Nebraska Department of REVENUE

Technical Documentation of the TRAIN Model (Tax and Revenue Analysis In Nebraska)

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1. INTRODUCTION

In 1998, the State of Nebraska developed a Computable General Equilibrium (CGE) model of Nebraska, designed to analyze tax policy issues, especially tax incentives. The model, called "Tax and Revenue Analysis in Nebraska (TRAIN)" is a comprehensive economic model describing the whole Nebraska economy. TRAIN is constructed using a set of mathematical equations, and is implemented on the General Algebraic Modeling System (GAMS) programming language. This document provides a technical description of the TRAIN model.

A general equilibrium analysis using a CGE model seeks to comprehensively describe the economic interactions among different markets. Equilibrium is the economic notion that under certain conditions, combinations of prices and quantities exist that result in all available goods being sold, and at these prices and quantities, individuals maximize their utility and firms maximize their profits. A general equilibrium model considers, implicitly or explicitly, all sectors of the economy simultaneously. CGE models are a standard tool of empirical analysis, and are widely used to analyze policies that affect multiple markets.

An analysis using a CGE model begins with the assumption of an economy in equilibrium. From this initial position, the economy is "shocked" by a change in tax or monetary policy, a change in technology, or an increase or decrease in quantities of some good due to some outside influence, such as a natural disaster, and a new equilibrium is found. The model solves for new equilibrium levels of supply, demand, and price, that result in a unique equilibrium solution across the economic sectors included in the model. Measuring the change in prices and quantities of goods and services between the initial equilibrium and the new equilibrium tells researchers how each sector of the economy was affected by the shock.

Section 2 provides an overview of the model's structure with a non-technical description. Section 3 explains the dynamics of the model. TRAIN is designed to track economic impacts through time. Section 4 describes the aggregation scheme of the model and data. Because an economic model cannot account for every individual economic agent, aggregation, or sectoring is an important element in the development of any CGE model. Section 5 details technical description of the model including mathematical equations, and GAMS codes.

2. THE STRUCTURE OF TRAIN

An economy is composed of complex relationships among innumerable interdependent economic agents. In order to explain the basic structure of the TRAIN model, this section will present a series of circular-flow diagrams that show the flows of goods and services and money through the economy. Figure 1 presents a simplified circular-flow diagram of the major economic interactions among economic agents that are captured in the model. The economic agents in the model include producers, consumers, governments, and the rest-of-the-world sector. No economic model can account for every individual economic agent in the economy. To provide focus to the model, individual agents are aggregated into sectors.

In order to describe the major features of the Nebraska economy, the TRAIN model divides the Nebraska economy into 74 distinct sectors. These sectors include 28 industrial sectors, two factor (capital and labor) sectors, an investment sector, nine household sectors, 33 government sectors and a rest-of-the-world sector. The TRAIN model contains more than 1,300 mathematical equations for describing economic behavior and relationships within and between the sectors of the Nebraska economy.

The 33 government sectors in the TRAIN model include seven federal government sectors, 18 state government sectors and eight local government sectors. The level of detail at the state government level allows the model to capture detailed impact of revenue and expenditure flows throughout the Nebraska economy. TRAIN accounts for the interactions between various markets and captures the overall economic impacts on the Nebraska economy while automatically calculating impacts on state tax revenue. The level of detail in the model allows TRAIN to calculate most tax impacts endogenously—within the model—without requiring additional calculations outside of the model. This approach allows economist to avoid making rigid or *ad hoc* assumptions that often result in inconclusive or questionable final results.

2.1 Producers and Households

The starting point for the TRAIN model is the relationship between the two major types of economic agents, producers and households. Producers, or business firms, are aggregated in the model into industry sectors, and each sector is treated as a representative firm in the model. Each producer is assumed to choose inputs and output to maximize profits. The inputs are labor, capital, and intermediate goods (outputs of other firms). Thus, the producer's supply of output is a function of price and the producer's demand for inputs is a function of price.

