus is less able to mimic year-to-year differences.

Table 5. U.S. Canola Prices Volatility

Standard Deviation		15.0	25.1	15.4
MKY	OLS % deviation from predicted Canola output (trend)	Simulated PNW Canola price of PNW output (%)	Actual Canola price (% deviation from trend) (OLS)	Actual Canola price (% deviation from trend) (ARMA)
1994	-29.84	16.66	22.21	-1.25
1995	-23.81	13.3	16.15	3.44
1996	-40.08	22.14	28.60	13.77
1997	-11.69	7.38	7.57	-16.39
1998	61.24	-21.94	-6.19	2.59
1999	30.09	-13.15	-31.72	-32.19
2000	76.79	-25.29	-43.74	-8.86
2001	64.83	-22.76	-29.29	-5.09
2002	18.45	-8.8	-17.68	-2.08
2003	9.85	-5.05	-20.60	-13.99
2004	-8.18	4.98	-22.60	-6.52
2005	2.60	-1.42	-32.72	-22.92
2006	-14.09	9.14	-19.45	13.23
2007	-16.09	10.68	20.02	19.83
2008	-19.15	13.19	18.95	-8.72
2009	-21.14	14.91	0.03	-6.68
2010	25.57	-11.54	15.78	16.18
2011	-24.37	13.59	39.99	11.36

The upshot is that for the validation, the actual level of price volatility is expected to lie between these two extremes of 15.4 and 25.1 (Table 5). In other words, if the model is calibrated appropriately, it should generate price movements that have a similar magnitude. As mentioned above, the simulated standard deviation of U.S. canola price changes is 15. This lies within the 15.4-25.1 range. If it was lower than this, simulated price responses would have been too muted. This would arise, for example, if trade across regions is modeled as overly costless and easy. If the responses were higher than 25.1, then price would be too sensitive. In this case, some slack would need to be built into the model. This could be accomplished through increasing the magnitude of the Armington elasticities, for example. This does not need to be done, however, as the results obtained above appear to be reasonably consistent with the historical experience.

With Wheat Historical Data

Valenzuela et al. (2007) incorporate agricultural commodities supply variation into a global computable general equilibrium model as yield shocks at the individual sector level. Unlike them, this study is focusing on the yield and price fluctuations on a regional commodity in the Pacific Northwest computable general equilibrium model. The detailed procedures on calibration of wheat yields and prices distribution are the same as above. I first regress the actual soft white winter wheat mean yield on squared year (linearize the relationship by squaring the explanatory variable “year”). Similarly, since I am only interested in variability in yields due to weather , instead of taking standard deviation of yield itself, the detrended residuals from the regression are used to calibrate the percentage deviation from trend for each year (residuals*100/predicted values), which are listed in the last column of Table 6. The percentage deviations from the regression are then translated into the CGE model as the productivity shocks. These shocks will then generate endogenous changes in the Pacific Northwest white winter wheat output and prices for each year. Lastly, standard deviations of predicted (simulated) soft white winter wheat from this PNW CGE model are then compared to the observed outcomes for year 1979-2008. The model is calibrated such that price volatility predicted by the model arising from yield shocks, is similar to the actual price volatility that is in the historical record for the region.

The actual soft white winter wheat mean yield (bushel per acre) from 1979-2008 in the PNW region are calculated based on the data from the National Agriculture Statistics Service (NASS), which is represented by the blue line in Figure 5. The red straight line represents the predicted soft white winter wheat yield for year 1979-2008. Data on soft white winter wheat prices (dollars per bushel) are collected from USDA ERS, which is shown in Figure 5.

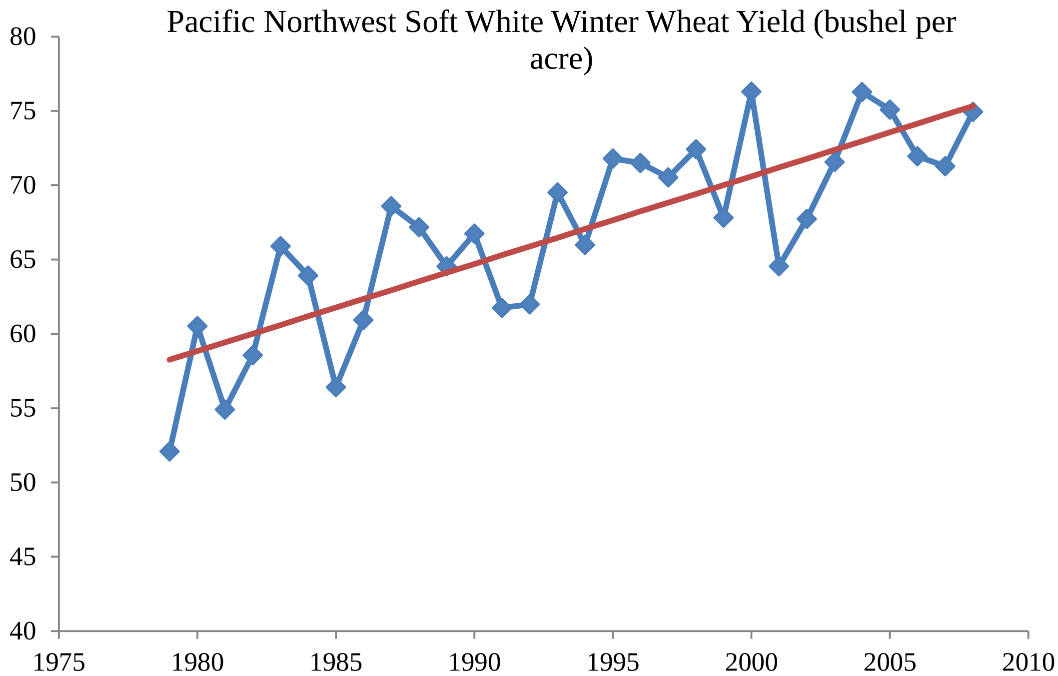

Figure 5. Actual versus Predicted Soft White Winter Wheat Yield in PNW region (bushel per acre)

Table 6. Actual Wheat Price Percentage Deviation from Trend

Observation	Predicted real price	Residuals	Real soft white winter wheat price (% deviation from trend)
1979	3.73	0.19	5.07
1980	3.73	0.20	5.37
1981	3.73	-0.05	-1.25
1982	3.73	0.20	5.27
1983	3.73	-0.19	-5.04
1984	3.74	0.04	0.95
1985	3.74	-0.01	-0.19
1986	3.74	-0.38	-10.24
1987	3.74	0.13	3.42
1988	3.74	0.73	19.63
1989	3.75	-0.30	-8.04
1990	3.75	-0.52	-13.98
1991	3.75	0.55	14.70
1992	3.75	-0.28	-7.45
1993	3.75	-0.21	-5.48
1994	3.76	0.14	3.82
1995	3.76	0.42	11.12
1996	3.76	-0.38	-10.00
1997	3.76	-0.41	-10.83
1998	3.76	-0.41	-10.83
1999	3.76	-0.29	-7.71
2000	3.77	-0.03	-0.71
2001	3.77	0.11	2.93
2002	3.77	0.19	4.95
2003	3.77	0.17	4.39
2004	3.77	-0.28	-7.48
2005	3.78	-0.32	-8.41
2006	3.78	0.46	12.28
2007	3.78	0.39	10.43
2008	3.78	0.13	3.33

Note: All values are in percentage change.

Table 7. Actual Wheat Yield Percentage Deviation from Trend

Observation	Predicted yield	Residuals	% deviation from predicted yield (trend)
1979	58.25	-6.17	-10.59
1980	58.84	1.67	2.85
1981	59.42	-4.52	-7.60
1982	60.01	-1.45	-2.42
1983	60.59	5.31	8.76
1984	61.18	2.75	4.50
1985	61.77	-5.36	-8.68
1986	62.35	-1.43	-2.30
1987	62.94	5.64	8.96
1988	63.53	3.65	5.74
1989	64.11	0.43	0.67
1990	64.70	2.04	3.15
1991	65.29	-3.55	-5.44
1992	65.88	-3.90	-5.92
1993	66.47	3.05	4.58
1994	67.06	-1.07	-1.60
1995	67.65	4.16	6.14
1996	68.24	3.27	4.79
1997	68.83	1.71	2.48
1998	69.42	3.01	4.33
1999	70.01	-2.19	-3.14
2000	70.60	5.69	8.06
2001	71.19	-6.65	-9.34
2002	71.78	-4.05	-5.64
2003	72.37	-0.81	-1.12
2004	72.96	3.31	4.54
2005	73.56	1.53	2.08
2006	74.15	-2.20	-2.96
2007	74.74	-3.47	-4.64
2008	75.34	-0.40	-0.53

Note: All values are in percentage change.

Table 8. Model Validation with Wheat Data

MKT Year	Simulated Composite commodity price (%)	Simulated domestic price of domestic output (%)	Simulated Producer price (%)	Actual (nominal) wheat price (% deviation from trend)	Real (Deflated) price (% deviation from trend)
Standard Deviation	4.7	9.5	4.8	24.3	8.6
1980	-2.22	-4.47	-2.20	20.34	5.37
1981	6.93	14.29	7.19	16.61	-1.25
1982	2.04	4.16	2.07	18.61	5.27
1983	-6.3	-12.56	-6.13	7.13	-5.04
1984	-3.42	-6.88	-3.39	1.83	0.95
1985	8.03	16.6	8.38	-1.92	-0.19
1986	1.93	3.94	1.96	-24.75	-10.24
1987	-6.44	-12.83	-6.27	-21.06	3.42
1988	-4.3	-8.62	-4.23	18.10	19.63
1989	-0.49	-1	-0.50	8.40	-8.04
1990	-2.39	-4.82	-2.38	-24.34	-13.98
1991	4.77	9.79	4.91	0.55	14.70
1992	5.24	10.75	5.40	-0.71	-7.45
1993	-3.48	-6.98	-3.44	-15.34	-5.48
1994	1.33	2.71	1.35	-0.97	3.82
1995	-4.57	-9.15	-4.49	26.10	11.12
1996	-3.64	-7.31	-3.60	11.01	-10.00
1997	-1.92	-3.88	-1.92	-11.83	-10.83
1998	-3.3	-6.63	-3.27	-33.31	-10.83
1999	2.66	5.42	2.71	-31.96	-7.71

Note: All values are in percentage change.

Table 9. Model Validation with Wheat Data (Continued)

MKT Year	Simulated Composite commodity price (%)	Simulated Domestic price of domestic output (%)	Simulated Producer price (%)	Actual (Nominal) wheat price (% deviation from trend)	Real (Deflated) price (% deviation from trend)
Standard Deviation	4.7	9.5	4.8	24.3	8.6
2000	-5.84	-11.66	-5.70	-33.53	-0.71
2001	8.74	18.09	9.14	-20.16	2.93
2002	4.96	10.19	5.11	-6.29	4.95
2003	0.91	1.85	0.92	-10.56	4.39
2007	4.03	8.26	4.13	77.14	10.43
2008	0.43	0.87	0.43	46.14	3.33

Note: All values are in percentage change.

Chapter 4. General Equilibrium Analysis of Biofuel Economics in the Pacific Northwest

4.1 Background on Oilseed-based Biofuels

Biofuels have become heavily studied and promoted in the last 10 years in the United States, in many cases because they are viewed as a means of promoting local economic development and regional vitality (Jaeger and Egelkraut, 2011). The biofuels sector of the Pacific Northwest (PNW) has lagged behind that of other regions but is currently undergoing intense study and development (Yoder et al., 2010; Stein, 2012). A focal point of this interest is an oilseed known as camelina, which can be processed into a high-grade bio-based jet and diesel fuel for military and commercial purposes. This oilseed has been grown for thousands of years in Europe and Central Asia, and is considered to be an ideal energy crop because of its low input requirements, suitability for marginal soils, and natural competitiveness with weeds (Putnam et al., 1993; Stein, 2012). It can potentially be a rotation crop in the PNW's dry inland agriculture, e.g., as an additional rotation in Wheat-Fallow systems. It performs well under drought conditions (Hulbert et al., 2012), and its oil has good properties for biodiesel. However, few acres in the PNW are presently devoted to oilseeds, let alone camelina. In turn, oilseed processors are not generally making biofuel from it, although they generally have the ability to do so (Stein, 2012).

At the present time, the aviation sector, both military and commercial, is making plans to offset petroleum-based jet fuel with jet fuel created from the oilseed camelina. The military is motivated in part by security concerns, seeking to diversify fuel sources to include "home grown" camelina-based fuel. The United States Navy has set a goal of 50% alternative energy use by 2020, with large investments going to the Navy biofuels program. In turn, the Air Force is interested in camelina-based jet fuel, recently demonstrating that planes can be flown on such a mix. Operators of commercial airlines and airports, including PDX and SEA, are also interested in using U.S.-grown biofuels, again for supply diversification, and perhaps for perceived environmental reasons, such as possible reduction in net greenhouse gas emissions. The U.S. Navy, Air Force, and numerous commercial airlines, such as Japan Airlines and KLM Royal Dutch Airlines, have been flying planes fueled with camelina-based jet fuel (Abbott, 2011). The U.S. Environmental Protection Agency recently declared that aviation biofuel – biojet, in industry parlance – is eligible to generate Renewable Identification Numbers that can be traded on the open market. This should additionally help with biojet's long-term viability (Wang and Kolhman, 2013).

In contrast to biofuels in other parts of the country, this emerging biofuels market is being driven primarily by final demanders who are motivated to diversify their sources of fuel. One might call this a "demand pull" approach to biofuels, rather than the "supply push" associated with other crops and other regions.

4.2 Objectives

The general purpose of this study is to offer an economic analysis of the potential development of a regional biofuel system. One objective is to quantify how prices and markets in the region will need to adjust, including sectors from which labor and capital will need to be drawn to meet the demand. Another objective is to evaluate the extent to which increased demand for oilseeds can be met by local sources, as opposed to sources outside the Pacific Northwest. One of the selling points of camelina is that it can be a “local” source of fuel. However, even if the oilseed feedstock is produced by local farms, does this imply that the processing will also necessarily occur within the region? And if processors are located here, will camelina feedstock necessarily be procured locally, or imported from outside the region? A third general objective is to examine the potential efficacy of different types of subsidies that are likely to be necessary to stimulate the development of the market. A full welfare accounting of the policy is not within the scope of the paper, but light will be shed on the likely impact of subsidies at different stages of the supply chain.

To quantify what the Pacific Northwest regional economy would look like with a functioning oilseed-biofuels system, a general equilibrium model is used for the region. The major benefits of the computable general equilibrium model is that it can simultaneously account for a number of different sectors key to the analysis, including the transportation sector, oilseed production sector, oilseed processing sector, and livestock sector. Accounting for the livestock sector is important because meal is a byproduct of the oil extraction process and could be used as a livestock feed additive.

However, use of camelina meal for beef cattle, broiler chickens, and laying hens is at present restricted by the Food and Drug Administration to approximately 10% of commercial livestock feed mixes, for swine feed rations only up to 2% (Stein, 2012), as its characteristics and safety are not really known. A market for byproducts may need to exist, however, in order for camelina-based biofuel to be economically feasible.

It is also important to account for competing production sectors, in particular, cereal grains. Proponents of camelina believe it can be incorporated into wheat rotations without displacing food products that are presently grown in the PNW. If supply of these is curtailed, their prices will rise, having detrimental effects on buyers, including firms and consumers.

It is also important to account for the petroleum sector. There will be partial substitution of camelina-based biofuels for traditional petroleum sources. Imports of foreign-sourced oil may decline to some extent. By using a CGE model, underpinned by IMPLAN (IMpact Analysis for PLANning) data (IMPLAN, 2012), the model can account for all these sectors in an exhaustive framework.

4.3 Literature Review

The study contributes to the existing literature in at least two ways. First, it identifies conditions under which different stages of a vertical supply chain can flourish within a given region. In a sense, it addresses the question of how policies can be designed to encourage development that targets the local level.

This policy focus separates it from related studies of biofuels, such as Yoder et al. (2010). They carry out a CGE analysis of biofuels with a special focus on Washington State. They estimate the availabilities of some feedstock including canola, corn, sugar cane, and sugar beets, and assess the potential for biofuels production to occur in the Northwest. Many ethanol and biodiesel processors in Washington State import nearly all of their virgin feedstock, despite having the potential to produce it. This is another motivation for the present study, which is distinct in focusing on camelina, new developments in aviation biojet demand, the spatial interplay of feedstock production versus processing, and on subsidies at different stages of the supply chain. Conditions under which processors are likely to import, versus rely on local sources, are examined, making this study notably different than all preceding ones.

The study also complements work by Diebel and Ball (1999), Walsh (2000), and Stein (2012). Building on the first two studies, Stein (2012) estimates potential supply curves for camelina in Idaho, Montana, Oregon, and Washington with a break-even price approach. His results suggest that given current market conditions, the supply of camelina in the Northwest will not be enough to meet biofuel targets without an increase in government promotion. This finding serves as an important motivation for this study. Unlike the approach proposed in this study, Stein uses a partial equilibrium framework and looks mainly at adoption by farmers, as opposed to the links between different market players. He does not examine policy, or consider the regional dimension that is paramount to this study.

The present study is also complementary to Jaeger and Siegel (2008), who assess the economic potential of biofuel production in Oregon for six oilseeds as potential feedstock, including camelina. They synthesize information on the cost of production, yield, other technical parameters, market prices, and government subsidies and tax credits. In contrast, this study generates new results, drawing upon a detailed economic model and data base, and considers important new developments that have occurred since their study was published.

The second major contribution to the literature is the presentation of a means of model validation that has little or no precedent in the literature on regional computable general equilibrium models. The approach does have precedent in the macro-economic literature, where large-scale models are parameterized to match certain stylized facts (Kydland and Prescott, 1996). It might be useful to motivate model validation by way of an example. Consider a spike in the regional demand for oilseeds caused by new regional demand for a product (biojet) made from it. Given an upward sloping supply curve for the underlying product, quantity supplied may rise by proportionately less than price rises. In other words, to get a certain quantity of feedstock, price might have to rise proportionately more than the targeted quantity change. It is also possible that price may rise proportionately less.

4.4 Supply Chain in the Model

A simplified version of the supply chain captured in the model is displayed in Figure 6. The top of the figure depicts two of the sectors that are central to the analysis: the transportation sector and the livestock sector. These are central because they directly purchase the two co-products generated from processed camelina: oil (for transportation) and meal (for livestock feed).