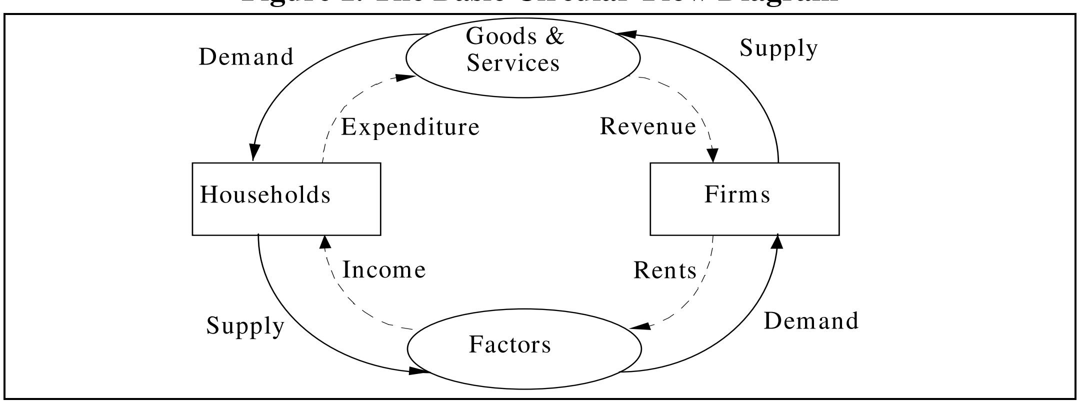
Households make two types of decisions. Households make decisions about buying goods and services, and they make decisions about selling their labor and capital services. Households are assumed to make these decisions in the way that maximizes their utility. The amount of labor supplied by households is a function of the wage rate. This relationship is called the "labor-supply function." The demand for goods or services is a function of price, and is called the "demand function." In addition to their labor income, households receive dividends and interest from their stocks and bonds and other ownership interests in capital. Taken together, the assumptions of profit maximization for producers, and utility maximization for households enforce competition within and between the sectors in the model, and result in equilibrium in the economy and the model.

2.2 Equilibrium

The two types of economic agents, producers and households, interact in two types of markets, a factor market and a goods-and-services market. Producers sell goods and services to households in the goods-and-services market. Households sell the factors of production—labor and capital services—to firms in the factor market. The model determines a price for the output of each of the 28 industry sectors. Prices are also determined for labor "wages," and capital services, "rents." Equilibrium in a market means that the quantity supplied (a function of price) is equal to the quantity demanded (also a function of price) in that market. Equilibrium in the factor market for labor and capital, and in the goods-and-services market for goods and services define a simple general equilibrium system. The TRAIN model calculates 30 prices (wages, rents, and one price for each of the 28 goods made by the 28 industry sectors). These 30 prices are all "market-clearing" prices. That is, at these prices the quantities supplied are equal to the quantities demanded in all 30 markets.

These relationships are shown in more detail in the Figure 1. This simple circular-flow diagram shows the basic supply and demand relationships between households and producer-firms. The outer set of flows, shown as solid lines, represent the flows of goods, services, capital, and labor between households and firms through the goods-and-services and factor market. The inner set of flows, shown as broken lines, represents monetary flows.

Figure 1. The Basic Circular-Flow Diagram

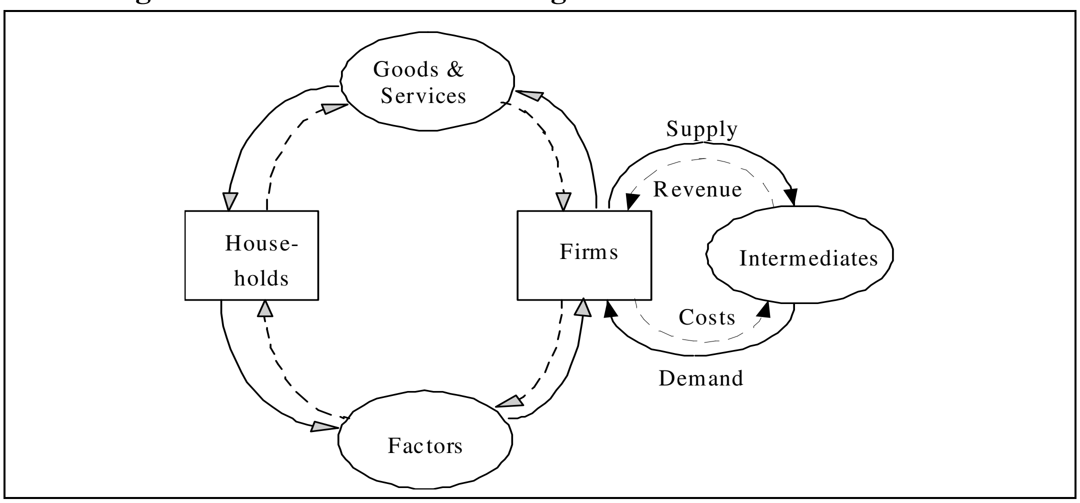


Firms supply goods and services to the goods-and-services market in exchange for revenues that they receive from the goods-and-services market. Firms demand capital and labor from the factor market in exchange for rents paid to the factor market. Households sell capital and labor services in the factor market and receive income in exchange. Households demand goods and services from the goods-and-services market in exchange for payments in the form of household expenditures.

2.3 Intermediate Goods

The economy of Nebraska is far more complex than that shown in the above figure. There are not only the final goods-and-services market but also intermediate goods markets in which firms sell to firms. A typical example of this might be chemicals sold to agricultural firms. The final output of the chemical industry (fertilizer, for example) is an intermediate good in the agricultural industry. This type of market is demonstrated in Figure 2. In this circular-flow diagram, an epicycle is added to show that a part of the supply of a firm (chemical industry, for example) is not sold to households, but is instead supplied to another firm through the intermediates market. For example, the agricultural sector demands fertilizer and part of the firm's revenue goes to pay the cost of fertilizer. The chemical firm supplies fertilizer and receives revenue from the agricultural sector through the intermediates market.

Figure 2. The Circular-Flow Diagram with Intermediate Goods

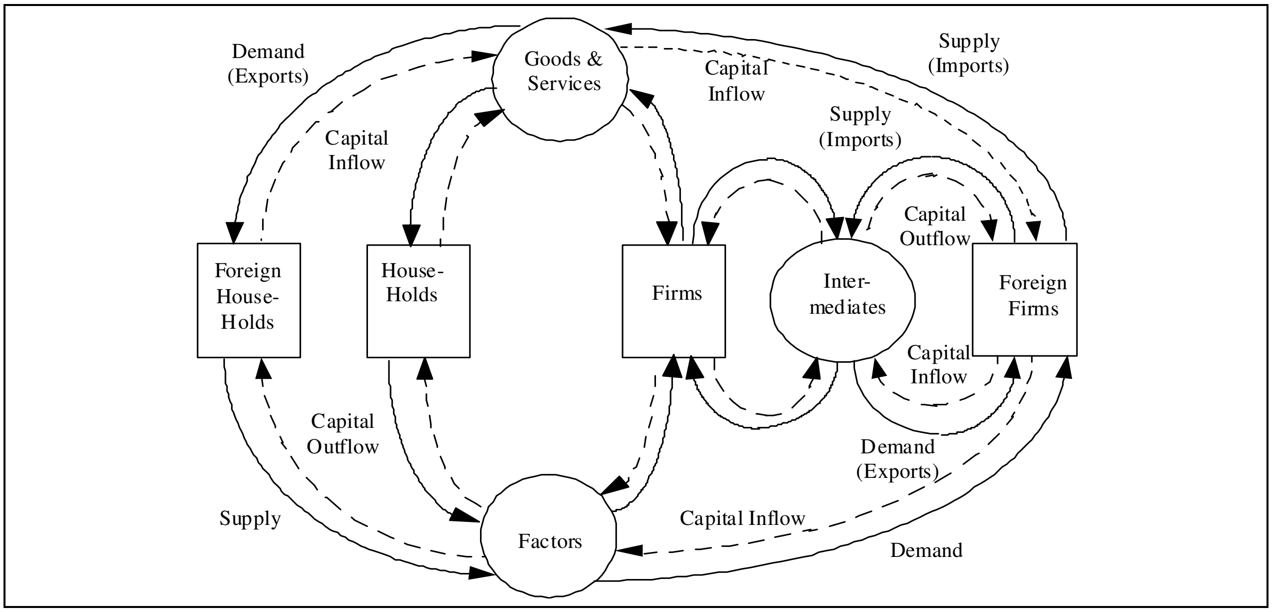


2.4 Rest of the World

In the TRAIN model, all economic sectors outside Nebraska are modeled as a single group called the "Rest of the World" (ROW). This is necessary because Nebraska has an open economy, meaning that Nebraska-based households and producers trade labor and capital, and goods and services with households and producers in other states and foreign countries. To simplify the model, no distinction is made between the rest of the US and foreign countries.

Figure 3 is a circular-flow diagram that incorporates the rest of the world into the previous diagrams. Agents in Nebraska interact with two types of foreign agents, foreign households and foreign firms. Foreign firms, on the right side of the diagram below, sell goods and services in the final goods-and-services market (at the top of the diagram), and in the intermediates market. That is, they supply goods and services to both households and other firms. Foreign households, on the left of the diagram, supply capital and labor to the factor market and demand goods and services from the final goods-and-services market. Note that the goods-and-services market and the intermediate market contain both domestic Nebraska and foreign-produced goods and services. Nebraska firms supply goods and services to foreign households through the final goods-and-services market. Similarly, Nebraska households supply capital and labor to Nebraska and foreign firms through the factor market.