The second row of Figure 6 shows that the transportation sector can use traditional fuel as well as oilseed-based fuel. The livestock sector, in turn, can use oilseed meal or other feeds captured within the CGE model. The model parameter associated with this choice is denoted `ica` and will be discussed in more detail below.

The third row of Figure 6 depicts a composite processed oilseeds sector. This sector produces oilseed-based fuel and oilseed meal in fixed proportions. This sector is "composite" because activity in this sector can take place either outside the Northwest, or within the Northwest, as seen in the fourth row of Figure 6. The precise composition is given by an Armington (1969) CES functional form, with the elasticity in the model denoted as `esubd` (Lofgren et al. 2002). Imported oilseeds (and all other products) are differentiated from Northwest-marketed products. More generally, the `esubd` parameter allows for imperfect substitution between region- produced goods, and goods from the rest of the U.S. and the rest of the world. The higher the value of `esubd`, the easier is substitution between Northwest-produced and imported oilseeds.

A further level of the supply chain can be seen on the fourth level of Figure 6 where there is a box representing the Northwest oilseed processing sector. This sector can use unprocessed oilseeds that are produced either within the Northwest, or imported from outside the Northwest. This too is governed by a CES function, with the elasticity denoted as `esubd`.

Looking to the bottom left corner of Figure 6, it is seen that unprocessed oilseeds from outside the region come either from the rest of the United States, or the rest of the world. The relevant elasticity is `esubm`. Looking at the bottom right corner of Figure 6, it is seen that oilseeds produced in the Northwest (i.e., oilseed farming) can either be used within the region, or sold outside the region. The relevant elasticity is `esubs`. Finally, sales to outside the region can go to the rest of the United States, or the rest of the world. This elasticity is given by `esube`. The supply of exports outside the region is derived from a constant elasticity of transformation (CET) function (Lofgren et al. 2002). It specifies the value of exports as a function of the ratio of region-level and U.S./international export prices under a fixed exchange rate. The export composite is a function of the price of exports to the rest of the U.S. and foreign sources.

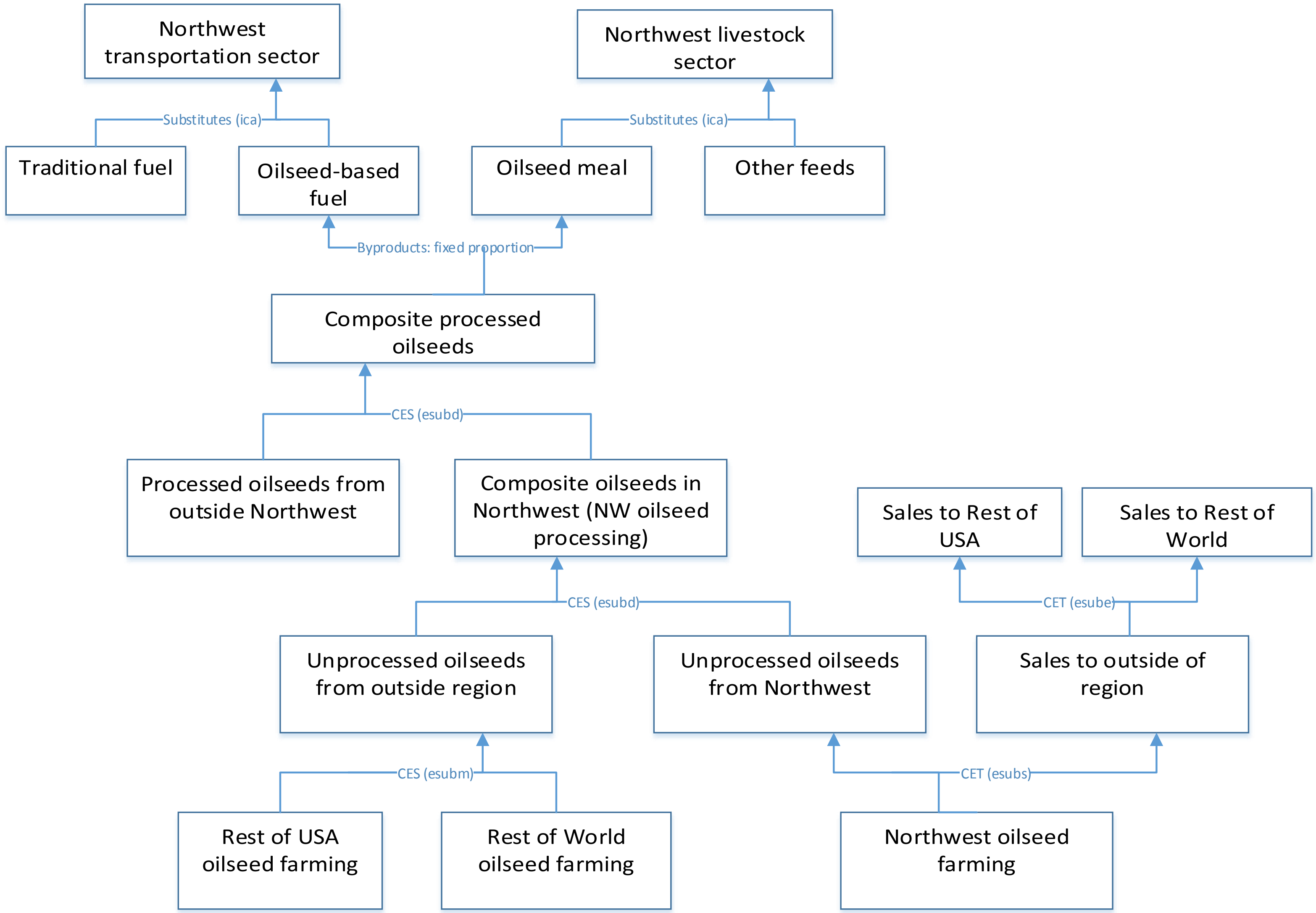

Figure 6. Sectoral flowchart

4.5 Data and Parameterization

The model described above is a simultaneous system of non-linear equations written for General Algebraic Modeling System (GAMS) software. The joint equilibrium values of the endogenous variables can be calculated using the PATH non-linear programming solver. The theoretical model above is adapted to the region using IMPLAN data obtained for this project (IMPLAN, 2012). These data, which are based on the structure of the National Income and Product Accounts, are used to create a Social Accounting Matrix (SAM). The SAM is a series of accounts which describe flows between agents, commodities, factors, and institutions including government. For this study the year 2011 is used, and the Pacific Northwest is represented as the states of Oregon, Washington, and Idaho. This is treated as a single geographic unit. This region is distinguished with the rest of the United States, and the rest of the world.

The IMPLAN data distinguish 509 distinct sectors of the economy. To make the analysis practical, most of these are aggregated into broadly defined manufacturing and service sectors. The aggregated 11 sectors examined in this study are reported in Table 10 (the aggregation of the 509 IMPLAN sectors is available in the Appendix). Sector 1 and 2 are the most important and interested ones in this biofuel study, which are unprocessed and processed oilseeds production sector, respectively. Sector 3 represents the oil industry including refined petroleum and related products. Sector 5 is the Pacific Northwest aviation sector.

Table 10. Sectors

No.	Sector Name
1	Oilseed farming (unprocessed camelina production)
2	Oilseed processing and refining (processed camelina production)
3	Refined petroleum and related products
4	Manufacturing
5	Transportation services
6	Animal production including cattle, poultry, eggs
7	Other agriculture (all other crop farming, etc)
8	Processed food
9	Construction, utilities, and mining
10	Wholesale and retail trade
11	Other services and miscellaneous

The SAM is used to calibrate a number of model parameters, e.g., the production function shift and share parameters for each sector. During calibration, all prices are set to unity and the base year factor levels and SAM flows are substituted into the model as equilibrium values of model variables. The process is similar to maximum likelihood estimation with one observation, in this case for the year 2011.

Table 11 is the empirical SAM with 11 aggregated key sectors for the base year 2011. All values are in millions of 2011 dollars.

The model also contains a number of free parameters set by the user. Many of the parameters are set to values commonly employed in the literature (e.g., Lofgren et al., 2002; Holland, Stodick, Devadoss, 2004; Yoder et al., 2010). For example, the elasticity of substitution between capital and labor in the production function (`esupb`) is set at 2. The rest-of-world export elasticity of demand for oilseeds is set to -1.175, since this value is estimated in Reimer et al. (2012). Values of `esubd` and `esubs`, which were introduced above, are from Bilgic et al. (2002). Based on their estimates, they are set at 1.447 and 1.339 for unprocessed and processed oilseeds, respectively. Values of `esube` and `esubm`, also introduced above, are from (Hertel et al., 2002). Based on their estimates, they are set at 4.9 and 5.2 for unprocessed and processed oilseeds, respectively.

Table 11. The SAM for Biofuel Sectors (in millions of 2011 dollars)

	OILSEED	OILSPROC	OIL	MANUF	TRANS	LIVESTOCK	OTHAGR	FOOD	CONSUTILM	WRTRADE	SERVICES
OILSEED-C	1.9			86.5		0.2	1.9	17.4	419.0		
OILSPROC-C		867.8		15.0	70.1			81.8		15.5	326.8
OIL-C		91.2	46.0	1226.4	44.1		3.6	466.6	117.2	24.2	225.4
MANUF-C	6.3	3804.5	947.9	267117.1	16682.2	1682.5	6784.8	8779.8	21304.2	8864.8	23201.3
TRANS-C	0.0	0.2	0.0	131.3	85.9	3.1	44.1	0.1	5.3	30.2	150.27
LIVESTOCK-C	0.0	34.3		4.6	1.2	1189.4	30.4	3131.3	1.9	0.0	3.3
OTHAGR-C	0.6	1995.6		2915.6	6.0	971.8	1235.1	4134.3	995.8	21.0	218.6
FOOD-C		1401.2	1.1	930.4	545.8	12.5	52.1	3567.9	155.0	222.5	2356.4
CONSUTILM-C	1.5	650.3	36.5	27968.8	890.9	1404.5	2651.1	1517.7	4800.8	747.7	4064.1
WRTRADE-C	0.0	29.4	5.1	4216.1	1165.6	2.9	9.3	102.6	123.2	1617.5	658.8
SERVICES-C	0.1	82.6	11.9	16771.4	1072.4	20.7	58.3	327.5	716.0	912.5	1742.0

4.6 Counterfactual Scenarios

Recall that the objective of the study is to research policies that might facilitate the development of a biofuel supply chain to meet the final demands of transportation providers. Four counterfactual scenarios, or cases, are developed. Before getting into the details of these, aspects that are common to all four cases are first described. Common assumptions about supply targets and processing costs are given in Table 12. These were developed based on information provided in Schumacher (2008), Stein (2012), and Hodges and Rahmani (2012).

For all cases, it is assumed that the production cost of camelina feedstock is 13 cents per pound and the extractable oil is 32%. The seed to oil conversion factor is then 24.22 pounds per gallon. The cost of feedstock for oil is assumed to be $3.15 per gallon. The cost of pressing seeds to oil is 54 cents per gallon, such that the total cost of oil is then $3.69 per gallon.

Boeing has had a projection that by 2015, biojet will account for 1% of the industry's 600 million gallons/year of jet fuel consumption (Wang and Kolhman, 2013). A slightly longer view is taken in this study. It is assumed that eventually, biojet will account for 2% of the industry's 600 million gallons/year of jet fuel consumption. This corresponds to a target of 12,000,000 gallons of fuel per year (Table 11).

Based on all of the above assumptions, the total cost to the aviation sector to buy camelina jet fuel is $44,261,250 (Table 12, Row 9). The total reduction of in purchases of regular jet fuel by aviation sector would be $36,000,000.

Table 12. Assumptions under 12 million gallon per year target

Activity	Assumed value	Targeted change for Cases 1-4 (`qint` parameter)
Production cost of camelina feedstock	$0.13/pound	
Camelina extractable oil	32%	
Seed-oil conversion factor, lbs/gal at 32% oil content	24.22 lb/gal	
Cost of feedstock for oil	$3.15/gallon	
Cost of pressing seeds to oil	$0.54/gallon	
Total cost of oil	$3.69/gallon	
Target: Oilseed-based fuel per year	12,000,000 gallons	
Value of camelina bought by processing sector		$37,781,250
Total cost to aviation sector to buy camelina jet fuel*		$44,261,250
Total reduction of in purchases of regular jet fuel by aviation sector*		$36,000,000
Value of camelina meal produced and sold to Northwest livestock users** (equal to reduction in use of other agriculture, e.g., grains, by Northwest livestock users)		$29,643,750

Notes: * Assume price of jet fuel is $3 per gallon, based on a U.S. Gulf Coast Kerosene-Type Jet Fuel Spot Price FOB (dollars per gallon) of $3.056 per gallon.
** Assume 16.5 pounds of camelina meal produced alongside each gallon of camelina fuel. Price of oilseed meal is taken as 15 cents per pound, which is taken from the USDA for July 2013.

Before implementing the above changes, it is worthwhile to note the baseline values of inter-industry relationships for the year 2011 in the IMPLAN data assembled for the study area (Washington, Oregon, and Idaho). In the 2011 baseline, processed oilseed use by Northwest fuel users was $70.1 million, while refined petroleum use by Northwest fuel users is $44.0 million. The Northwest livestock industry, in turn, uses no processed oilseeds but uses approximately $971.8 million worth of other agriculture (e.g., grains) in its industry.

The rightmost column of Table 12 then presents the changes in these four variables that arise when the 12,000,000 gallon per year target is implemented. These changes are common to all of the scenarios that will be developed below. Northwest fuel users increase use of processed oilseeds (e.g., biojet) by $44,261,250, or 63.9%. Other agriculture use by Northwest livestock industry decreases by $29,643,750, or 3.0%, while processed oilseed use by the livestock industry rises by $29,643,750. Finally, $37,781,250 worth of camelina is now bought by the oilseed processing sector.

It is important to emphasize that these changes are assumed as part of all of the counterfactual experiments. The model parameter that can induce these changes is `ica`. It is calibrated to induce the targeted changes in the rightmost column of Table 11. Figure 2 shows where and how `ica` is implemented. Specific coding used for the shocks, along with data and model code, are available on a website developed for this study.

4.7 Results

Case 1: No policy

Case 1 is an initial exploratory analysis to show how introduction of a new oilseeds crop such as camelina into the PNW economy will change prices, incomes, and other economic variables. Results are summarized in Table 13. The next four columns report predicted changes in 2011 million dollars.

Table 13 provides detail on the regional supply and demand changes for processed oilseeds (representing biojet and camelina meal) and unprocessed oilseeds (i.e., camelina). Results are now discussed by case.

Under Case 1, regional production of processed oilseeds (e.g., biojet and camelina meal) rises by 2.02% to $10,820.0 million (Table 13). Imports of processed oilseeds rise by 2.4% to $1,192.3 million. Regional output of unprocessed oilseeds, meanwhile, rises to $68.1 million, an increase of 3.7%. Unprocessed oilseed imports from outside the region increase by 7.4% to $539.2 million, such that total supply is $607.3 million instead of $567.8 million in the baseline.

The key thing to observe here is that the effect on the regional economy is mixed. Nearly all of the increased supply of processed camelina (i.e., biojet) comes from new supply from within the region (88.5% = 100 * 214.1 / 241.8). By contrast, most of the demand for additional camelina (the raw feedstock) is met through imports from outside the region (94%). In other words, only 6% of the additional demand comes from the Northwest region (6% = 100 * 2.5 / 39.5). So without policies in place, Northwest farmers are not receiving sufficient incentive to ramp up production in a meaningful way. The increase in demand is easily met by a small percentage expansion of oilseed farming outside the region. Because of the high integration of spatial markets, regional prices rise by only 0.1% and 1.2% for processed and unprocessed oilseeds, respectively. The ease of substitution between regions implies that Northwest farmers need not necessarily increase their production of oilseeds to have a functioning biojet market.

The point here is that the modest target envisioned in the counterfactual (2% of the aviation industry's fuel needs met with camelina), can be met largely if processing occurs in the Northwest, but with most (94%) of the raw feedstock imported into the region.

Table 13. Supply and Demand for Processed and Unprocessed Oilseeds

	2011 baseline values	Case 1: Demand change only	Case 2: Subsidize oilseed processing	Case 3: Subsidize oilseed farming	Case 4: Higher import costs
Processed oilseeds (biofuel and meal)					
Regional output (QX)	10,605.9	10,820.0	22,911.4	11,110.2	10,788.2
Imports (QM)	1,164.6	1,192.3	1,991.8	1,192.3	773.7
Total regional supply	11,770.5	12,012.3	24,903.2	12,302.5	11,561.9
Regional demand (QQ)	4,037.5	4,128.3	7,645.9	4,174.4	3,781.2
Exports (QE)	7,733.0	7,884.0	17,222.0	8,127.9	7,717.1
Total regional demand	11,770.5	12,012.3	24,867.9	12,302.3	11,498.3
Regional price (PD)	--	0.1%	-10%	-1.0%	17.2%
Unprocessed oilseeds (e.g., camelina feedstock)					
Regional output (QX)	65.6	68.1	70.5	85.1	84.8
Imports (QM)	502.2	539.2	586.7	539.9	529.8
Total supply	567.8	607.3	657.2	625.0	614.6
Regional demand (QQ)	527.0	565.4	614.3	570.7	565.9
Exports (QE)	40.9	42.0	42.9	54.1	46.8
Total regional demand	567.9	607.4	657.2	624.8	612.7
Regional price (PD)	--	1.2%	3.3%	-10%	5.4%
Regional GDP	--	0.02%	0.9%	0.1%	0.1%
Payments to regional labor	--	0.02%	0.9%	0.1%	0.1%
Payments to regional capital	--	0.02%	1.1%	0.2%	0.1%

Note: Values are in 2011 $ million unless otherwise noted.

Case 2: Subsidize oilseed processing

Suppose that regional policymakers are unhappy with the "base case" above, and want to encourage more of the raw feedstock (camelina) to be sourced locally. They therefore subsidize sales of local processed oilseeds (including biojet and camelina meal) such that the regional price falls by 10%. Processed camelina from outside the region is not subsidized, however, implying that only the price of regional processed camelina is made lower for final demanders (whether they are in or outside the Northwest region).

This 10% target is somewhat arbitrary, yet not inconsistent with what commonly happens in the biofuels industry. This particular policy mechanism is typically through tax credits to biofuel processors, and tariffs on biofuel imports. To implement this, a sales tax parameter denoted `tqs` is manipulated within the model. In particular, this parameter `tqs` is set to be –0.638 for processed oilseeds. The negative value signifies that instead of a tax, there is a subsidy. This generates a 10% lower regional price of processed oilseeds.