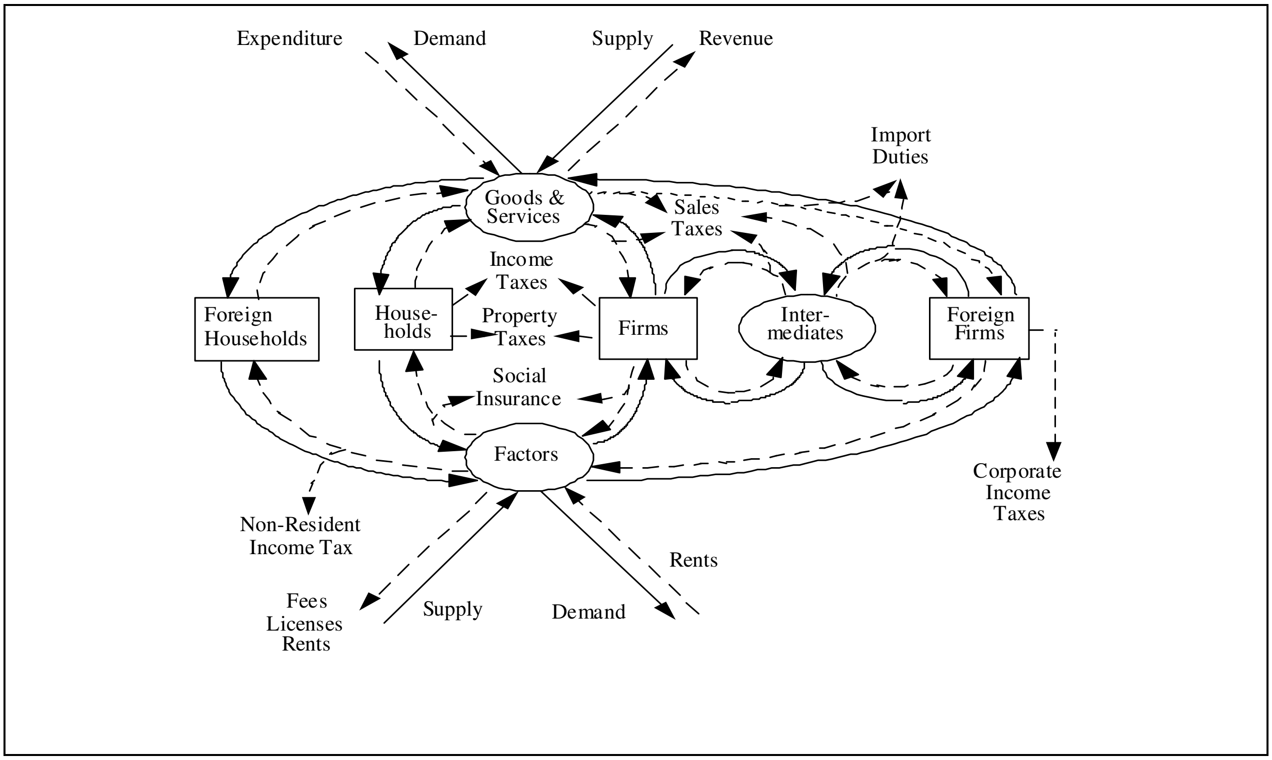
Figure 3. The Circular-Flow Diagram with Intermediate Goods and Trade



2.5 Government

The TRAIN model is designed to capture the impact of taxing and spending by governments. The government sectors are added to the final version of the circular-flow diagram in Figure 4, below. The government sector in the diagram depicts the taxing and spending of three levels of government (federal, state, and local). Governments interact with the economy at many levels. Governments buy labor services in the factor market and buy goods and services in the goods-and-services market. The monetary flows to government are spread throughout the diagram. These include income taxes, property taxes, payments for social insurance, license fees. Governments provide payments for wages and rents, transfer payments to households, payments to firms for goods and services.

Figure 4. The Complete Circular-Flow Diagram



3. THE DYNAMICS OF TRAIN

One of the most important and unique features of TRAIN is that it is a dynamic CGE model. A dynamic model is able to trace economic impacts of policy decisions through time. Many CGE models are static models. This type of model assumes the economy is initially in equilibrium, then a shock is added—a tax increase, for example—and the model computes the final equilibrium levels of prices and output. A static model is unable to trace economic impacts through over time. This is a weakness of static of models for some types of policy analysis. Most economic policies take longer than one year for their full effects to occur, but at the same time Nebraska's state government must produce balanced annual budgets.

3.1 Dynamic Considerations

TRAIN models dynamic changes in the economy by solving for a static equilibrium in the present period using stock variables fed exogenously to the model from the results from the previous period. For each new period, the stock variables are updated and used to calculate the solution for the model in the next period.

There are two kinds of adjustment behaviors incorporated in TRAIN. The first kind occurs in the goods-and-services market. In the goods-and-services market, agents are assumed to adjust prices based on the quantity of goods and services available. These adjustments are assumed to occur within the current time period. Equilibrium levels in this market are Walrasian in nature, where prices adjust to market-clearing levels.