Note that as before, this scenario allows that the product of interest, camelina, produces not just oil, but also meal, which is likely to be useful mostly as a livestock feed additive.

The results of this counterfactual can be seen by looking back to Table 13. When processed oilseeds from the region (only) are subsidized, regional production of processed oilseeds rises by 116.0% to $22,911.4 million (Table 13). Total supply of processed oilseeds is $24,903.2 million instead of $11,770.5 million in the baseline.

The increased regional production comprises 93.7% of this increase, so the policy clearly stimulates regional processing (93.7% = 100 * 12305.5 / 13132.7). Regional output of unprocessed oilseeds, meanwhile, rises to $70.5 million, an increase of 7.5%. Yet unprocessed oilseed imports from outside the region increase by 16.8% to $586.7 million, such that total supply is $657.2 million instead of $567.8 million in the baseline. In the end, the rise in supply of raw feedstock (unprocessed oilseeds) comes almost entirely from imports from outside the region (94.5% = 100 * 84.5 / 89.4).

With the processed oilseed subsidy, prices for unprocessed oilseeds (the raw feedstock) increase by 3.3%. This induces a small rise in regional production of oilseeds (from $65.6 to $70.5 million), but – as noted – this is swamped by more supply from outside the region. The lesson is that providing subsidies for processing does not imply that production of the feedstock will occur there. The inter-regional substitution possibilities appear to be too great for oilseed processors to source only from the local area.

Suppose that policymakers want to encourage local production as much as possible. They therefore subsidize sales of local processed oilseeds (including biojet and camelina meal) such that the regional price (PD) falls by 10%. To implement this, a sales tax parameter denoted `tqs` is manipulated within the model. This parameter `tqs` is set to be –0.638 for processed oilseeds. This generates a 10% lower regional price of processed oilseeds. Regional production of processed oilseeds rises by 116.0% to $22,911.4 million (Table 13). Imports of processed oilseeds rise by 71.0% to $1,991.8 million. Regional output of unprocessed oilseeds, meanwhile, rises to

$70.5 million, an increase of 7.5%. Unprocessed oilseed imports from outside the region increase by 16.8% to $586.7 million, such that total supply is $657.2 million instead of $567.8 million in the baseline. Total supply of processed oilseeds is $24,903.2 million instead of $11,770.5 million in the baseline.

This scenario allows that the product of interest, camelina, produces not just oil, but also meal, which is likely to be useful mostly as a livestock feed additive. The demand for biojet made from camelina oil is unlikely to be enough of a demand to ratchet up price to level required for farmers, as well as oilseed processors, to be interested. The design of the counterfactuals looks at ways to motivate the development of these incentives.

Case 3: Subsidize oilseed farming (unprocessed oilseeds)

Suppose that policymakers are not happy with the above scenario, and want to encourage local production of the raw feedstock as much as possible. In contrast to subsidizing oilseed processing, they decide to subsidize sales of regionally produced camelina (the unprocessed oilseed feedstock). To implement this, a sales tax parameter denoted `tqs` is manipulated within the model such that there is a 10% fall in the regional price of unprocessed oilseeds (the parameter `tqs` is set to be −15.31 for unprocessed oilseeds; details on the calibration of this parameter are available on request from the authors). Again, as with Case 2, this does not have to be a literal subsidy on sales; it could be a tax credit or some other type of incentive. The key effect is that local oilseeds appear 10% cheaper to processors, and so forth down the value chain (extra-regional oilseeds are not subsidized in this manner). The ability to achieve this target can be seen in Table 13. For Case 2 the regional price of unprocessed oilseeds falls 10%.

Under Case 3, regional production of unprocessed oilseeds rises by 29.7% to $85.1 million. Unprocessed oilseed imports from outside the region increase by 7.5% to $539.9 million, such that total supply is $625.0 million instead of $567.8 million in the baseline. Imports from outside the region constitute 66% of the increased supply. Although this is still the majority of the increase, regional production is much higher than before ($85.1 million versus only $70.5 million for Case 3, which was the next highest case). The subsidy on localized production achieves the desired effect. Yet while a subsidy on oilseed sales clearly has the effect of favoring production within the region, imports of raw feedstock still increase even more (an increase of $37.7 million versus $19.5 million).

Regional production of processed oilseeds, meanwhile, rises by 4.8% to $11,110.2 million (Table 13). Imports of processed oilseeds rise by 2.4% to $1,192.3 million. Total regional demand for processed oilseeds is $12,302.5 million instead of $11,770.5 million in the baseline. The regional processing sector therefore gets a boost as well.

Case 4: Higher import costs

It is possible that the above cases have underestimated the extent to which regional oilseed farming and processing is likely to expand as a result of increased demand for products that can be made from oilseeds. This might have happened if substitution possibilities across locations are less flexible than characterized above. What if transport costs are higher than has been estimated for oilseeds (processed or raw) from outside the region? Or what if – despite the calibration and validation effort – the model has somehow underestimated import costs including tariffs? In this scenario, the parameter governing import costs, `tm`, is assigned to be 0.5 for both processed and unprocessed oilseeds. This effectively forces the imported price to be 50% higher than before (not reported in Table 13). This is arbitrary, yet is a way to account for the hypothesis that transport or tariff costs within the model are higher than in the baseline calibration, or, could become higher in the future. Looking at Table 13, it is seen that this generates a 5.4% rise in regional price of unprocessed oilseeds, and a 17.2% rise in the price of processed oilseeds. (Recall that as with Cases 1-3, biojet in Case 4 is targeted to comprise 2% of future aviation fuel needs in the counterfactual scenario.)

Under Case 4, regional production of unprocessed oilseeds rises 29.1% to $84.8 million. Unprocessed oilseed imports from outside the region increase by 5.5% to $529.8 million, such that total supply is $614.6 million instead of $567.8 million in the baseline.

Regional production of processed oilseeds rises by 1.7% to $10,788.2 million (Table 13). Imports of processed oilseeds fall by 33.6% to $773.7 million. Total supply of processed oilseeds is $11,498.3 million, instead of $11,770.5 million in the baseline.

This is the only case in which imports to the region actually fall despite the large positive demand shock for biojet. This is also only one of two cases in which production of unprocessed oilseeds (raw feedstock) rises substantially (by at least 30%).

The great advantage of this case, of course, is that the biofuel supply chain in this instance relies on the local region (maintaining the assumption that this is a goal of policymakers) without the costliness of subsidies.

4.8 Conclusions

In this study a regional computable general equilibrium model is used to examine supply chain issues in a new oilseeds-based biofuel market for the Northwest region of the United States, focusing on Washington, Oregon, and Idaho. Regional market and inter-sector effects of expanded biojet market are analyzed. The extent that increased demand for oilseeds are met by local sources (i.e., originating in Northwest region) is examined. One idea explored within the study is that the local farm community might benefit from additional demand for a new crop that can be easily grown on their acres. However, it is conceivable that all the oilseed demand will be met by outside suppliers. Or perhaps the policy is not useful for promoting regional production.

As such, the substitution possibilities between the Northwest, Rest of United States, and Rest of World play a large role in the analysis. Oilseed farming in the Northwest increases under all cases that we examine. Yet by far the largest increase is when sales of unprocessed oilseeds in the region are subsidized by 10%. The size of the oilseed processing sector, which is the direct user of oilseeds in the model, is the largest in Case 2 where sales of processed oilseeds in the region are subsidized by 10%.

Subsidizing the processed or unprocessed oilseeds within the region has the effect of encouraging local supplies to develop. It would, however, be an expensive policy. It has been reported that some airports (e.g., Portland International Airport) and airlines (e.g., Alaska Airlines) have expressed tremendous interest in alternative fuels, such as those made from camelina. However, when asked they tend to indicate that they could not pay more for these fuels than what they (and their competitors) pay for conventional petroleum-based fuels (NARA, 2014).

Since an engineering estimate of the cost of camelina-based biojet has been made in Table 12, this can provide a first approximation to the subsidy that would be needed to bring its price directly with the conventional alternative that is currently in use. Since the U.S. Gulf Coast Kerosene-Type Jet Fuel Spot Price FOB is $3.06 per gallon, and the total cost of camelina for oil is estimated to be $3.69 per gallon, the resulting subsidy to equalize these prices is 17.2%. In other words, a subsidy of at least 17% is likely to be needed on each gallon of biojet that is produced to make it comparable in price to the current alternative.

A major theme of this chapter has been to understand the potential for within-region as opposed to outside-the-region development of this industry. The results suggest that ultimately, local sourcing will only occur if (right varietal development) and if trade costs are high, or if there are substantial subsidies on local production.

When trade costs are high, the processor's price change changes very little. There is no incentive for them to undertake this program. It is important to emphasize that these industries, although regional, also rely on exports to the Rest of United States and Rest of World. In Case 4, this industry loses a significant amount of exports. In this case their output rises, but this is very insignificant. It is small enough that there is some question whether it would be a successful project for them, given the start-up costs that be experienced, which is something that is not modeled explicitly within the study at hand. It is concluded that processors need a subsidy to make this worth their time.

It is important to acknowledge that in practice, ramping up oilseed production and processing is not necessarily going to be a smooth linear process. To obtain these production levels, additional oilseed acres and processing plants within the Northwest are required. The counterfactual scenario is not able to mimic the dynamic adjustment process of this, and jumps ahead to present the equilibrium that occurs *after* these expansions have taken place. Since the model provides a snapshot of a future equilibrium once all adjustments have been made, it should be aware that there could be additional costs or supply chain bottlenecks that are unconsidered within this analysis.

While the model shows that new biofuel demand could have important impacts on rural agribusiness, the regional macroeconomic impacts that are estimated here are small. This is mainly because the sectors involved are only a fraction of the overall regional economy. However, there is reason to expect that these effects could be understated. As mentioned above, the scenarios consider only a fairly modest target with respect to how much the aviation sector could diversify their sources of fuel. A higher share seems possible, given the aviation sector's stated demand for fuel source diversification. This qualification should be kept in mind when considering the effects on the regional economy that are predicted within the study.

Chapter 5. Supply and Demand Response for Pacific Northwest Wheat

5.1 Background and Overview

Recall that the second goal of developing a computable general equilibrium model for Pacific Northwest region is to understand how Northwest wheat economy may be affected by long-run drivers, including climate change, population, input costs. This is the other important application of the developed computable general equilibrium (CGE) model and will be discussed from this chapter through chapter 6.

Pacific Northwest agriculture will be affected in future decades by climate change. For instance, climate impacts on wheat yield are likely positive due to warmer and moister winters, and fertilization effect of CO_2. The Northwest wheat sector (farmers and processors/distributors) is the central concern of this study. Potential effects are being studied as part of a research project called Regional Approaches to Climate Change (REACCH). Some of the effects can be measured in terms of total production, productivity (e.g., crop yields or total factor productivity), and the spatial and temporal distribution of these physical outcomes and economic impacts (Antle, 2009). However, many of the economic uncertainties such as commodity and input prices, production technology, and policies, as well as increased probability of disturbances associated with a changing climate cannot be modeled, but they could be represented in regional Representative Agricultural Pathways. There is interest to understand how these effects will affect the wheat markets in the Pacific Northwest region.

The connection of RAPs to the computable general equilibrium model is made through a series of hypothetical scenarios, that is, model-specific parameters that are consistent with a pathway. Key economic relations are estimated econometrically using historical data, including a foreign export demand decision model and a Northwest wheat output supply model.

There are two major benefits of doing some of this work using econometrics. First, this allows us to consider important economic variables that are otherwise not in the CGE model itself. For example, some of the key predictions coming out of the RAPs concern the potential future export demand for Pacific Northwest wheat. Key determinants of this future potential demand are the population and economic size of foreign wheat-importing countries. This information is not in the CGE model, however, which has a regional focus on the Pacific Northwest, and only considers trade with the rest of U.S. and rest of World. Once a fitted econometric model of foreign wheat import demand is available, future estimates of key explanatory variables can be plugged into the fitted model, and then used to generate new counterfactual values of variables or parameters that are in the CGE model, and which can be "shocked" under a counterfactual scenario.

Second, even when a parameter or variable that is described in a RAP is already within the CGE model, there may be some uncertainty about the appropriate elasticity – or response rate – that this parameter or variable has on other endogenous variables of interest. Econometric analysis provides a means to resolve this uncertainty. By using data on historical values of key variables, their inherent, time-invariant relationships can be estimated quantitatively.

Importance of Wheat

Before the econometric analyses are carried out, it is good to first provide some overview as to the importance of soft white wheat in the REACCH study area, which includes south-eastern Washington, north-eastern Oregon, and parts of western Idaho. A good way to start is to examine a Social Accounting Matrix that can be created from the IMPLAN database for Washington, Oregon, and Idaho.

Based upon the information provided by the data for year of 2011, the Pacific Northwest output of wheat is $2,288.6 million (Figure 7), and the exports to rest of U.S. and rest of World are $451.7 million and $720.0 million, respectively. Northwest inventories of wheat is $55.6 million. Income generation for labor and capital are $112.1 million and $628.0 million, respectively.

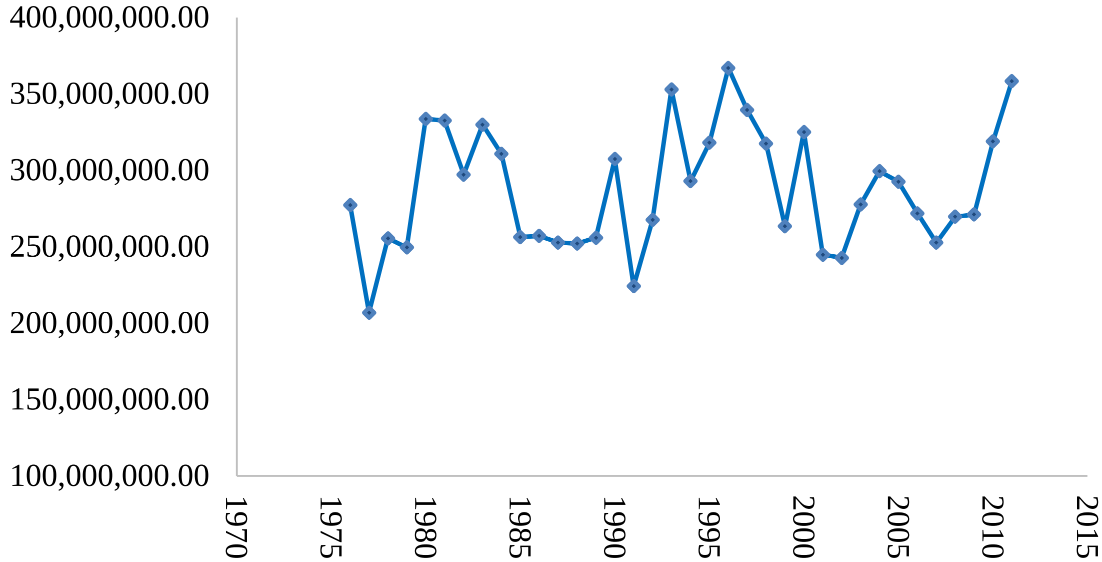

Figure 7. Pacific Northwest Wheat Output (bushel)

Table 14. Breakout of Northwest Economy in Social Accounting Matrix

No.	Sector Name
1	Wheat (PNW grain farming)
2	Wheat products (made from wheat)
3	Agricultural inputs
4	Wheat substitutes in production (alternative land uses)
5	Manufactured goods
6	Other agriculture (all other crop farming, livestock, etc)
7	Processed food
8	Construction, utilities and mining
9	Wholesale and retail trade
10	Other services and miscellaneous

Detailed information on Northwest wheat market can be informed from IMPLAN data for 2011 (Table 15). Table 15 shows the quantity of commodity (C) as intermediate input per unit of activity (A). For example, the intermediate use of wheat as a commodity by wheat activity itself is $111.1 million dollars (Column 1 and Row 11), and the intermediate use of wheat as a commodity by wheat products is $52.2 million dollars (Colum 2 and Row 11). As mentioned in the introduction section, for this application, key sectors such as Pacific Northwest wheat, flour, pastry, bakery, fertilizer, pesticides, machinery and equipment operation costs will be discussed in details below. In the IMPLAN data, much of the flour manufacturing and baking/pastry manufacturing within the Pacific Northwest will be with wheat.

Table 15. The SAM for Base Year 2011 (in millions of 2011 dollars)

	Activity (A)									
	Wheat	Wheat Prods	Ag Inputs	Wheat Subs	Manuf.	Other Ag	Food	Constr. Utility	Whole Sale	Other Services
WHEAT-C	111.1	52.2		310.2	9.2	159.6	631.4	844.4	0.5	38.2
WHTPRODS-C	1.3	758.1	3.9	29.6	127.2	23.0	703.3	73.9	58.6	312.0
AGINPUTS-C	0.1	121.9	706.8	3.2	4381.6	1.0	521.5	246.3	182.5	365.9
WHTSUBS-C	24.8	79.9	18.0	1501.4	122.8	525.8	2121.3	494.2	7.3	17.9
MANUF-C	1195.7	1797.7	19646.1	4681.3	249715.9	2562.4	10575.9	16644.0	25426.6	23042.8
OTHAGR-C	4.6	1492.2	0.3	14.5	2745.4	779.1	5065.0	60.3	20.5	165.8
FOOD-C		159.7	5.1	4.1	784.0	6.8	4787.0	107.6	801.4	2389.2
CONSUTILM-C	276.6	301.4	336.8	1577.0	27635.4	2200.9	2021.3	4517.8	1638.6	4064.1
WRTRADE-C	4.6	20.0	452.2	17.6	3922.2	37.1	113.8	105.3	2899.2	809.0
OTHSER-C	7.0	81.9	1935.9	19.4	14265.6	51.2	331.5	546.0	1984.8	1742.0

Source: Author's calculations based upon IMPLAN (2011) data.

5.2 Literature on Wheat Markets and Climate Change

Global and regional climate change impacts have been the central concern among agricultural economics studies since last century. A number of impacts studies have been done by agricultural economic researchers. For example, Deschenes and Greenstone (2007) measures the economic impacts of climate change on agricultural land in the United States. They estimate the effect of random year-to-year variation in temperature and precipitation on agricultural profits and produce the estimates of very small impacts. Results from Hallstrom (1999) ‘s study show that indirect effects of climate forecasts on crop prices are as important to the value of information as the direct predicted changes in expected yields.

Volatilities in wheat yield and prices due to climate change have been examined through various models, but few studies have been done within a CGE framework. One notable study is by Valenzuela et al. (2001). They reproduce observed wheat price volatility in agricultural markets with econometrically estimated key parameters and compared them with model predictions by developing a validation CGE model.

Many studies have focused on yield issues in crops other than wheat. Reimer and Li (2009) examine yield variability in staple grains for world as a whole. Specially, they test how yield variability affects buyers and sellers of cereal grains and oilseeds within a multi-country Ricardian trade model. The study concludes that world trade would need to expand substantially if crop yield variability were to rise, otherwise most countries will suffer welfare losses.

Another key study is by Antle et al. (2013), who consider the economics of climate change in the Pacific Northwest wheat-producing region. Their work is concerned with developing Representative Agricultural Pathways (RAPs), which describe narratives and trends in key drivers at a regional or global scale. This study directly builds on their work by going the next step and incorporating their findings into a CGE model.

5.3 Econometric Models

As mentioned, the objective of this part of the dissertation is to introduce RAPs into the CGE model. The overall goal is to have an indication of – or at least a mechanism for understanding – future potential economic outcomes for the wheat sector in the Pacific Northwest. A major problem with the existing CGE model, however, is that it does not have some of the key economic relationships within it that are described by the RAPs. In addition, even when the CGE model does account for those relationships, the key parameters which govern levels of response may be unknown.

To estimate the magnitudes of elasticities that will be used to supplement the general equilibrium model, a foreign export demand of Northwest wheat and Northwest wheat output supply model will now be formulated. The key counterfactual scenarios that considered in the general equilibrium model in Chapter 6 are converted from the estimation results of these two equations.

Export Demand Model

The foreign demand for wheat has been well studied (Thursby and Thursby, 1988; Devadoss and Meyers, 1990; Reimer, Zheng, and Gehlhar, 2012). The upshot of these studies is that there are a number of key determinants of foreign export demand, including price, foreign population, the exchange rate between the two countries, and especially various policies, such as grain embargoes, export enhancement programs, and other U.S. Farm Bill programs.

To estimate the magnitude of impacts of long run drivers of Northwest wheat foreign demand, the following econometric model is formulated:

$$(12)\quad lnEXPORT_t = \beta_1 + \beta_2 lnPRICE_t + \beta_3 lnPOP_t + \beta_4 lnEXRATE_t + \beta_5 EMBARGO + \beta_6 POLICY + \beta_6 PRICESPIKE_{2008} + \varepsilon_t$$

As seen from equation 12, the aggregate foreign exports of Northwest wheat is formulated as a function of its price ($PRICE_t$), population of top six major importers (POP_t), real weighted wheat exchange rate ($EXRATE_t$), a dummy variable representing the aftermath of the U.S. embargo of sales of grain to the Soviet Union ($EMBARGO$), a dummy variable representing the 1985 Farm Bill ($POLICY$), and a dummy variable representing the commodity price spike of 2008 ($PRICESPIKE_{2008}$). The six major importing countries of Pacific Northwest wheat are Philippines, Korea, Japan, Taiwan, Yemen, and Pakistan. The variable $POLICY$ indicates the Food Security Act of 1985 (Farm Act of 1985), including the initial implementation of Export Enhancement Program. The variable *PRICESPIKE* is a dummy variable representing the years 2007-2009, and represents a situation when the traditional price-quantity relationship for wheat exports appears to have broken down. In particular, during this period a large amount of grains were diverted to biofuel production the United States. This caused acreage of wheat to fall in an unprecedented manner. In addition, supply from other countries diminished quickly (e.g., from drought in Australia). Instead of representing these effects separately, their cumulative effect (as represented by a severe price spike) is put into the model.

By taking natural logs on both sides in equation 12, the coefficients, β' s, represent elasticities. For example, β_2 denotes the price elasticity of foreign export demand of Pacific Northwest wheat, and β_3 denotes the response of Northwest wheat demand to changes in population in those major importing countries. β_2 and β_3 are the two parameters with most importance to the investigation with respect to RAPs. The error term is denoted ε_t and initially assumed to be independently and identically distributed with mean zero and homoscedastic variance. These and other assumptions are tested below.

The above specification was chosen in part because it corresponds very well to the setup of these relationships within the CGE model. The above specification would not be appropriate, necessarily, for explaining every aspect that one might want to study, e.g., to test certain hypotheses about the nature of U.S. wheat exports. However, the above specification appears to get the most important aspects of the theory correctly, with respect to the particular purpose of this application, which is, incorporating RAPs into the CGE model.

Output Supply Model

As mentioned above, the RAPs concern some aspects of the foreign demand for Pacific Northwest wheat. They also concern some aspects of the willingness of farmers in the Pacific Northwest to supply wheat to the market. As with export demand, the CGE model does not necessarily have the most recent or detailed information in it concerning farmers' willingness to supply. For this reason, a supply model of Pacific Northwest wheat is set up. As with the foreign export demand model, this model is chosen in part because it corresponds very well to the setup of these relationships within the CGE model, and captures key aspects of the RAPs that are of interest.

As with foreign export relationships, there is a reasonably extensive existing literature on which to draw with respect to how to econometrically model the supply of agricultural products. Relevant studies in this area include Nerlove (1958), and Sadoulet and de Janvry (1995), and Mittal and Reimer (2008). Key lessons from these models are used in part to inform the specification below, along with other considerations that must be made when thinking how to best incorporate RAPs into the CGE model. This includes choice of dependent variable, and the choice of right-hand side variable. One difficult choice that had to be made is whether to include *acreage* or *output* as the dependent variable to be explained. Northwest farmers arguably have more control over the former. The latter (*output*) is a function of acreage, but is also influenced by yield (output per acre). *Output*, however, is a variable to which there is a direct correspondence in the CGE model. It is, therefore, chosen to be the left-hand side (dependent) variable of the regression model developed below.

The model is now described, starting with notation. Pacific Northwest wheat output supply at time *t* is denoted $Output_t$. This is modeled as a function of lagged own price ($PRICE_{t-1}$), current regional wheat yield ($Yield_t$), and wheat production costs at previous period ($ProdCost_{t-1}$):

$$(13)\ lnOutput_t = \alpha_1 + \alpha_2 lnPRICE_{t-1} + \alpha_3 lnYield_t + \alpha_4 lnProdCost_{t-1} + \varepsilon_t$$

where $Output_t$ is the aggregated wheat production of three states including Oregon, Washington and Idaho. Last year's price, $PRICE_{t-1}$, is used as the 'expected' price of wheat at time *t* in supply model since last year's price (of wheat plus alternative commodities) affects producers' decision made on this year's acreage planted and amount of investment. It is assumed that this is fixed in repeated samples therefore this is something that is ideally tested. Similarly, last year's input costs of wheat production will also affect producers' decision making at this year, but this year's yield of wheat directly affects its output.

In equation 13, α 's are the parameters to estimate. As in the demand equation above, the error term ε_t here is also initially assumed to be independently and identically distributed with mean zero and homoscedastic variance. These and other assumptions are also tested below.

5.4 Data Description for Export Demand and Supply Models

Historical data used for estimating above export demand and supply models are collected from various data sources. The time series dataset to estimate the export demand equation are available from calendar year 1973 to 2013. Data on the Northwest wheat export is taken from USDA, World Agricultural Outlook Board, World Agricultural Supply and Demand Estimates and supporting materials. Data on the wheat price in foreign export demand equation is the Portland No. 1 soft white wheat price that are obtained from *Grain and Feed Market News*, USDA Agricultural Marketing Service. These prices, which are annual dollars per bushel, were chosen since they are fairly representative of Northwest U.S. exported wheat. All prices are deflated by annual producer price index of soft white wheat with the base year of 1982.

Population data of major importers of Northwest wheat are collected from U.S. Department of Commerce. The variable $EXRATE$ is the real annual wheat trade weighted exchange rates indices with base of 2005. The Commodity trade weighted indexes are derived by creating a geometric index of real country exchange rate times trade weighted for different commodities. Data on $EXRATE$ are collected from USDA, ERS. Data on wheat farm programs are from USDA, Farm Service Agency, Wheat Fact Sheets.

Data on three states wheat output (bushel) and prices ($/bushel) are collected from USDA, National Agricultural Statistics Service. Data on wheat production costs ($/planted acre) are obtained from Economic Research Service, USDA. The dataset available to estimate the wheat output supply model is from market year 1976 to 2011.

5.5 Econometric Issues

Nonstationarity: Given the time-series nature of the data, I first investigate the dynamic properties of the price series. If the series are nonstationary then the least squares estimator does not have its usual properties and t-statistics are not reliable. The danger is that regression results may indicate a significant relationship when there is none.

The stationarity of the price series is tested using an Augmented Dickey-Fuller unit-root test (a constant is included but no trend is included). The null hypothesis is that the series is nonstationary (Hill, Griffiths, and Lim, 2008, p. 335), the price series follows an unit root process, and the alternative is that the variable tested was generated by a stationary process.

The test result for the variable $lnPRICE_t$ in above wheat export demand equation is listed in Table 16. The null hypothesis is rejected as the computed test statistic is smaller than all level of critical values (note that this is one (left) tailed test). This is also confirmed by Mackinnon approximate p-value for Z (t) = 0.0000 which says that the null will be rejected. Hence, the price series of wheat is stationary.

Table 16. Augmented Dickey-Fuller test for Unit Root

Test	1% Critical Value	5% Critical Value	10% Critical Value
Statistic Z(t)	-6.427	-4.251	-3.544
Approximate P-value for Z(t) = 0.0000			

Autocorrelation: Since this is a time series analysis, autocorrelation is potentially a problem, that is, off-diagonal entries in the variance-covariance matrix may not all be zeroes. This could arise for several reasons, including spatial autocorrelation, prolonged influence of shocks, inertia, data manipulation, and mis-specification. To determine if the disturbances actually are autocorrelated, I carry out the Breusch-Godfrey serial correlation LM test, which is a robust test for autocorrelation in the residuals from a regression analysis and is more general than the standard Durbin-Watson statistic or Durbin's h statistic. The null hypothesis is that there is no autocorrelation of any order. The test result (Table 17) indicates that I would fail to reject the null, which means that my price series data do not have autocorrelation problem.

Table 17. Breusch-Godfrey LM Test for Autocorrelation

lags(p)	F-test	Degree of freedom	Prob > F
1	0.373	(1, 33)	0.5454

Heteroscedastic variance: The classical linear regression model assumes homoskedastic variance. To test for this, Breusch-Pagan test is used, which tests whether the estimated variance of the error terms are dependent on the values of the independent variables. If the p-value (preferably) is 0.05 or smaller, then the null hypothesis is rejected and there is significant evidence there is heteroskedastictiy. In my case, the p-value is 0.2804 (Table 18), which means that I would fail to reject the null hypothesis.

Table 18. Breusch-Pagan Test for Heteroskedasticity

Ho: Constant variance
Variables: fitted values of lnExport
Chi2(1) = 1.17
Prob > chi2 = 0.2804

5.6 Estimation Results of Supply and Demand Response

Based upon the results of diagnostic tests above, the wheat supply and export econometric models are estimated with Ordinary Least Square approach. The estimation results of wheat foreign export demand and output supply model are reported in Table 19 and 20.

Table 19. Estimation Results of Export Demand Equation (OLS)

Dep. var: ln wheat exports	Coefficients
Intercept	1.320 (2.3)
lnPrice	-0.099 (0.23)
lnPopulation	0.499** (0.23)
lnWheatExchangeRate	-0.548** (0.21)
Aftermath of Soviet grain embargo	0.136* (0.07)
Food Security Act of 1985	0.230*** (0.06)
Commodity price spike of 2008	-0.243** (0.10)

Notes: Standard error is in parenthesis. *R s*quare is 0.44. The asterisks ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 20. Estimation Results for Wheat Output Supply Model (OLS)

Dep. var: ln wheat supply	Coefficients
Intercept	16.415*** (0.50)
lnLagPrice	0.175 (0.17)
lnYield	0.894*** (0.15)
lnLagInputCost	-0.169** (0.07)

Notes: Standard error is in parenthesis. *R s*quare is 0.57. The asterisks ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Once I have a fitted model (equation 14 and 15), plug in hypothetical value on RHS, then I can imagine different scenarios affecting wheat demand shifters. For example, if there is an 35% increase in population of six major importing countries by the year 2050, this will lead to foreign wheat demand shitting out by 17.4%. To conclude, I report the two fitted models:

Export Demand Fitted equation:

(14)

$$ln\widehat{EXPORT}_t = 1.32 - 0.10lnPRICE_t + 0.50lnPOP_t - 0.55lnEXRATE_t + 0.14DUMMY_{soviet} + 0.23POLICY - 0.24PRICESPIKE_{2008}$$

Supply fitted equation:

(15)

$$ln\widehat{Output}_t = 16.42 + 0.18lnPRICE_{t-1} + 0.89lnYield_t - 0.17lnProdCost_{t-1}$$

In the following Chapter, these estimated coefficients on variables included in the econometric models above are then used to construct alternative scenarios in the CGE model developed earlier to represent associated REACCH RAPs. That is, the estimated changes in Northwest wheat output and foreign export are then plugged into the CGE model as the targeting shocks.

Chapter 6. Integrating Representative Agricultural Pathways into A General Equilibrium Model

6.1 Objectives

The ultimate objective of this Northwest wheat study is to introduce Representative Agricultural Pathways (RAPs), which describe narratives and trends in key drivers at a regional or global scale, into a computable general equilibrium economic model designed for the REACCH study area.

This chapter introduces the RAPs in detail and discusses how the three RAPs and the general equilibrium model are connected. The general objective is to provide confidence intervals concerning economic variables of interest concerning development of the Northwest wheat sector over the next few decades. As before, the general equilibrium model traces a shock in one part of the Pacific Northwest economy, such as a weather shock that changes wheat yields, to all other parts of the economy, including consumers, producers, government, and businesses that otherwise might seem far removed from wheat producers.

6.2 Representative Agricultural Pathways

Representative Agricultural Pathways (RAPs) refer to a trans-disciplinary approach to agricultural model inter-comparison, improvement and impact assessment (Antle and Valdivia, 2012). Many of the economic uncertainties such as commodity and input prices, production technology, and policies, as well as increased probability of disturbances associated with a changing climate cannot be modeled, but they could be represented in regional RAPs. The regional RAPs are linked to global agricultural and shared social-economic pathways, and used along with climate change projections to simulate future outcomes for the wheat-based farms in the Regional Approaches to Climate Change (REACCH) project region (Antle et al., 2013). Three RAPs for the Pacific Northwest region are developed by the DevRAP tool (Valdivia and Antle, 2012) and followed procedures in Antle et al. (2013b). The three RAPs are labeled as Business-as-Usual (RAP1), Dysfunctional World (RAP2), and Optimal Policies (Aggressive Climate Policy) (RAP3), respectively. Details on the three RAPs are as follows. These are direct quotes from Antle et al. (2013).

RAP1: Business-as-Usual (BAU)

> *At the global level, political institutions established in the late 20th and early 21st century remain in place and functional. No major global military conflicts occur, the U.S. remains the major military superpower, and the U.S. and other regional organizations prevent regional military conflicts from becoming global. Similarly, U.S. institutions and policy continue without major disruptions. Federal and state finances are stabilized. In the Pacific Northwest (PNW), rural development continues with moderate increases in population in regional centers, larger and more diversified regional economies. Federal financial challenges and higher commodity prices result in cuts in traditional farm subsidy programs. Regional farm economy expands as farmland ownership continues to be consolidated into larger commercial operations, "agriculture in the middle" declines, and very small farms focus on high-value specialty crops or part-time "hobby farms."(MacDonald et al. 2013) Recent trends in mechanical, chemical and biological technology continue. Trends towards environmental regulation to protect air and water quality continue, but fiscal pressures lead to real reductions in traditional commodity subsidies and other agriculture-specific conservation programs making conservation more individualized. A distinct national Greenhouse Gas (GHG) mitigation policy is not enacted, but climate mitigation and adaptation are integrated as components of various environmental, land use, energy and conservation*

policies, as well as private and public agricultural R&D. Agricultural prices increase in real terms due to continued growth in demand, especially for feed grains and for politically mandated production of biofuels. Some rural farm-based communities continue to sustain infrastructure and social cohesion, while others continue to experience net out-migration.

RAP2: Dysfunctional World

At the global level, political institutions established in the late 20th and early 21st century remain in place but become increasingly dysfunctional. Both political and financial support for the United Nations (UN), the World Trade Organization, and other international institutions declines. Countries pursue increasingly protectionist trade policies and spend increasing shares of their national budgets on their militaries, aggravated by increasingly frequent and violent regional conflicts, often incited by economic disagreements and conflict over access to increasingly scarce natural resources. U.S. political gridlock continues, with ongoing major structural fiscal deficits and severe reductions in funding for health, education and physical infrastructure. The middle class recedes in importance, with an increasingly bi-modal distribution of income in urban and rural regions. In the PNW, an unbalanced rural development occurs, with an almost complete loss of "agriculture in the middle" and consolidation of most commodity production into large corporate entities with contract arrangements for farm management and subsequent effects to rural farm-based communities. Suburban development continues largely unregulated in peri-urban areas and more rural areas. Traditional farm subsidy programs are largely eliminated, and conservation and environmental programs are limited, due to budget constraints, and social conflict in agricultural communities escalates. Advances in large-scale mechanical, chemical and biological technology continue, but disruptions to global agricultural R&D and agricultural trade result in substantially higher and volatile agricultural commodity prices. This slows the rate of chemical and biological technological advance somewhat over BAU. No national climate policy is enacted, and regional and state climate policies are largely ineffective. All biofuel policies are abandoned. Some biofuels development occurs, but fossil fuels remain the major energy source.