The second type of adjustment behavior occurs in the factor market. In these markets, capital and labor are traded between households and producers. Adjustments in these markets take multiple time periods, reflecting the amount of time it takes for labor migration to take place or capital investment to occur. In TRAIN, these time periods are accounted for by the labor migration elasticity and the adjustment coefficient in the model's investment function.

TRAIN incorporates the different types of adjustment behavior in a two-stage process. The first stage models an instantaneous adjustment of prices to quantities in the goods-and-services market. Stage two models a lagged response in the factor market. This is schematically depicted in Figure 5. In TRAIN, static equilibria are sequenced through time to reflect changes in the economy's capital stock due to investment. In any time period, these equilibria are connected to each other through capital accumulation, labor migration, and population changes. Each single period equilibrium calculation begins with an initial capital stock in each sector and labor endowment in the economy. For example, the introduction of a government policy such as a tax cut sets the economy on a transition path, which approaches a new steady state over time. The magnitude and source of the policy shock determine (1) the position of the new steady state path, (2) the shape and slope of the transition path, and (3) the time required to reach the new steady state path. If the policy shock is very small, then the transition path will reach the new steady state in a relatively short time.

3.2 Household Savings and Investment

In many rational-level CGE models, total investment is determined by the volume of total savings in the national economy. Investment in these models is said to be "savings driven." Incorporating the effect of current savings on the future capital stock and household income produces a dynamic sequence of equilibria for each time period.

In a regional model, unlike a national model, savings need not be equal to investment. A regional model can be thought of as an open economy within an isolated economy. So, in a national model, it is likely that a substantial fraction of any increased savings will translate into increased national investment. In a regional model, increased regional savings may not translate into increased regional investment. Within the larger economy, a common currency and access to information about the supply of household and producer demand for capital make it very likely that excess savings will "leak" out of the region and into the larger economy.

When Nebraska households save more than Nebraska firms demand, excess savings flow out of the state, and when the reverse is true, savings flow into the state. In a closed economy, saving could not flow in or out; therefore, we would assume that interest rates would adjust so that the amount of saving would be sold at a market-clearing interest rate.

Figure 5. The Structure of the Dynamic TRAIN

Period t				Period (t +1)
Endowment	Stage 1	Result of Stage 1	Stage 2	Endowments
Labor stock	Calculation of static CGE	After-tax Real wage	Labor migration	Updated labor stock
Capital stock		Prices of goods	Net investment	Updated capital stock
		Output level		
		Rental price of capital		

TRAIN incorporates the assumption of savings as the residual of after-tax income less consumption. Modeling savings as a fixed share of after-tax income imposes a distribution of the remaining share of income across goods. Therefore, the goods-and-services market is forced to absorb additional income from the factor market. Given that savings are essentially a leakage in a regional economic model, rather than an engine driving investment, the choice of a saving function is less important than it is in a model of an isolated or national economy.

Investment in TRAIN is determined by an investment function that is independent of regional savings. The level of regional investment is driven by rates of return in the region relative to the rest of the nation. When the model is used to study an tax incentives, it seems appropriate to treat the inflow of external savings as a residual that responds to the level of investment in the region because regions are open economies and investment funds appear to be geographically mobile in the US.

3.3 Economic Growth

In the TRAIN model, the Nebraska economy grows over time through the process of capital accumulation and population growth. TRAIN assumes that the economy in the base year is on a steady-state path in which capital and labor grow at the same rate (keeping the capital-labor ratio constant), and prices, including wages and interest rates, are stable on the path. This assumption is critically important. Just as the assumption that the economy is in equilibrium in the base year is central to the development of the static version of model, the assumption of a balanced growth path is central to the development of the dynamic version of TRAIN.

The equilibria in any sequence or time periods are connected to each other through capital accumulation. Each single-period equilibrium calculation begins with an initial capital service endowment. Savings and capital inflows in the current period will augment the capital service endowment available in the next period. When the capital endowment grows at the same rate as the effect labor force, the economy is on a balanced growth path.

The definition of the steady-state growth path is a situation where tax policy is unchanging and

$$\frac{\dot{L}}{L} = \frac{\dot{K}}{K} = n$$

where L = labor endowment, $\dot{L}$ = increase in labor endowment, K = capital endowment, $\dot{K}$ = increase in capital endowment, and n = growth rate of effective units of labor.

Moreover, we separate the growth of effective labor units into components that reflect population growth and Harrod-neutral technical change (increase in productivity of existing labor). Thus,

$$n = (1+h)(1+g) - 1$$

where g = growth rate of natural unit of labor, h = growth rate of output per worker hour.