RAP3: Aggressive Climate Policy (Optimal Policies)

At the global level, political institutions established in the late 20^th^ and early 21^st^ century remain in place and functional and major industrial countries agree to undertake aggressive policies to mitigate GHG emissions and invest in adaptive measures and capability. Accordingly, OECD and other major countries agree to enact a coordinated "carbon-equivalent emissions tax" and put much of the proceeds into a clean technology development and climate *adaptation fund. Biofuel mandates are replaced by targeted investments in R&D. These actions spur investment in and production of many types of renewable energy and also encourage substitution away from fossil-fuel intensive production process. No major global military conflicts occur, the U.S. remains the major military superpower, and the U.S. and other regional organizations prevent regional military conflicts from becoming global. Similarly, U.S. institutions and policy continue without major disruptions. Federal and state finances are stabilized. In the PNW, rural development continues with moderate increases in population in regional centers, larger and more diversified regional economies having a positive impact on community and social well-being. Traditional commodity subsidies are replaced by the carbon tax and an expansion of conservation and environmental programs, which slow the consolidation of land into larger farms and support some expansion of mid- and small-scale farms. Recent trends in mechanical, chemical and biological technology continue, but in response to the carbon tax, there is more innovation technology that helps reduce fossil fuel intensity. Global commodity prices rise moderately along with the increases in fossil fuels due to the carbon tax.*

6.3 Implementation of RAPs (simulations)

The RAPs are not specific enough to include quantitative predictions of future drivers. Indeed, some of the changes cannot be given a quantitative measurement. Cases where previous researchers have tried to assign numbers are reported in Table 21. At the same time, the CGE model to be used in this study does not account for some of the changes in the RAPs. For example, it has no representation of political processes. For these reasons it is necessary to assign specific ranges for each variable or indicator included using the general guidelines given in the RAPs along with data (e.g., population projections) wherever possible. The whole list of possible ranges of variables for three RAPs are listed in Table 21. All changes are in percentages, and indicate a range of values, including the low and high end of the range. For scenario construction, all variables are set to low, middle and high range. A “pathway” is a narrative or trend for key drivers at global or regional scale. A “scenario” is a set of model-specific parameters that is consistent with a pathway.

Table 21. Possible Range of RAPs

CATEGORY	VARIABLE / INDICATOR	RAP1 (*Business-as-Usual*)	RAP2 (*Dysfunctional World*)	RAP3 (*Sustainable Development*)
Bio-Physical*	Soil Erosion Reduction	- 10 to 0	-10 to 0	-10 to 0
	Crop genetic improvement (yield potential)	+20 to 40	+0 to 20	+20 to 40
	Irrigation	-5 to 0	-10 to -5	+10 to 20
	Pests, weeds and diseases Control	-10 to +10	-10 to +10	20 to 40
Socio-Economic*	GDP	+130 to 150	+50 to 80	+100 to 130
	Population	+20 to 40	+20 to 40	+20 to 40
	Farm size - commercial	+40 to 60	+60 to 80	+10 to 30
	Farm number - small	+20 to 40	-60 to -40	+40 to 60
Technology*	Improvements in conservation technologies	+20 to 40	No change	+60 to 100
	Fossil Fuels	+0 to 30	+40 to 70	+100 to 150
	Chemicals	+0 to 30	+30 to 60	+70 to 100
	Fertilizers	+0 to 30	+30 to 60	+70 to 100
Prices from Global/National Models (with climate change)	Wheat	-20 to 50	-60 to 20	+10 to 80
	Corn	-20 to 50	-60 to 20	+10 to 80
	Cattle	-20 to 50	-60 to 20	+10 to 80
	Biofuels	+0 to 40	No change	-60 to -30
	Fossil Fuels	+30 to 60	+60 to 90	+130 to 180
	Chemicals	+30 to 60	+60 to 90	+100 to 130
	Fertilizers	+30 to 60	+60 to 90	+100 to 130

Source: Antle et. al. (2013). Note: all changes are in percent from low to high end of range.

As mentioned, it is not possible to account for every factor in the RAPs, which are a wide-ranging collection of “what if” scenarios. When looking specifically at the Pacific Northwest agricultural sector, there are three variables of most interest and relevance for the purpose of constructing counterfactual scenarios in the computable general equilibrium model. The focus will be on (1) future population changes in six major importing countries of Pacific Northwest wheat, (2) future changes in input costs (eg., fertilizer), and (3) changes in Northwest yields owing primarily to climate change as well as other inter-annual variability. The real numbers assigned to these three variables for each RAP are listed in Table 22. The range of future population changes in six major importing countries for three RAPs are the same, which is 20 to 40. The ranges of input costs change for three RAPs are 30 to 60, 60 to 90, and 100 to 130 respectively. In RAP 1 and RAP 3, the ranges of Northwest wheat yield change is assigned 20 to 40, and it is assigned 0 to 20 for RAP 2. All values are in percentage change. For scenario construction in GAMs, all variables are set to low, middle and high range. Total number of scenarios is 81 (27 per RAP).

Data used to calibrate the general equilibrium model is IMPLAN data for the year 2011 A description of IMPLAN has been provided in earlier chapters of this dissertation. Besides its wide use in economic impact analysis, another advantage of IMPLAN data is that it has been used in the global warming debate through studies of the agricultural dimensions of global climate change since 1989. With this comprehensive data set, I am able to quantitatively investigate the economic impacts of changing in agricultural sector due to weather shock on other parts of Pacific Northwest.

6.4 Simulation Results

As mentioned above, the three RAPs are used to parameterize the computable general equilibrium model developed in earlier chapters to simulate price and quantity distribution on Northwest wheat. Population, input costs and yield are taken as exogenous variables in the simulation model, according to the ranges given in Table 21. Based upon the fitted equations that are econometrically estimated in Chapter 5, the exact relationships between changes in exogenous variables and endogenous variables can be drawn. For example, in the Northwest wheat foreign export equation, as the estimated coefficient on population variable is 0.50, the foreign demand of Pacific Northwest wheat by six major importing countries will increase by 10% if there is a 20% growth in the population of these foreign countries. If there is a 40% population growth in major importing countries, there will be a 20% rise in Pacific Northwest wheat, similarly to the other two variables. If there is a 30% decrease in input costs, the Northwest wheat will supply 5.1% more. Assume fertilizer costs double (all else held constant), the Pacific Northwest wheat output falls 17%, and exports to outside falls 23.9%; producer price rises 5.0%, and regional price of wheat rises 9.3%. With the increasing input costs of production, the Northwest wheat demand (all classes of wheat) falls 10.1%, and wheat farmers demand 4.7% less labor and capital. In general, the three state governments' revenues fall 0.05%. All of these are based upon the fitted regression equations from Chapter 5.

The simulation for 81 scenarios for three RAPs are carried out separately. That is, there are 27 scenarios for each RAP. I assume an equal weight to 27 different permutations. Details are listed in Table 22. Simulated changes in the endogenous variables are listed from Table 23 to Table 28. The endogenous variables with most interest are Northwest wheat output, wheat producer price, domestic and foreign export of Northwest wheat, Pacific Northwest GDP, along with factor returns. Recall that factor closures are as follows: capital is mobile and supply is fixed, labor is mobile and supply is fixed. That is, factor supply does not change under this closure, but factor returns do. Changes in factor markets will be discussed in detail later.

Mean and standard deviation of changes on both exogenous and endogenous variables are reported through Table 23 and 28. In case of RAP 1, the mean of percentage change in population is 30, and its standard deviation is 8.3. Mean and standard deviation of change in input costs are 45, and 12.5, respectively. In the meanwhile, mean and standard deviation of change in wheat yield are 30, and 8.3, respectively.

Correspondingly, the distribution of change in endogenous variables are drawn from scenarios simulations. As shown in Table 23 and 24, in case of RAP 1, the mean and standard deviation of change in wheat output are 27.1 and 9.3, respectively, whose range is relatively consistent with distribution of foreign population change. The mean of percentage change in wheat producer price is -3.3, and its standard deviation is 1.3.

The percentage change in wheat export to the rest of world is relatively large. Its mean is 44.1 and its standard 14.4. The mean and standard deviation of wheat domestic export are 34.7 and 12.8, respectively, which are relatively smaller than its change in export to outside the United States.

As designed in the earlier section, the closure regarding factor markets for all cases we considered above is that: a). capital is mobile and supply is fixed; b).Labor is mobile and supply is fixed. Labor and capital 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 (Yoder et al., 2010). The quantity demanded of labor and capital for three RAPs are reported within Tables 29 through 32. All values are in 2011 million dollars. From Table 29 we can conclude that the biggest increase in demanded labor in wheat sector is in case of RAP 1. The biggest increase in capital returns also occurs in RAP 1. Recall that RAP1 is Business-as-Usual scenario, where assumes that rural development continues with moderate increases in population in the Pacific Northwest region, and regional farm economy expands as farmland ownership continues to be consolidated into larger commercial operations.

In general the health of the Pacific Northwest wheat sector, as represented by wheat prices, exports quantities, and producer economic welfare, appears to be quite viable under a range of alternative future scenarios.

6.5. Analysis

It is important to ask which of these scenarios is most relevant to Pacific Northwest wheat producers, and what, if any, role there is for public policy and for private decision makers. Overall, the future for wheat production in this region is not necessarily dire. Foreign wheat-consuming populations are projected to grow. Yields in the Northwest are not expected to necessarily decline in a major way, based upon the best agronomic and climate information available from the efforts going on in this area, especially from the REACCH project as described above. Certain parts of Northwest agriculture are likely to be challenged with respect to water availability. However, in this study, the focus has been on rainfed wheat-growing areas, and this part of the agricultural economy appears like it will likely have reasonable stability in the years to come. Perhaps the biggest source of uncertainty is the evolution of input costs as well as new policies related to greenhouse gas emissions in agriculture.

The analysis of this chapter provides a way to examine how RAPs can be placed into an economic model. The process is not perfect, as much of the information in the RAPs is difficult to quantify in a way that can be used in the CGE model. The focus of this chapter has been narrower than what is implied by RAPs, and it should not be viewed as a projection of likely future scenarios in the Northwest wheat economy. Rather, it should be viewed as a joining of two research areas that previously have not been connected in the literature.

Table 22. Representatives for three RAPs

	Population Change	Input Costs Change	Yield Change
RAP1: Business-as-usual (%)	20	30	20
	30	45	30
	40	60	40
RAP2: Dysfunctional world (%)	20	60	0
	30	75	10
	40	90	20
RAP3: Optimal policies (%)	20	100	20
	30	115	30
	40	130	40

Note: All values are in percentage change.

Table 23. RAP 1

Population (in 6 major importing countries)	Input Cost	Yield	Wheat Output	Producer Price	Foreign Export ROW	Domestic Export - RUS	PNW GDP	Factor returns - Labor	Factor returns - Capital
(20, 30, 40)	(30, 45, 60)	(20, 30, 40)							
20	30	20	17.92	-2.48	28.89	23.08	0.05	0.11	0.13
20	30	30	27.29	-3.95	42.84	36.47	0.07	0.16	0.2
20	30	40	36.67	-5.22	56.91	49.98	0.1	0.21	0.26
20	45	20	14.35	-1.85	23.6	18.01	0.04	0.09	0.11
20	45	30	23.3	-3.35	36.89	30.76	0.06	0.14	0.17
20	45	40	32.26	-4.64	50.28	43.61	0.09	0.19	0.23
20	60	20	10.78	-1.18	18.33	12.96	0.03	0.07	0.08
20	60	30	19.32	-2.71	30.97	25.08	0.05	0.12	0.14
20	60	40	27.85	-4.03	43.68	37.28	0.07	0.16	0.2
30	45	20	17.57	-1.86	29.78	21.25	0.05	0.1	0.13
30	45	30	27.1	-3.36	44.09	34.69	0.07	0.16	0.2
30	45	40	36.68	-4.66	58.57	48.3	0.1	0.21	0.26
30	30	20	21.36	-2.49	35.46	26.59	0.06	0.13	0.16
30	30	30	31.35	-3.96	50.51	40.72	0.08	0.18	0.23
30	30	40	41.42	-5.23	65.77	55.07	0.11	0.24	0.29
30	60	20	13.78	-1.19	24.12	15.94	0.04	0.08	0.11
30	60	30	22.85	-2.72	37.7	28.69	0.06	0.14	0.17
30	60	40	31.96	-4.04	51.42	41.58	0.08	0.19	0.23
40	60	20	16.69	-1.2	29.72	18.84	0.05	0.1	0.13
40	60	30	26.3	-2.73	44.25	32.21	0.07	0.15	0.19

Note: All values are in percentage change.

Table 24. RAP 1 (Continued)

Population (in 6 major importing countries)	Input Cost	Yield	Wheat Output	Producer Price	Foreign Export ROW	Domestic Export - RUS	PNW GDP	Factor returns - Labor	Factor returns - Capital
(20, 30, 40)	(30, 45, 60)	(20, 30, 40)							
40	60	40	35.98	-4.05	58.99	45.79	0.09	0.21	0.26
40	45	20	20.7	-1.87	35.77	24.4	0.06	0.12	0.16
40	45	30	30.81	-3.37	51.1	38.52	0.08	0.18	0.22
40	45	40	41.02	-4.67	66.69	52.89	0.11	0.24	0.29
40	30	20	24.72	-2.5	41.85	30	0.07	0.15	0.18
40	30	30	35.34	-3.97	58.01	44.89	0.09	0.2	0.25
40	30	40	46.09	-5.24	74.47	60.07	0.12	0.26	0.32

Note: All values are in percentage change.

Table 25. RAP2

Population (in 6 major importing countries)	Input Cost	Yield	Wheat Output	Producer Price	Foreign Export ROW	Domestic Export - RUS	PNW GDP	Factor returns - Labor	Factor returns - Capital
(20, 30, 40)	(60, 75, 90)	(0, 10, 20)							
20	60	0	-6.2	2.73	-6.42	-10.75	-0.02	-0.04	-0.05
20	60	10	2.24	0.62	5.81	0.96	0.01	0.01	0.02
20	60	20	10.78	-1.18	18.33	12.96	0.03	0.07	0.08
20	75	0	-9.01	3.52	-10.44	-14.6	-0.03	-0.06	-0.07
20	75	10	-0.92	1.36	1.22	-3.44	-0.003	-0.008	-0.005
20	75	20	7.24	-0.47	13.13	7.97	0.02	0.04	0.06
20	90	0	-11.81	4.36	-14.44	-18.43	-0.03	-0.08	-0.09
20	90	10	-4.07	2.16	-3.35	-7.81	-0.01	-0.03	-0.03
20	90	20	3.72	0.28	7.97	3.03	0.01	0.02	0.03
30	75	0	-7.08	3.51	-6.58	-12.84	-0.02	-0.05	-0.05
30	75	10	1.42	1.36	5.82	-1.22	0.004	0.006	0.01
30	75	20	10.03	-0.48	18.54	10.71	0.03	0.06	0.08
30	60	0	-4.14	2.72	-2.31	-8.84	-0.01	-0.03	-0.03
30	60	10	4.75	0.61	10.72	3.38	0.01	0.03	0.04
30	60	20	13.78	-1.19	24.12	15.94	0.04	0.08	0.11
30	90	0	-10.01	4.36	-10.82	-16.81	-0.03	-0.07	-0.08
30	90	10	-1.9	2.15	0.96	-5.77	-0.006	-0.02	-0.01
30	90	20	6.31	0.28	13.03	5.54	0.02	0.04	0.05
40	90	0	-8.29	4.35	-7.36	-15.25	-0.02	-0.06	-0.06
40	90	10	0.2	2.14	5.09	-3.81	0	-0.003	0.006

Table 26. RAP2 (Continued)

Population (in 6 major importing countries)	Input Cost	Yield	Wheat Output	Producer Price	Foreign Export ROW	Domestic Export - RUS	PNW GDP	Factor returns - Labor	Factor returns - Capital
(20, 30, 40)	(60, 75, 90)	(0, 10, 20)							
40	90	20	8.82	0.27	17.9	7.97	0.02	0.05	0.07
40	60	0	-2.15	2.71	1.63	-6.99	-0.007	-0.02	-0.01
40	60	10	7.18	0.6	15.45	5.71	0.02	0.04	0.06
40	60	20	16.69	-1.2	29.72	18.84	0.05	0.1	0.13
40	75	0	-5.23	3.5	-2.89	-11.14	-0.02	-0.04	-0.04
40	75	10	3.68	1.35	10.25	0.93	0.01	0.02	0.03
40	75	20	12.74	-0.49	23.77	13.37	0.03	0.07	0.1

Note: All values are in percentage change.

Table 27. RAP3

Population (in 6 major importing countries)	Input Cost	Yield	Wheat Output	Producer Price	Foreign Export ROW	Domestic Export - RUS	PNW GDP	Factor returns - Labor	Factor returns - Capital
(20, 30, 40)	(100, 115, 130)	(20, 30, 40)							
20	100	20	1.33	0.83	4.48	-0.31	0.003	0.006	0.01
20	100	30	8.83	-0.79	15.46	10.21	0.02	0.05	0.07
20	100	40	16.28	-2.19	26.46	20.75	0.04	0.1	0.12
20	115	20	-2.1	1.66	-0.49	-5.08	-0.006	-0.02	-0.01
20	115	30	5.04	-0.004	9.9	4.88	0.01	0.03	0.04
20	115	40	12.11	-1.43	20.3	14.84	0.03	0.07	0.09
20	130	20	-5.61	2.57	-5.56	-9.93	-0.02	-0.04	-0.04
20	130	30	1.17	0.87	4.25	-0.53	0.003	0.005	0.01
20	130	40	7.87	-0.6	14.05	8.86	0.02	0.05	0.06
30	115	20	0.17	1.65	4	-2.93	0	-0.003	0.005
30	115	30	7.7	-0.01	15.09	7.47	0.02	0.05	0.06
30	115	40	15.19	-1.45	26.23	17.92	0.04	0.09	0.12
30	100	20	3.79	0.82	9.3	2.05	0.01	0.02	0.03
30	100	30	11.71	-0.8	21.04	13.05	0.03	0.07	0.09
30	100	40	19.62	-2.2	32.84	24.13	0.05	0.12	0.15
30	130	20	-3.51	2.56	-1.39	-7.98	-0.01	-0.03	-0.02
30	130	30	3.62	0.86	9.06	1.82	0.01	0.02	0.03
30	130	40	10.7	-0.61	19.53	11.64	0.03	0.06	0.08

Table 28. RAP 3 (Continued)

Population (in 6 major importing countries)	Input Cost	Yield	Wheat Output	Producer Price	Foreign Export ROW	Domestic Export - RUS	PNW GDP	Factor returns - Labor	Factor returns - Capital
(20, 30, 40)	(100, 115, 130)	(20, 30, 40)							
40	130	20	-1.49	2.55	2.6	-6.1	-0.005	-0.01	-0.007
40	130	30	5.99	0.85	13.69	4.09	0.02	0.03	0.05
40	130	40	13.44	-0.62	24.83	14.34	0.04	0.08	0.1
40	100	20	6.16	0.81	13.95	4.33	0.02	0.03	0.05
40	100	30	14.51	-0.81	26.44	15.82	0.04	0.09	0.11
40	100	40	22.87	-2.21	39.05	27.42	0.06	0.13	0.17
40	115	20	2.37	1.64	8.31	-0.85	0.006	0.01	0.02
40	115	30	10.29	-0.02	20.1	9.99	0.03	0.06	0.08
40	115	40	18.19	-1.46	31.98	20.91	0.05	0.11	0.14

Note: All values are in percentage change.

Table 29. Factor Returns in case of RAP 1

	Labor Returns (Change in absolute value)	Capital Returns (Change in absolute value)
Mean	502.3	433.3
95% confidence interval - low	440	381
95% confidence interval - high	564	486
Standard deviation	164.6	139.2
Coefficient of variation	32.8	32.1
Confidence interval	62.10	52.51

Note: All numbers are in 2011 million dollars.

Table 30. Factor Returns in case of RAP 2

	Labor returns (Change in absolute value)	Capital returns (Change in absolute value)
Mean	14.1	28.6
95% confidence interval - low	-46.0	-21.5
95% confidence interval - high	74.3	78.7
Standard deviation	159.6	132.8
Coefficient of variation	1127.8	464.0
Confidence interval	60.19	50.08

Note: All numbers are in 2011 million dollars.

Table 31. Factor Returns in case of RAP 3

	Labor Returns (Change in absolute value)	Capital Returns (Change in absolute value)
Mean	138.7	131.5
95% confidence interval - low	84.0	85.7
95% confidence interval - high	193.4	177.3
Standard deviation	145.0	121.4
Coefficient of variation	104.51	92.29
Confidence interval	54.69	45.79

Note: All numbers are in 2011 million dollar.

Table 32. Distribution of key variables

	Exogenous Variables			Endogenous Variables						
	Population (for 6 major importers)	Input Cost	Yield	Wheat Output	Producer Price	Foreign Export (ROW)	Domestic Export (RUS)	PNW GDP	Labor Returns	Capital Returns
RAP 1										
Mean	30.00	45.00	30.00	27.09	-3.28	44.10	34.73	0.07	0.16	0.20
Standard Deviation	8.32	12.48	8.32	9.27	1.27	14.43	12.77	0.02	0.05	0.06
RAP 2										
Mean	30.00	75.00	10.00	1.44	1.48	5.88	-1.13	0.00	0.00	0.01
Standard Deviation	8.32	12.48	8.32	7.89	1.78	11.86	10.69	0.02	0.05	0.06
RAP 3										
Mean	30.00	115.00	30.00	7.64	0.09	15.02	7.44	0.02	0.04	0.06
Standard Deviation	8.32	12.48	8.32	7.44	1.46	11.36	10.10	0.02	0.05	0.05

Notes: All values are in percentage change.

Chapter 7. Summary and Conclusions

In my dissertation a regional computable general equilibrium model is developed and used to examine two important issues for the Northwest region of the United States, focusing on Washington, Oregon, and Idaho.

One new contribution of this work is to show a new way of calibrating and validating the general equilibrium model to the particular circumstances of topics that are studied. Borrowing techniques from the literature on calibration of real business cycle models, historical data on output and prices are used to parameterize and validate the model. The approach provides an indication of how much price versus quantity typically handles most of the adjustment in this region, for example, to yield shocks arising from year-to-year weather changes. The model is calibrated such that price volatility predicted by the model arising from yield shocks, is similar to the actual price volatility that is in the historical record for the region. Calibration and validation of the regional computable general equilibrium model are discussed in Chapter 3.

Once the model is parameterized and validated, two applications of the model are carried out. Both of these applications have been studied very little or not at all before in the economics literature. In Chapter 4 the potential of an oilseed crop, called camelina, to be used as a new biofuel crop for the transportation sector of the Northwest region and beyond are examined. The aim of this study is to identify conditions, or policies, under which the industry will flourish within the Northwest. Several policy options are examined within the model with regard to meeting stated targets by the aviation sector for using camelina as a biofuel. The policy options include mandates, subsidies to the unprocessed oilseed sector (i.e., camelina farming), and subsidies to the processed oilseed sector. This analysis makes clear that subsidies for this sector are likely necessary, and that it will ultimately have to be government that provides this support.

In Chapter 5 and 6, the second application of the developed CGE model for the Pacific Northwest region is discussed. The ultimate goal is to integrate Representative Agricultural Pathways (RAPs) within the CGE designed for REACCH area, in order to quantitatively examine how Northwest wheat economy may be affected by long run drivers, including climate change, population, input costs. The Northwest wheat sector (farmers and processors/distributors) is the central concern of this study, and in general appears to be quite viable under a range of future alternative scenarios.

The connection of RAPs and CGE model is made through a series of hypothetical scenarios, that is, model-specific parameters that are consistent with a pathway. Since the CGE model does not embody all of the key parameters, these linkages are established by a series of external models that then “piggyback” onto the main model. In particular, in Chapter 5, a foreign export demand decision model and a Northwest wheat output supply model are built to estimate the key parameters that will be used to generate new counterfactual values of variables or parameters that are in the computable general equilibrium model.

In Chapter 6, the details of three RAPs are introduced and described, and their quantitative implementation is discussed. For example, in the case of RAP 1, trends towards environmental regulation to protect air and water quality continue, but fiscal pressures lead to real reductions in traditional commodity subsidies and other agriculture-specific conservation programs making conservation more individualized. A distinct national Greenhouse Gas (GHG) mitigation policy is not enacted, but climate mitigation and adaptation are integrated as components of various environmental, land use, energy and conservation policies, as well as private and public agricultural R&D. Northwest prices increase in real terms due to continued growth in demand. Results for the other RAPs are somewhat similar, since key underlying determinants tend to overcome any weakness associated with future possible climate or policy scenarios.

These efforts provide a foundation for future work in this area. A major limitation of the present study is the use of a static CGE model. This does not provide information of the time path of the changes examined here. Policymakers often would prefer to know the timing of changes being considered. The approach of this dissertation implies that all such changes occur, simultaneously, before the new equilibrium can be examined.

Another limitation of the existing approach is that imperfect competition within the agricultural economy is not examined. There are reasons to expect that there is not always full information and perfectly functioning markets as assumed here. It is not clear that there are necessarily any biases in the results that may arise from this assumption, but the reader should be aware that this is one way in which the model departs from some of the realities of the regional economy.

The model used here has several limitations and would benefit from enhancements in future work. These include:

(1) better consideration of labor patterns and job changes. The labor closure used in this study assumes that capital is mobile, with supply is fixed; and that labor is mobile, with fixed supply. Alternative closures could have been chosen, although it is expected that the results would have changed little. Information obtained about the biofuels sector suggests that development of new infrastructure tends to be highly capital intensive. This implies that few net jobs are actually created or destroyed as changes occur in this sector.

(2) better consideration of the technology assumed for economic sectors, including the elasticity of substitution among inputs for production. The elasticity of substitution for production for all activities in this model were set at 2, and little work was done to explicitly model the production and distribution of aviation biofuels. The elasticity parameter could be higher or lower for different specific industries examined in this study, and better evidence on the nature of the production sector could be obtained. This type of research is constrained by data availability, but is a possible topic for future research.

(3) more explicit consideration of risk and uncertainty. Both of the applications in this study involve activities that have yet to take place. There is therefore a great deal of uncertainty about what the future holds. Microeconomic theory teaches us that risk and uncertainty tend to lower the likelihood of investment taking place. This analysis has not explicitly considered risk and uncertainty, again because there are data limitations that are difficult to overcome. However, this is an important area for future work.

In summary, while it is felt that much progress has been made in this study, with respect to economic modeling of current problems in the Pacific Northwest economy, there is room for improvement, and important qualifications on the results derived herein. It is hoped that this research sheds light on the policy issues examined therein, and also provides a methodological framework for future work on regional issues that span economic sectors.

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Appendix A

Documentation for the CGE Model

Index sets used in the model:

A – activities
C – commodities
CM⊂C – commodities which have at least one source of imports (from ROW or from RUS or from both)
CE⊂C – commodities which have at least one destination for exports (to ROW or to RUS or to both)
CNM⊂C – commodities which are not imported
CNE⊂C – commodities which are not exported
CM1⊂C – commodities which have exactly one import source
CE1⊂C – commodities which have exactly one export destination
CM2⊂C – commodities which are imported from both sources
CE2⊂C – commodities which are exported to both destinations
F – factors of production and indirect business taxes
FF⊂F – factors of production
I – institutions
H⊂I – households
G⊂I – government units
HG⊂I – households and government units
FG⊂G – federal government units
SG⊂G – state government units
T – trading regions (FT: rest of world, DT: rest of US)

<u>Base Parameters:</u>

<u>Prices (set by user):</u>
XROT – Initial exchange rate

PMROT,C – Initial regional import price in regional currency
PWEOC,T – Initial world export price in foreign currency
PEROC,T – Initial regional export price in regional currency
PMOC – Initial composite import price in regional currency
PEOC – Initial composite export price in regional currency
PQOC – Initial composite commodity price
PDOC – Initial regional price of regional output
PXOC – Initial producer price
PAOA – Initial activity price
PVAOA – Initial value added price
WFOFF – Initial average wage or rental rate for factor FF
pwmT,C – World import price in foreign currency (exogenous)

Quantities (calculated from initial data):
QMROT,C – Initial regional imports
QEROC,T – Initial regional exports
QMOC – Initial composite import quantity
QEOC – Initial composite export quantity
QQOC – Initial composite quantity supplied to regional demanders
QDOC – Initial quantity of regional output supplied to regional demanders
QXOC – Initial quantity of regional output
QAOA – Initial activity level
QINTOC,A – Initial quantity of intermediate use of commodity C by activity A
IMAKEQOI,C – Initial institutional make matrix (quantity)
QFOFF,A – Initial quantity of factor FF demanded by activity A
QHOC,H – Initial household consumption
QINVOC – Initial investment demand
QIINVOI – Initial institutional investment demand
QFSOFF – Initial factor supply
INDTOG – Initial indirect business taxes receipts for each government unit
EMPLOYA – Employment data (actual number of jobs in each sector)

Accounting variables (calculated from initial data):
YFOI,FF – Initial transfer of income to institution I from factor FF
YHOH – Initial gross household income
NYHOH – 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

Factors:
WFDISTOFF,A – Initial factor price distortion factor
IADJO – Initial investment adjustment factor
SADJO – Initial savings adjustment factor
SGADJO – Initial state government spending adjustment factor
SHIFTFFOFF – Initial shift variable for factor supply equation

Parameters set by user:
frischC – Frisch parameter for Stone-Geary utility function
ineC,H – Income elasticity
xedC,T – Elasticity of demand for world export demand function
esubpA – Elasticity of substitution for production function
esubdC – Elasticity of substitution between regional output and imports
esubsC – Elasticity of transformation between regional output and exports
esubeC – Elasticity of transformation between foreign and regional exports
esubmC – Elasticity of substitution between foreign and regional imports
tqC – Sales tax rate
tcC – Consumption tax rate (paid only by households)
tqsC – Sales tax rate on services not previously taxed
tmT,C – Import tax rate
teC,T – Export tax rate
efacFF – Demand elasticity for factors of production

Parameters calculated from initial data (exogenous variables):
thetaA,C – Yield of output C per unit of activity A
icaC,A – Quantity of C as intermediate input per unit of activity A
tbA – Indirect business tax rate
tyG,H – Household income tax rate
trhH,HH – Inter-household transfers
mpsH – Marginal propensity to save
cwtsC – Weight of commodity C in the consumer price index
wfaFF,A – Price for factor FF in activity A
xshiftC,T – Shift parameter for world export demand function
lambdaC,H – Subsistence level parameter for Stone-Geary utility function
betaC,H – Marginal budget share parameter for Stone-Geary utility function
engelwtH – Engel aggregation weight
qgC,G – Government consumption
shryI,FF – Institutional share of factor income
tbshrG – Government unit share of indirect business taxes
sgovbal – Initial state government budget balance

adA – Shift parameter for production function
delF,A – Share parameter for production function
rhoA – Exponent for production function
aqC – Shift parameter for armington demand function
adelC – Share parameter for armington demand function
arhoC – Exponent for armington demand function
asC – Shift parameter for supply transformation function
sdelC – Share parameter for supply transformation function
srhoC – Exponent for supply transformation function
aeC – Shift parameter for export transformation function
edelC – Share parameter for export transformation function
erhoC – Exponent for export transformation function
amC – Shift parameter for armington import function
mdelC – Share parameter for armington import function
mrhoC – Exponent parameter for armington import function

Calculation of base values (SAM is the adjusted data from IMPLAN):

$$PMRO_{T,C} = pwm_{T,C} * (1+tm_{T,C}) * XRO_T$$

$$PERO_{C,T} = PWEO_{C,T} * (1-te_{C,T}) * XRO_T$$

$$PVAO_A = \frac{\sum_{FF} SAM_{FF,A}}{SAM_{TOTAL,A} * PAO_A}$$

$$QMRO_{T,C} = \frac{SAM_{T,C}}{PMRO_{T,C}}$$

$$QERO_{C,T} = \frac{SAM_{C,T}}{PMRO_{C,T}}$$

$$QMO_C = \frac{\sum_T SAM_{T,C}}{PMO_C}$$

$$QEO_C = \frac{\sum_T SAM_{C,T}}{PEO_C}$$

$$QQO_C = \frac{SAM_{TOTAL,C} - \sum_T SAM_{C,T}}{PQO_C}$$

$$QDO_C = \frac{\sum_A SAM_{A,C} + \sum_I SAM_{I,C} - \sum_T SAM_{C,T}}{PDO_C}$$

$$QXO_C = \frac{\sum_A SAM_{A,C} + \sum_I SAM_{I,C}}{PXO_C}$$

$$QAO_A = \frac{SAM_{TOTAL,A}}{PAO_A}$$

$$QINTO_{C,A} = \frac{SAM_{C,A}}{PQO_C}$$

$$IMAKEQO_{I,C} = \frac{SAM_{I,C}}{PXO_C}$$

$$QFO_{'CAP',A} = SAM_{'CAP',A}$$

$$IFLBR=NO:QFO_{'LAB',A} = SAM_{'LAB',A}$$

$$ELSE:QFO_{'LAB',A} = EMPLOY_A$$

$$WFO_{FF} = \frac{\sum_A SAM_{FF,A}}{\sum_A QFO_{FF,A}}$$

$$QHO_{C,H} = \frac{SAM_{C,H}}{(1+tcc)*PQO_C}$$

$$QINVO_C = \frac{SAM_{C,INV}}{PQO_C}$$

$$QIINVO_{HG} = SAM_{HG,'INV'}$$

$$QFSO_{FF} = \frac{\sum_A SAM_{FF,A}}{WFO_{FF,A}}$$

$$INDTO_G = SAM_{G,INDT}$$

$$YFO_{I,FF} = SAM_{I,FF}$$

$$YHO_H = \sum_{FF} SAM_{H,FF} + \sum_I SAM_{H,I} + \sum_T SAM_{H,T} + \sum_C PX_C * SAM_{H,C}$$

$$NYHO_H = \sum_C SAM_{C,H}$$

$$YFGO = \sum_{FG} SAM_{FG,TOTAL}$$

$$EFGO = \sum_{FG} SAM_{TOTAL,FG} - \sum_{FG} SAM_{'INV',FG}$$

$$ESGO = \sum_{SG} SAM_{TOTAL,SG} - \sum_{SG} SAM_{'INV',SG}$$

$$FSAVXO=\frac{SAM_{'INV','FT'}}{XRO_{'FT'}}$$

$$DSAVXO=\frac{SAM_{'INV','DT'}}{XRO_{'DT'}}$$

$$FSAVMO=\frac{SAM_{'FT','INV'}}{XRO_{'FT'}}$$

$$DSAVMO=\frac{SAM_{'DT','INV'}}{XRO_{'DT'}}$$

$$wfa_{FF,A}=\frac{SAM_{FF,A}}{QFO_{FF,A}}$$

$$WFDISTO_{FF,A}=\frac{wfa_{FF,A}}{WFO_{FF}}$$

$$SHIFTFFO_{FF}=\frac{QFSO_{FF}}{WFO_{FF}^{efac_{FF}}}$$

$$CPIO=\sum_{C} cwtsc*PDO_{C}$$

<u>Calibration of parameters:</u>

$$theta_{A,C}=\frac{SAM_{A,C}}{PXO_{C}*QAO_{A}}$$

$$ica_{C,A}=\frac{QINTO_{C,A}}{QAO_{A}}$$

$$tb_{A}=\frac{SAM_{INDT,A}}{SAM_{TOTAL,A}}$$

$$ty_{G,H}=\frac{SAM_{G,H}}{SAM_{TOTAL,H}}$$

$$trh_{H,HH}=\frac{SAM_{H,HH}}{(1-\sum_{G} ty_{G,HH})SAM_{TOTAL,H}}$$

$$mps_{H}=\frac{SAM_{INV,H}}{(1-\sum_{G} ty_{G,HH})SAM_{TOTAL,H}}$$

$$cwts_{C}=\frac{\sum_{H} SAM_{C,H}}{\sum_{CC}\sum_{H} SAM_{CC,H}}$$

$$xshift_{C,T} = \frac{QERO_{C,T}}{PWEO_{C,T}^{xed_{C,T}}}$$

$$engelwt_{H} = \frac{1}{\sum_{C} \frac{QHO_{C,H} * PQO_{C} * ine_{C,H}}{NYHO_{H}}}$$

$$ine_{C,H} = engelwt_{H} * ine_{C,H}$$

$$beta_{C,H} = \frac{QHO_{C,H} * PQO_{C} * ine_{C,H}}{NYHO_{H}}$$

$$lambda_{C,H} = \frac{QHO_{C,H} * PQO_{C} + \frac{beta_{C,H} * NYHO_{H}}{frisch_{C}}}{PQO_{C}}$$

$$qg_{C,G} = \frac{SAM_{C,G}}{PQO_{C}}$$

$$shry_{I,FF} = \frac{SAM_{I,FF}}{SAM_{TOTAL,FF} - \sum_{T} SAM_{T,FF}}$$

$$tbshr_{G} = \frac{SAM_{G,'INDT'}}{\sum_{GG} SAM_{GG,'INDT'}}$$

$$sgovbal = \sum_{SG} SAM_{'INV',SG}$$

$$rho_{A} = \frac{1}{esubp_{A}} - 1$$

$$del_{FF,A} = \frac{WFDIST_{FF,A} * WFO_{FF} * QFO_{FF,A}^{rho_{A}+1}}{\sum_{FFF} WFDIST_{FFF,A} * WFO_{FFF} * QFO_{FFF,A}^{rho_{A}+1}}$$