On the steady-state path, all relative prices remain constant. When introducing new tax policy, tax policy change will alter the steady state path and set the economy on a transition path and then, eventually the economy approaches a new steady-state.

4. AGGREGATION AND DATA

TRAIN, like all other empirical economic models, treats aggregates rather than individual agents. A correct aggregation or sectoring is a critical element in the development of any CGE model because it determines the flows that the model will be able to trace explicitly. For the TRAIN model, the Nebraska economy has been divided into 77 distinct sectors: 28 industrial sectors, two factor sectors (labor and capital), nine household sectors, one investment sector, 36 government sectors, and one sector that represent the rest of the world. The following tables briefly describe each sector.

In constructing a general equilibrium model, it is always assumed that the initial condition of the economy is in equilibrium. TRAIN is constructed so that observed data in the base year is in equilibrium. The data sets for this study consist of a Social Accounting Matrix (SAM), a Capital Coefficient Matrix (CCM), and a miscellaneous data set. As the primary data set, the SAM is constructed so that it satisfies the general equilibrium of the model in the base year. CCM and other miscellaneous data provide important parameters for solving the model.

A SAM, which is an extension of a traditional Input-Output model including income distribution, taxation, and consumption data, is a square matrix with balancing incomes and expenditures. Each entry in the matrix identifies an exchange of goods and services purchased by one sector from another sector or itself. The entries along a row in the SAM show each payment received by that particular sector. Summing the data across a row gives the total of revenues earned by that sector. The entries down a column in the SAM show the expenditures made by a particular sector. Summing the data down a column gives the total expenditures by sector.

Constructing a SAM for Nebraska requires data from various sources. The data for the industrial and household sectors are from IMPLAN, a commercial economic impact model and database program. IMPLAN provides the transaction matrix of goods and services among industries, gross output, final demands and final payments by sectors, imports, and factor incomes that were required for constructing the SAM. Factor incomes are updated by data provided by the US Department of Commerce. Federal government revenue data come from Internal Revenue Service. Federal government expenditure data are obtained from the US Department of Commerce database. Revenue and expenditure data for state and local governments come from the Nebraska Department of Revenue, and the Legislative Fiscal Office.

The CCM for Nebraska is aggregated and updated from a National Capital Coefficient Data Matrix provided by the US Department of Commerce. Capital stock and depreciation rates for Nebraska are estimated from "Fixed Reproducible Tangible Wealth of the United States" report produced by the US Department of Commerce.

4.1 The Industrial Sectors

TRAIN divides Nebraska's industrial sector into 28 distinct industries. Table 1 provides the names, descriptions, NAICS code, Industry name, and IMPLAN code for each sector.

4.2 The Factor Sectors

TRAIN contains two factors of production sectors in the model, labor and capital. Capital includes all factors of production other than labor. These sectors are named LABOR and CAPIT.

Table 1. Industrial Sectoring and Codes

Sector	Description	NAIC	Industry	IMPLAN
AGCRO	Crops	111	Livestock	1-10
AGLIV	Livestock	112	Crops	11-14
OTHPR	Primary	113 114- 115 211 212 213	Forestry Fishing and hunting Extracting Oil and gas Mining Support Activities	15-40
UTILI	Utility	22	Utilities	41-51
CONST	Construction	23	Construction	52-64
FOODS	Food	311	Food Manufacturing	65-88 93-105
MEATS	Meat Processing	3116	Meat Processing	89-92
MFRCO	Nonmetallic Mineral Manufacturing	321 322 327 337	Wood product Paper Nonmetallic Mineral Product Furniture and related Product	134-153 199-216 368-378
CHEMS	Chemicals & Related	324 325 326	Petroleum and Coal Products Chemical Manufacturing Plastics and Rubber Products	156-198
METAL	Metals & Machinery	331 332 333	Primary Metal Manufacturing Fabricated Metal Product Industrial Machinery	217-261 267-300
FARMM	Farm machinery	3331	Farm machinery and equipment	262-266
ELECT	Electronic Technology	334 335	Computer and Electronic Product Electronic Equipment	301-342
TRANM	Transportation Equipment	336	Transportation Equipment	343-367

Table 1. Industrial Sectoring and Codes (cont.)