$$ad_{A} = \frac{QAO_{A} * (1 - tb_{A} - \sum_{C} ica_{C,A})}{(\sum_{FF} del_{FF,A} * QFO_{FF,A}^{-rho_{A}})^{\frac{-1}{rho_{A}}}}$$

$$arho_{CM} = \frac{1}{esubd_{CM}} - 1$$

$$adel_{CM} = \frac{PMO_{CM} * QMO_{CM}^{1+arho_{CM}}}{PMO_{CM} * QMO_{CM}^{1+arho_{CM}} + PDO_{CM} * QDO_{CM}^{1+arho_{CM}}}$$

$$aq_{CM}=\frac{QQO_{CM}}{(adel_{CM}*QMO_{CM}^{-arho_{CM}}+(1\text{-}adel_{CM})*QDO_{CM}^{-arho_{CM}})^{\frac{-1}{arho_{CM}}}}$$

$$srho_{CE}=\frac{1}{esubs_{CE}}+1$$

$$sdel_{CE}=\frac{PEO_{CE}*QEO_{CE}^{1\text{-}srho_{CE}}}{PEO_{CE}*QEO_{CE}^{1\text{-}srho_{CE}}+PDO_{CE}*QDO_{CE}^{1\text{-}srho_{CE}}}$$

$$as_{CE}=\frac{QXO_{CE}}{(sdel_{CE}*QEO_{CE}^{1\text{-}srho_{CE}}+(1\text{-}sdel_{CE})*QDO_{CE}^{srho_{CE}})^{\frac{1}{srho_{CE}}}}$$

$$erho_{CE2}=\frac{1}{esube_{CE2}}+1$$

$$edel_{CE2}=\frac{PERO_{CE2,FT}*QERO_{CE2,FT}^{1\text{-}erho_{CE2}}}{PERO_{CE2,FT}*QERO_{CE2,FT}^{1\text{-}erho_{CE}}+PERO_{CE2,DT}*QERO_{CE2,DT}^{1\text{-}erho_{CE2}}}$$

$$ae_{CE2}=\frac{QEO_{CE2}}{(edel_{CE2}*QERO_{CE2,FT}^{1\text{-}erho_{CE2}}+(1\text{-}edel_{CE2})*QDRO_{CE2,DT}^{erho_{CE2}})^{\frac{1}{erho_{CE2}}}}$$

$$mrho_{CM2}=\frac{1}{esubm_{CM2}}-1$$

$$mdel_{CM2}=\frac{PMRO_{FT,CM2}*QMRO_{FT,CM2}^{1+mrho_{CM2}}}{PMRO_{FT,CM2}*QMRO_{FT,CM2}^{1+mrho_{CM2}}+PMRO_{DT,CM2}*QMRO_{DT,CM2}^{1+mrho_{CM2}}}$$

$$am_{CM2}=\frac{QMO_{CM2}}{(mdel_{CM2}*QMRO_{FT,CM2}^{-mrho_{CM2}}+(1\text{-}mdel_{CM2})*QMRO_{DT,CM2}^{-mrho_{CM2}})^{\frac{-1}{mrho_{CM2}}}}$$

<u>Equations:</u>

Regional foreign import price equation:

$$PMR_{'FT',CM}=pwm_{'FT',CM}*(1+tm_{'FT',CM})*XR_{'FT'}$$

Regional foreign export price equation:

$$PER_{CE,'FT'}=PWE_{CE,'FT'}*XR_{'FT'}*(1\text{-}te_{CE,'FT'})\text{ if }QERO_{CE,'FT'}\neq 0$$

Regional RUS import price equation:

$$PMR_{'DT',CM}=CPI*pwm_{'DT',M}*(1+tm_{'DT',CM})*XR_{'DT'}$$

Regional RUS export price equation:

$$PER_{CE,'DT'}=CPI*PWE_{CE,'DT'}*XR_{'DT'}*(1\text{-}te_{CE,'DT'})\text{if }QERO_{CE,'DT'}\neq 0$$

World export demand function:

$$QER_{CE,T} = xshift_{CE,T} * PWE_{CE,T}^{xed_{CE,T}} * \text{ if } QERO_{CE,T} \neq 0$$

Armington import composite equation:

$$QM_{CM2} = am_{CM2} * (mdel_{CM2} * QMR_{FT,CM2}^{-mrho_{CM2}} + (1-mdel_{CM2}) * QMR_{DT,CM2}^{-mrho_{CM2}})^{\frac{-1}{mrho_{CM2}}}$$

Row-RUS import ratio:

$$\frac{QMR_{FT,CM2}}{QMR_{DT,CM2}} = (\frac{PMR_{DT,CM2}}{PMR_{FT,CM2}} * \frac{mdel_{CM2}}{1-mdel_{CM2}})^{\frac{1}{1+mrho_{CM2}}}$$

Import quantity for imports from exactly one source:

$$QM_{CM1} = QMR_{DT,CM1}(\text{if } QMRO_{DT,CM1} \neq 0) + QMR_{FT,CM1}(\text{if } QMRO_{FT,CM1} \neq 0)$$

Import price for imports from exactly one source:

$$PM_{CM1} = PMR_{DT,CM1}(\text{if } QMRO_{DT,CM1} \neq 0) + PMR_{FT,CM1}(\text{if } QMRO_{FT,CM1} \neq 0)$$

Value of imports:

$$PM_{CM2} * QM_{CM2} = \sum_{T} PMR_{T,CM2} * QMR_{T,CM2}$$

Export composite transformation equation:

$$QE_{CE2} = ae_{CE2} * (edel_{CE2} * QER_{CE2,FT}^{erho_{CE2}} + (1-edel_{CE2}) * QER_{CE2,DT}^{erhoCE2})^{\frac{1}{erho_{CE2}}}$$

ROW-RUS export ratio:

$$\frac{QER_{CE2,DT}}{QER_{CE2,FT}} = \left(\frac{PER_{CE2,DT}}{PER_{CE2,FT}} * \frac{edel_{CE2}}{1-edel_{CE2}}\right)^{\frac{1}{erho_{CE2}-1}}$$

Export quantity for exports to exactly one destination:

$$QE_{CE1} = QER_{CE1,DT}(\text{if } QERO_{CE1,DT} \neq 0) + QER_{CE1,FT}(\text{if } QERO_{CM1,FT} \neq 0)$$

Export price for exports to exactly one destination:

$$PE_{CE1} = PER_{CE1,DT}(\text{if } QERO_{CE1,DT} \neq 0) + PER_{CE1,FT}(\text{if } QERO_{CM1,FT} \neq 0)$$

Value of exports:

$$PE_{CE2} * QE_{CE2} = \sum_{T} PER_{CE2,T} * QER_{CE2,T}$$

Absorption equation:

$$PQ_{C} * QQ_{C} = (1+tq_{C}) * PM_{C} * QM_{C}(\text{if } C \subset CE) + (1+tq_{C}+tqs_{C}) * PD_{C} * QD_{C}$$

Value of regional output:

$$PX_{C} * QX_{C} = PD_{C} * QD_{C} + PE_{C} * QE_{C}(\text{if } C \subset CE)$$

Activity price equation:

$$PA_{A} = \sum_{C} PX_{C} * theta_{A,C}$$

Value added price equation:

$$PVA_A = PA_A*(1-tb_A)-\sum_C PQ_C*ica_{C,A}$$

Leontief-CES production function:

$$QA_A = \frac{ad_A}{1-tb_A-\sum_C ica_{C,A}}*(\sum_{FF} del_{FF,A}*QF_{FF,A}^{-rho_A})^{\frac{-1}{rho_A}}$$

Factor demand equation:

$$WFDIST_{FF,A}*WF_{FF} = \frac{PVA_A*ad_A}{1-tb_A-\sum_C ica_{C,A}}*(\sum_{FFF} del_{FFF,A}*QF_{FFF,A}^{-rho_A})^{\frac{-1}{rho_A}-1}*del_{FF,A}*QF_{FF,A}^{-rho_A-1}$$

Intermediate input demand equation:

$$QINT_{C,A} = ica_{C,A}*QA_A$$

Output function:

$$QX_C = \sum_A theta_{A,C}*QA_A + \sum_I IMAKEQ_{I,C}$$

Armington commodity composite equation:

$$QQ_{CM} = aq_{CM}*(adel_{CM}*QM_{CM}^{-arho_{CM}}+(1-adel_{CM})*QD_{CM}^{-arho_{CM}})^{\frac{-1}{arho_{CM}}}$$

Import regional demand ratio:

$$\frac{QM_{CM}}{QD_{CM}} = (\frac{PD_{CM}}{PM_{CM}}*\frac{adel_{CM}}{1-adel_{CM}})^{\frac{1}{1+arho_{CM}}}$$

Composite supply for non-imported commodities:

$$QQ_{CNM} = QD_{CNM}$$

Output transformation equation:

$$QX_{CE} = as_{CE}*(sdel_{CE}*QE_{CE}^{srho_{CE}}+(1-sdel_{CE})*QD_{CE}^{srho_{CE}})^{\frac{1}{srho_{CE}}}$$

Export regional supply ratio:

$$\frac{QE_{CE}}{QD_{CE}} = (\frac{PE_{CE}}{PD_{CE}}*\frac{1-sdel_{CE}}{sdel_{CE}})^{\frac{1}{srho_{CE}-1}}$$

Output transformation for non-exported commodities:

$$QX_{CNE} = QD_{CNE}$$

Factor income equation:

$$YF_{1,FF} = shry_{1,FF}(\sum_A WFDIST_{FF,A}*QF_{FF,A}*WF_{FF,A}-CPI*\sum_T SAM_{T,FF})$$

Household income equation:

$$YH_H = \sum_{FF} YF_{H,FF} + \sum_{C} PX_C * IMAKEQ_{H,C} + cpi * \sum_{T} SAM_{H,T}$$
$$+ QINV_H + CPI * \sum_{G} SAM_{H,G} + \sum_{HH} \left(trh_{H,HH} * (1 - \sum_{G} ty_{G,HH}) * YH_{HH} \right)$$

Net household income equation:

$$NYH_H = YH_H - \sum_{HH} \left(trh_{HH,H} * (1 - \sum_{G} ty_{G,H}) * YH_H \right) * YH_H - cpi * \sum_{T} SAM_{T,H}$$
$$- SADJ * mps_H * (1 - \sum_{G} ty_{G,H}) * YH_H - YH_H * \sum_{G} ty_{G,H}$$

Household consumption demand:

$$QH_{C,H} = lambda_{C,H} + beta_{C,H} * (NYH_H - \sum_{CC} lambda_{CC,H} * (1 + tc_{CC}) * PQ_{CC}) / ((1 + tc_C) * PQ_C)$$

Investment demand equation:

$$QINV_C = IADJ * QINVO_C$$

Institutional investment demand equation:

$$QINV_{HG} = QINVO_{HG}$$

Federal government revenue:

$$YFG = \sum_{H} \sum_{FG} ty_{FG,H} * YH_H + cpi * \sum_{T} \sum_{FG} SAM_{FG,T} + \sum_{C} \sum_{FG} PX_C * IMAKEQ_{FG,C}$$
$$+ \sum_{FG} \sum_{FF} YF_{FG,FF} + \sum_{FG} QINV_{FG,'INV'} + cpi * \sum_{FG} \sum_{FGG} SAM_{FG,FGG} + \sum_{FG} INDT_{FG}$$

Federal government expenditures:

$$EFG = cpi * \sum_{FG} \sum_{I} SAM_{I,FG} + cpi * \sum_{FG} \sum_{T} SAM_{T,FG} + \sum_{FG} \sum_{C} PQ_C * qg_{C,FG} - cpi * \sum_{FG} SAM_{'INV',FG}$$

State government revenue:

$$YSG = \sum_{H} \sum_{SG} ty_{SG,H} * YH_H + cpi * \sum_{T} \sum_{SG} SAM_{SG,T} + \sum_{C} \sum_{SG} PX_C * IMAKE_{SG,C} + \sum_{SG} \sum_{FF} YF_{SG,FF}$$
$$+ \sum_{SG} QINV_{SG} + cpi * \sum_{SG} \sum_{SGG} SAM_{SG,SGG} + \sum_{SG} INDT_{SG} + CPI * \sum_{SG} \sum_{FG} SAM_{SG,FG}$$
$$+ \sum_{C} tq_C * (PM_C * QM_C (if(C \subset CM) + PD_C * QD_C) + \sum_{C} tqs_C * PD_C * QD_C$$
$$+ \sum_{H} \sum_{C} tc_C * PQ_C * QH_{C,H}$$

State government expenditures:

$$ESG = cpi * \sum_{SG} \sum_{I} SAM_{I,SG} + cpi * \sum_{SG} \sum_{T} SAM_{T,SG} + SGADJ * \sum_{SG} \sum_{C} PQ_C * qg_{C,SG}$$
$$- cpi * \sum_{SG} SAM_{'INV',SG} - CPI * sgovbal$$

State government budget balanced:

$$YSG = ESG + CPI * sgovbal$$

Factor market equation:

$$QFS_{FF}=\sum_{A} QF_{FF,A}$$

Composite commodity market equation:

$$QQ_{C}=\sum_{A} QINT_{C,A}+\sum_{H} QH_{C,H}+\sum_{FG} qg_{C,FG}+SGADJ*\sum_{SG} qg_{C,SG}+QINV_{C}$$

ROW current account balance:

$$\sum_{\substack{CE \\ QERO_{CE,'FT'}\neq 0}} PER_{CE,'FT'}*QER_{CE,'FT'}+cpi*\sum_{H} SAM_{H,'FT'}+cpi*\sum_{G} SAM_{G,'FT'}+XR_{'FT'}*FSAVX$$

$$=\sum_{\substack{CM \\ QMRO_{'FT',CM}\neq 0}} PMR_{'FT',CM}*QMR_{'FT',CM}+cpi*\sum_{FF} SAM_{'FT',FF}+cpi*\sum_{HG} SAM_{'FT',HG}+XR_{'FT'}*FSAVM$$

RUS current account balance:

$$\sum_{\substack{CE \\ QERO_{CE,'DT'}\neq 0}} PER_{CE,'DT'}*QER_{CE,'DT'}+cpi*\sum_{H} SAM_{H,'DT'}+cpi*\sum_{G} SAM_{G,'DT'}+cpi*XR_{'DT'}*DSAVX$$

$$=\sum_{\substack{CM \\ QMRO_{'DT',CM}\neq 0}} PMR_{'DT',CM}*QMR_{'DT',CM}+cpi*\sum_{FF} SAM_{'DT',FF}+cpi*\sum_{HG} SAM_{'DT',HG}+CPI*XR_{'DT'}*DSAVM$$

Savings investment balance:

$$\sum_{C} PX_{C}*IMAKEQ_{'INV',C}+SADJ*\sum_{H}\left(mps_{H}*\left(1-\sum_{G} ty_{G,H}\right)*YH_{H}\right)+\sum_{FF} YF_{'INV',FF}$$

$$+\left(YFG\text{-}EFG\right)+XR_{'FT'}*FSAVX+CPI*XR_{'DT'}*DSAVX+CPI*sgovbal$$

$$=\sum_{C} PQ_{C}*QINV_{C}+\sum_{HG} QINV_{HG}+XR_{'FT'}*FSAVM+CPI*XR_{'DT'}*DSAVM$$

$$+WALRAS$$

Price normalization equation:

$$\sum_{C}(1+tc_{C})*PQ_{C}*cwts_{c}=CPI$$

Indirect taxes calculation:

$$INDT_{G}=tbshr_{G}*\sum_{A} tb_{A}*PA_{A}*QA_{A}$$

Factor supply equation:

$$QFS_{FF}=SHIFTFF_{FF}*WF_{FF}^{efac_{FF}}$$

Appendix B

Aggregation of IMPLAN sectors for use in CGE model

OILSF   Oilseed farming
1   ! Oilseed farming

ANIMAL   Animal production including cattle poultry eggs
11   ! Cattle ranching and farming
12   ! Poultry and egg production
13   ! Animal production except cattle and poultry and e

OILSDPROC   Oilseed processing and refining
52   ! Soybean processing
53   ! Other oilseed processing
54   ! Fats and oils refining and blending

OTHAGR   Other Agriculture
2   ! Grain farming
3   ! Vegetable and melon farming
4   ! Tree nut farming
5   ! Fruit farming
6   ! Greenhouse and nursery production
7   ! Tobacco farming
8   ! Cotton farming
9   ! Sugarcane and sugar beet farming
10   ! All other crop farming
14   ! Logging
15   ! Forest nurseries forest products and timber trac
16   ! Fishing
17   ! Hunting and trapping
18   ! Agriculture and forestry support activities

REFINED   Petroleum refineries
142   ! Petroleum refineries

TRANS   Transportation Services
391   ! Air transportation

392 ! Rail transportation
393 ! Water transportation
394 ! Truck transportation
395 ! Transit and ground passenger transportation
397 ! Scenic and sightseeing transportation and support
497 ! State and local government passenger transit

CONST Construction
33 ! New residential 1-unit structures nonfarm
34 ! New multifamily housing structures nonfarm
35 ! New residential additions and alterations nonfarm
36 ! New farm housing units and additions and alteration
37 ! Manufacturing and industrial buildings
38 ! Commercial and institutional buildings
39 ! Highway street bridge and tunnel construction
40 ! Water sewer and pipeline construction
41 ! Other new construction
42 ! Maintenance and repair of farm and nonfarm resident
43 ! Maintenance and repair of nonresidential buildings
44 ! Maintenance and repair of highways streets bridge
45 ! Other maintenance and repair construction

MIN Mining
19 ! Oil and gas extraction
20 ! Coal mining
21 ! Iron ore mining
22 ! Copper nickel lead and zinc mining
23 ! Gold silver and other metal ore mining
24 ! Stone mining and quarrying
25 ! Sand gravel clay and refractory mining
26 ! Other nonmetallic mineral mining
27 ! Drilling oil and gas wells
28 ! Support activities for oil and gas operations
29 ! Support activities for other mining

UTIL Utilities
30 ! Power generation and supply
31 ! Natural gas distribution
32 ! Water sewage and other systems
495 ! Federal electric utilities
498 ! State and local government electric utilities