Sector	Description	NAIC	Industry	IMPLAN
OTHMA	Other Manufacturing	312 313 314 315 316 323 339	Beverage and Tobacco Product Textile Mills Textile Product Mills Apparel Manufacturing Leather and Allied Product Printing and Related Miscellaneous Manufacturing	106-133 154-155 379-394
WHOLE	Wholesale Trade	42	Wholesale Trade	395
RETAI	Retail Trade	44 45	Retail Trade	396-407
TRAST	Transportation	48 49	Transportation Warehousing and Storage	408-419 518
INFOR	Information	51	Information	417-432
BANKS	Banking	521-523 525	Banking	433-436 439
INSUR	Insurance Carriers	524	Insurance Carriers	437-438
REALE	Real Estate	531	Real Estate	440-441
PSERV	Professional Services	54	Professional, Scientific, and Technical Services	447-460
BSERV	Business Services	55 56	Management of Companies Administrative and Support	461-471
ESERV	Educational Services	61	Educational Services	472-474
OSERV	Other Services	532-533 81	Rental and Leasing Services Other Services	442-446 504-517
HEALT	Health Services	62	Health Care and Social Services	475-487
ENTER	Entertainment	71	Arts, Entertainment, and Recreation	488-498
ACCOM	Accommodation	72	Accommodation and Food Services	499-503

4.3 The Household Sectors

TRAIN model divides Nebraska households into nine sectors, based on household income. Adjusted gross income (AGI) is used to determine the sectors. These household sectors reflect nine expenditure categories in the IMPLAN database. Table 2 shows gross income range for each household group.

Table 2. Household Sectoring by Income Class

Household	Gross Income Range
1	$0 – $15,000
2	$15,001 – $30,000
3	$30,001 – $40,000
4	$40,001 – $50,000
5	$50,001 – $70,000
6	$70,001 – $100,000
7	$100,001 – $150,000
8	$150,001 – $200,000
9	Above $200,000

4.4 The Government Sectors

TRAIN includes 33 government sectors representing federal, state, and local governments. This sectoring allows the model to trace explicitly the major government expenditure and revenue flows. The model includes seven federal government sectors, divided into five revenue receiving sectors and two expenditures sectors. The revenue sectors represent major federal taxes including social-security taxes (FTSOC), personal income taxes (FTPIT), corporation income taxes (FTPRO), and import duty taxes (FTDUT). The miscellaneous revenue sector (FTMSC) groups all other federal taxes including excise taxes on tobacco, alcohol, and liquid fuels as the main revenue sources. Table 3 shows federal government sectors and major revenue sources.

TRAIN divides the Nebraska state government into 18 sectors, including 12 revenue receiving sectors and six expenditures sectors. State revenues are collected into four types of funds, the general fund, special funds, other revenues, and distributive funds. The general fund is the largest accounting unit. Most tax revenues without a specific expenditure allocation are deposited into the general fund.

The model treats the general fund as one distinct revenue unit. Table 4 summarizes state government revenue sectors and their major revenue sources. Table 5 summarizes Nebraska State expenditure sectors with major sources of revenues, departments concerned, and expenditure outline.

Table 3. Federal Government Sectors

Sector	Description	Major Revenue Source(s)
Revenue : 5 Sectors		
FTSOC	Social-security tax	Industries Households
FTPIT	Personal income tax	Households
FTPRO	Corporation income tax	Industries
FTDUT	Import duty tax	Industries
FTMSC	Miscellaneous taxes	Industries Households
Expenditure : 2 Sectors		
FSDNO	Federal non-defense spending	
FSDDE	Federal defense spending	

Note that all federal spending and transfers are exogenous to the model.

Table 4. Nebraska State Revenue-Receiving Sectors

Sector	Description	Major Revenue Source(s)
NTINS	Insurance tax	Insurance premiums tax
NTMVS	Motor vehicles	License fees, Registration fees, Title fees
NTGAS	Gasoline	Motor fuels tax, Aircraft fuels tax
NTSAU	Sales	Sales and use taxes
NTPRO	Bank & Corporation	Corporation income taxes
NTLAB	Unemployment Insurance	Compensation insurance fund
NTPIT	Personal income tax	Personal income tax
NTUNI	University fees	Nebraska state university fees
NTINH	Inheritance	Transfer tax
NTSIN	Alcohol, tobacco & horse racing	Alcoholic tax, Cigarette tax, Wagering tax
NTMSC	Miscellaneous taxes	Remaining revenue
NGENF	General Fund	State revenue units, Investment

Finally TRAIN contains eight sectors representing local governments. Four of these are revenue sources, including, property taxes (LTPRP), local sales and use taxes (LTSAU), miscellaneous

Table 5. Nebraska State Expenditure Sectors

Sector	Major Departments	Major Sources of Revenue	Major Expenditure
NSTRA	Transportation	Highway taxes, Motor-vehicle Fees	Engineering, Construction, Transfers to local
NSCOR	Youth and adult correction	General fund	Labor, Goods & services
NSK12	Education	General fund	Transfers to local
NSUNI	Higher education	General fund	Labor, Goods & Services
NSHAW	Health and welfare	General fund, Transfers from federal	Transfers to households And local
NSOTH	Legislature, Social services, Water resources, Administrative services, etc.	General fund, Special funds	Rental of factors, Labor, Goods & services, Transfers to Local

revenues (LTMSC), and intergovernmental transfers from the federal government and the State of Nebraska. The sectoring of local government revenue agencies reflects their revenue sources. Since intergovernmental transfers are directly deposited into expenditure units, the model doesn’t account for intergovernmental transfer as a distinct unit. Local government expenditure agencies are sectored according to expenditure on transportation (LSTRA), corrections and legal affairs (LSCOR), education (LSK12), health and welfare (LSHAW), and other expenditures (LSOTH). Table 6 shows a listing of the local government sectors.