TRAD Wholesale and retail trade

390 ! Wholesale trade
396 ! Pipeline transportation
400 ! Warehousing and storage
401 ! Motor vehicle and parts dealers
402 ! Furniture and home furnishings stores
403 ! Electronics and appliance stores
404 ! Building material and garden supply stores
405 ! Food and beverage stores
406 ! Health and personal care stores
407 ! Gasoline stations
408 ! Clothing and clothing accessories stores
409 ! Sporting goods hobby book and music stores
410 ! General merchandise stores
411 ! Miscellaneous store retailers
412 ! Nonstore retailers

FOOD Processed food
48 ! Flour milling
49 ! Rice milling
50 ! Malt manufacturing
51 ! Wet corn milling
55 ! Breakfast cereal manufacturing
56 ! Sugar manufacturing
57 ! Confectionery manufacturing from cacao beans
58 ! Confectionery manufacturing from purchased chocolate
59 ! Nonchocolate confectionery manufacturing
60 ! Frozen food manufacturing
61 ! Fruit and vegetable canning and drying
62 ! Fluid milk manufacturing
63 ! Creamery butter manufacturing
64 ! Cheese manufacturing
65 ! Dry condensed and evaporated dairy products
66 ! Ice cream and frozen dessert manufacturing
67 ! Animal except poultry slaughtering
68 ! Meat processed from carcasses
69 ! Rendering and meat byproduct processing
70 ! Poultry processing
71 ! Seafood product preparation and packaging
72 ! Frozen cakes and other pastries manufacturing
73 ! Bread and bakery product except frozen manufacture
74 ! Cookie and cracker manufacturing
75 ! Mixes and dough made from purchased flour
76 ! Dry pasta manufacturing

77 ! Tortilla manufacturing
78 ! Roasted nuts and peanut butter manufacturing
79 ! Other snack food manufacturing
80 ! Coffee and tea manufacturing
81 ! Flavoring syrup and concentrate manufacturing
82 ! Mayonnaise dressing and sauce manufacturing
83 ! Spice and extract manufacturing
84 ! All other food manufacturing
85 ! Soft drink and ice manufacturing
86 ! Breweries
87 ! Wineries
88 ! Distilleries
89 ! Tobacco stemming and redrying
90 ! Cigarette manufacturing
91 ! Other tobacco product manufacturing

<u>MAN Manufactures</u>
46 ! Dog and cat food manufacturing
47 ! Other animal food manufacturing
92 ! Fiber yarn and thread mills
93 ! Broadwoven fabric mills
94 ! Narrow fabric mills and schiffli embroidery
95 ! Nonwoven fabric mills
96 ! Knit fabric mills
97 ! Textile and fabric finishing mills
98 ! Fabric coating mills
99 ! Carpet and rug mills
100 ! Curtain and linen mills
101 ! Textile bag and canvas mills
102 ! Tire cord and tire fabric mills
103 ! Other miscellaneous textile product mills
104 ! Sheer hosiery mills
105 ! Other hosiery and sock mills
106 ! Other apparel knitting mills
107 ! Cut and sew apparel manufacturing
108 ! Accessories and other apparel manufacturing
109 ! Leather and hide tanning and finishing
110 ! Footwear manufacturing
111 ! Other leather product manufacturing
112 ! Sawmills
113 ! Wood preservation
114 ! Reconstituted wood product manufacturing
115 ! Veneer and plywood manufacturing

116 ! Engineered wood member and truss manufacturing
117 ! Wood windows and door manufacturing
118 ! Cut stock resaving lumber and planning
119 ! Other millwork including flooring
120 ! Wood container and pallet manufacturing
121 ! Manufactured home mobile home manufacturing
122 ! Prefabricated wood building manufacturing
123 ! Miscellaneous wood product manufacturing
124 ! Pulp mills
125 ! Paper and paperboard mills
126 ! Paperboard container manufacturing
127 ! Flexible packaging foil manufacturing
128 ! Surface-coated paperboard manufacturing
129 ! Coated and laminated paper and packaging materials
130 ! Coated and uncoated paper bag manufacturing
131 ! Die-cut paper office supplies manufacturing
132 ! Envelope manufacturing
133 ! Stationery and related product manufacturing
134 ! Sanitary paper product manufacturing
135 ! All other converted paper product manufacturing
136 ! Manifold business forms printing
137 ! Books printing
138 ! Blankbook and looseleaf binder manufacturing
139 ! Commercial printing
140 ! Tradebinding and related work
141 ! Prepress services
143 ! Asphalt paving mixture and block manufacturing
144 ! Asphalt shingle and coating materials manufacturing
145 ! Petroleum lubricating oil and grease manufacturing
146 ! All other petroleum and coal products manufacturing
147 ! Petrochemical manufacturing
148 ! Industrial gas manufacturing
149 ! Synthetic dye and pigment manufacturing
150 ! Other basic inorganic chemical manufacturing
151 ! Other basic organic chemical manufacturing
152 ! Plastics material and resin manufacturing
153 ! Synthetic rubber manufacturing
154 ! Cellulosic organic fiber manufacturing
155 ! Noncellulosic organic fiber manufacturing
156 ! Nitrogenous fertilizer manufacturing
157 ! Phosphatic fertilizer manufacturing
158 ! Fertilizer mixing only manufacturing
159 ! Pesticide and other agricultural chemical manufacture

160 ! Pharmaceutical and medicine manufacturing
161 ! Paint and coating manufacturing
162 ! Adhesive manufacturing
163 ! Soap and other detergent manufacturing
164 ! Polish and other sanitation good manufacturing
165 ! Surface active agent manufacturing
166 ! Toilet preparation manufacturing
167 ! Printing ink manufacturing
168 ! Explosives manufacturing
169 ! Custom compounding of purchased resins
170 ! Photographic film and chemical manufacturing
171 ! Other miscellaneous chemical product manufacturing
172 ! Plastics packaging materials film and sheet
173 ! Plastics pipe fittings and profile shapes
174 ! Laminated plastics plate sheet and shapes
175 ! Plastics bottle manufacturing
176 ! Resilient floor covering manufacturing
177 ! Plastics plumbing fixtures and all other plastics
178 ! Foam product manufacturing
179 ! Tire manufacturing
180 ! Rubber and plastics hose and belting manufacturing
181 ! Other rubber product manufacturing
182 ! Vitreous china plumbing fixture manufacturing
183 ! Vitreous china and earthenware articles manufacture
184 ! Porcelain electrical supply manufacturing
185 ! Brick and structural clay tile manufacturing
186 ! Ceramic wall and floor tile manufacturing
187 ! Nonclay refractory manufacturing
188 ! Clay refractory and other structural clay products
189 ! Glass container manufacturing
190 ! Glass and glass products except glass containers
191 ! Cement manufacturing
192 ! Ready-mix concrete manufacturing
193 ! Concrete block and brick manufacturing
194 ! Concrete pipe manufacturing
195 ! Other concrete product manufacturing
196 ! Lime manufacturing
197 ! Gypsum product manufacturing
198 ! Abrasive product manufacturing
199 ! Cut stone and stone product manufacturing
200 ! Ground or treated minerals and earths manufacturing
201 ! Mineral wool manufacturing
202 ! Miscellaneous nonmetallic mineral products

203 ! Iron and steel mills
204 ! Ferroalloy and related product manufacturing
205 ! Iron steel pipe and tube from purchased steel
206 ! Rolled steel shape manufacturing
207 ! Steel wire drawing
208 ! Alumina refining
209 ! Primary aluminum production
210 ! Secondary smelting and alloying of aluminum
211 ! Aluminum sheet plate and foil manufacturing
212 ! Aluminum extruded product manufacturing
213 ! Other aluminum rolling and drawing
214 ! Primary smelting and refining of copper
215 ! Primary nonferrous metal except copper and alumin
216 ! Copper rolling drawing and extruding
217 ! Copper wire except mechanical drawing
218 ! Secondary processing of copper
219 ! Nonferrous metal except copper and aluminum shap
220 ! Secondary processing of other nonferrous
221 ! Ferrous metal foundaries
222 ! Aluminum foundries
223 ! Nonferrous foundries except aluminum
224 ! Iron and steel forging
225 ! Nonferrous forging
226 ! Custom roll forming
227 ! All other forging and stamping
228 ! Cutlery and flatware except precious manufacture
229 ! Hand and edge tool manufacturing
230 ! Saw blade and handsaw manufacturing
231 ! Kitchen utensil pot and pan manufacturing
232 ! Prefabricated metal buildings and components
233 ! Fabricated structural metal manufacturing
234 ! Plate work manufacturing
235 ! Metal window and door manufacturing
236 ! Sheet metal work manufacturing
237 ! Ornamental and architectural metal work manufacture
238 ! Power boiler and heat exchanger manufacturing
239 ! Metal tank heavy gauge manufacturing
240 ! Metal can box and other container manufacturing
241 ! Hardware manufacturing
242 ! Spring and wire product manufacturing
243 ! Machine shops
244 ! Turned product and screw nut and bolt manufacture
245 ! Metal heat treating

246 ! Metal coating and nonprecious engraving
247 ! Electroplating anodizing and coloring metal
248 ! Metal valve manufacturing
249 ! Ball and roller bearing manufacturing
250 ! Small arms manufacturing
251 ! Other ordnance and accessories manufacturing
252 ! Fabricated pipe and pipe fitting manufacturing
253 ! Industrial pattern manufacturing
254 ! Enameled iron and metal sanitary ware manufacturing
255 ! Miscellaneous fabricated metal product manufacture
256 ! Ammunition manufacturing
257 ! Farm machinery and equipment manufacturing
258 ! Lawn and garden equipment manufacturing
259 ! Construction machinery manufacturing
260 ! Mining machinery and equipment manufacturing
261 ! Oil and gas field machinery and equipment
262 ! Sawmill and woodworking machinery
263 ! Plastics and rubber industry machinery
264 ! Paper industry machinery manufacturing
265 ! Textile machinery manufacturing
266 ! Printing machinery and equipment manufacturing
267 ! Food product machinery manufacturing
268 ! Semiconductor machinery manufacturing
269 ! All other industrial machinery manufacturing
270 ! Office machinery manufacturing
271 ! Optical instrument and lens manufacturing
272 ! Photographic and photocopying equipment manufacture
273 ! Other commercial and service industry machinery ma
274 ! Automatic vending commercial laundry and dryclean
275 ! Air purification equipment manufacturing
276 ! Industrial and commercial fan and blower manufacture
277 ! Heating equipment except warm air furnaces
278 ! AC refrigeration and forced air heating
279 ! Industrial mold manufacturing
280 ! Metal cutting machine tool manufacturing
281 ! Metal forming machine tool manufacturing
282 ! Special tool die jig and fixture manufacturing
283 ! Cutting tool and machine tool accessory manufacture
284 ! Rolling mill and other metalworking machinery
285 ! Turbine and turbine generator set units manufacture
286 ! Other engine equipment manufacturing
287 ! Speed changers and mechanical power transmission e
288 ! Pump and pumping equipment manufacturing

289 ! Air and gas compressor manufacturing
290 ! Measuring and dispensing pump manufacturing
291 ! Elevator and moving stairway manufacturing
292 ! Conveyor and conveying equipment manufacturing
293 ! Overhead cranes hoists and monorail systems
294 ! Industrial truck trailer and stacker manufactories
295 ! Power-driven handtool manufacturing
296 ! Welding and soldering equipment manufacturing
297 ! Packaging machinery manufacturing
298 ! Industrial process furnace and oven manufacturing
299 ! Fluid power cylinder and actuator manufacturing
300 ! Fluid power pump and motor manufacturing
301 ! Scales balances and miscellaneous general purpos
302 ! Electronic computer manufacturing
303 ! Computer storage device manufacturing
304 ! Computer terminal manufacturing
305 ! Other computer peripheral equipment manufacturing
306 ! Telephone apparatus manufacturing
307 ! Broadcast and wireless communications equipment
308 ! Other communications equipment manufacturing
309 ! Audio and video equipment manufacturing
310 ! Electron tube manufacturing
311 ! Semiconductors and related device manufacturing
312 ! All other electronic component manufacturing
313 ! Electromedical apparatus manufacturing
314 ! Search detection and navigation instruments
315 ! Automatic environmental control manufacturing
316 ! Industrial process variable instruments
317 ! Totalizing fluid meters and counting devices
318 ! Electricity and signal testing instruments
319 ! Analytical laboratory instrument manufacturing
320 ! Irradiation apparatus manufacturing
321 ! Watch clock and other measuring and controlling
322 ! Software reproducing
323 ! Audio and video media reproduction
324 ! Magnetic and optical recording media manufacturing
325 ! Electric lamp bulb and part manufacturing
326 ! Lighting fixture manufacturing
327 ! Electric house wares and household fan manufacturing
328 ! Household vacuum cleaner manufacturing
329 ! Household cooking appliance manufacturing
330 ! Household refrigerator and home freezer manufacture
331 ! Household laundry equipment manufacturing

332 ! Other major household appliance manufacturing
333 ! Electric power and specialty transformer manufacture
334 ! Motor and generator manufacturing
335 ! Switchgear and switchboard apparatus manufacturing
336 ! Relay and industrial control manufacturing
337 ! Storage battery manufacturing
338 ! Primary battery manufacturing
339 ! Fiber optic cable manufacturing
340 ! Other communication and energy wire manufacturing
341 ! Wiring device manufacturing
342 ! Carbon and graphite product manufacturing
343 ! Miscellaneous electrical equipment manufacturing
344 ! Automobile and light truck 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 parts manufacturing
351 ! Aircraft manufacturing
352 ! Aircraft engine and engine parts manufacturing
353 ! Other aircraft parts and equipment
354 ! Guided missile and space vehicle manufacturing
355 ! Propulsion units and parts for space vehicles and
356 ! Railroad rolling stock manufacturing
357 ! Ship building and repairing
358 ! Boat building
359 ! Motorcycle bicycle and parts manufacturing
360 ! Military armored vehicles and tank parts manufacture
361 ! All other transportation equipment manufacturing
362 ! Wood kitchen cabinet and countertop manufacturing
363 ! Upholstered household furniture manufacturing
364 ! Nonupholstered wood household furniture manufacture
365 ! Metal household furniture manufacturing
366 ! Institutional furniture manufacturing
367 ! Other household and institutional furniture
368 ! Wood office furniture manufacturing
369 ! Custom architectural woodwork and millwork
370 ! Office furniture except wood manufacturing
371 ! Showcases partitions shelving and lockers
372 ! Mattress manufacturing
373 ! Blind and shade manufacturing
374 ! Laboratory apparatus and furniture manufacturing

375 ! Surgical and medical instrument manufacturing
376 ! Surgical appliance and supplies manufacturing
377 ! Dental equipment and supplies manufacturing
378 ! Ophthalmic goods manufacturing
379 ! Dental laboratories
380 ! Jewelry and silverware manufacturing
381 ! Sporting and athletic goods manufacturing
382 ! Doll toy and game manufacturing
383 ! Office supplies except paper manufacturing
384 ! Sign manufacturing
385 ! Gasket packing and sealing device manufacturing
386 ! Musical instrument manufacturing
387 ! Broom brush and mop manufacturing
388 ! Burial casket manufacturing
389 ! Buttons pins and all other miscellaneous manufacture

OTHSERV Other services and Miscellaneous
398 ! Postal service
399 ! Couriers and messengers
413 ! Newpaper publishers
414 ! Periodical publishers
415 ! Book publishers
416 ! Database directory and other publishers
417 ! Software publishers
418 ! Motion picture and video industries
419 ! Sound recording industries
420 ! Radio and television broadcasting
421 ! Cable networks and program distribution
422 ! Telecommunications
423 ! Information services
424 ! Data processing services
425 ! Nondepository credit intermediation and related a
426 ! Securities commodity contracts investments
427 ! Insurance carriers
428 ! Insurance agencies brokerages and related
429 ! Funds trusts and other financial vehicles
430 ! Monetary authorities and depository credit interme
431 ! Real estate
432 ! Automotive equipment rental and leasing
433 ! Video tape and disc rental
434 ! Machinery and equipment rental and leasing
435 ! General and consumer goods rental except video tap
436 ! Lessors of nonfinancial intangible assets

437 ! Legal services
438 ! Accounting and bookkeeping services
439 ! Architectural and engineering services
440 ! Specialized design services
441 ! Custom computer programming services
442 ! Computer systems design services
443 ! Other computer related services including facility
444 ! Management consulting services
445 ! Environmental and other technical consulting service
446 ! Scientific research and development services
447 ! Advertising and related services
448 ! Photographic services
449 ! Veterinary services
450 ! All other miscellaneous professional and technical
451 ! Management of companies and enterprises
452 ! Office administrative services
453 ! Facilities support services
454 ! Employment services
455 ! Business support services
456 ! Travel arrangement and reservation services
457 ! Investigation and security services
458 ! Services to buildings and dwellings
459 ! Other support services
460 ! Waste management and remediation services
461 ! Elementary and secondary schools
462 ! Colleges universities and junior colleges
463 ! Other educational services
464 ! Home health care services
465 ! Offices of physicians dentists and other health
466 ! Other ambulatory health care services
467 ! Hospitals
468 ! Nursing and residential care facilities
469 ! Child day care services
470 ! Social assistance except child day care services
471 ! Performing arts companies
472 ! Spectator sports
473 ! Independent artists writers and performers
474 ! Promoters of performing arts and sports and agents
475 ! Museums historical sites zoos and parks
476 ! Fitness and recreational sports centers
477 ! Bowling centers
478 ! Other amusement gambling and recreation industri
479 ! Hotels and motels including casino hotels

480 ! Other accommodations
481 ! Food services and drinking places
482 ! Car washes
483 ! Automotive repair and maintenance except car wash
484 ! Electronic equipment repair and maintenance
485 ! Commercial machinery repair and maintenance
486 ! Household goods repair and maintenance
487 ! Personal care services
488 ! Death care services
489 ! Drycleaning and laundry services
490 ! Other personal services
491 ! Religious organizations
492 ! Grantmaking and giving and social advocacy organization
493 ! Civic social professional and similar organization
494 ! Private households
496 ! Other Federal Government enterprises
499 ! Other State and local government enterprises
500 ! Noncomparable imports
501 ! Scrap
502 ! Used and secondhand goods
503 ! State & Local Education
504 ! State & Local Non-Education
505 ! Federal Military
506 ! Federal Non-Military
507 ! Rest of the world adjustment to final uses
508 ! Inventory valuation adjustment
509 ! Owner-occupied dwellings