Table 6. Local Government Sectors

Sector	Description	Major Revenue Source(s)
Revenue : 3 sectors		
LTPRP	Property tax	Industries Household
LTSAU	Local sales and use tax	Industries
LTMSC	Miscellaneous	Industries Household
Expenditure : 5 sectors		
LSTRA	Local transportation	
LSCOR	Local corrections	
LSK12	Education, K-12	
LSHAW	Local health and welfare	
LSOTH	Others	

5. MODEL SPECIFICATION

This section contains descriptions of three behavioral specifications for representative agents in TRAIN, a mathematical equation, the GAMS form of the equation, and a brief narrative describing the equation, its key elements and important economic assumptions embodied in each.

5.1 Households

Consumers purchase goods and services in order to maximize their utility subject to a budget constraint. The model adapts the Cobb-Douglas formulation as consumers' utility function with unitary income elasticities, zero cross price elasticities, and unitary own price elasticities. It assumes that a representative household, *h*, consumes *i* types of goods and services where the consumption bundles are denoted by the vector c = ($c_1 \ldots c_i$). The prices of these goods are denoted by the vector p = ($p_1 \ldots p_i$) and the consumer's real disposable income is y_h^d.

Private Consumption

(5-1) $$c_{ih} = \bar{c}_{ih}\left(\frac{\bar{y}_h^d}{y_h^d} \div \frac{p_h}{\bar{p}_h}\right)^{\beta_{ih}} \prod_{i' \in I}\left[\frac{p_i\left(1+\sum_{g\in GS}\tau_{gi}^c\right)}{\bar{p}_i\left(1+\sum_{g\in GS}\tau_{gi}^q\right)}\right]^{\lambda_{i'i}} \qquad \forall i \in I, h \in H$$

GAMS: CH(I,H) =E= CH0(I,H) * ((YD(H) / YD0(H)) / (CPI(H) / CPI0(H))) ** BETA(I,H) * PROD(J, ((P(J) * (1 + SUM(GS, TAUC(GS,J)))) / (P0(J) * (1 + SUM(GS, TAUQ(GS,J))))) ** LAMBDA(J,I));

Description: This functional form allows for the dependence of consumption on real disposable income, own prices, and all other prices after taxes. Beta and Lambda represent unitary income elasticities, and zero cross price and unitary own price elasticities, respectively. TAUQ is the initial tax rate and TAUC is the tax rate set in the experiment.

Consumer Price Indices

(5-2) $$p_h = \frac{\sum_{i\in I} p_i\left(1+\sum_{g\in GS}\tau_{gi}^c\right)c_{ih}}{\sum_{i\in I} \bar{p}_i\left(1+\sum_{g\in GS}\tau_{gi}^q\right)c_{ih}} \qquad \forall h \in H$$

GAMS: CPI(H) =E= SUM(I, P(I) * (1 + SUM(GS, TAUC(GS,I))) * CH(I,H))
/ SUM(I, P0(I) * (1 + SUM(GS, TAUQ(GS,I))) * CH(I,H));

Description: Consumer price indices for each household type are calculated against a reference period.

Household Gross Incomes

(5-3)
$$y_h = \sum_{F \in f} \frac{\alpha_{hf} a_h^w}{\sum_{h \in H} \alpha_{hf} a_h^w} \left(1 - \sum_{g \in GF} \tau_{gf}^h\right)\left(\Omega_f y_f + (1 - \Omega_f)\bar{y}_f\right) \quad \forall h \in H$$

GAMS: Y(H) =E= SUM(F, A(H,F) * HW(H) / SUM(H1, A(H1,F) * HW(H1)) *(OMEGA(F) * Y(F) * (1 - SUM(GF, TAUFH(GF,F)))+

(1-OMEGA(F))*Y0(F)*(1-SUM(G,TAUFH(G,F)))));

Description: Nebraska household gross income is a function of payments to factors supplied by each household group and is apportioned to households on a fixed scale of shares per household type. The weights in OMEGA quantify the sensitivity of Nebraska household income to factor income earned in Nebraska. TAUFH are employee portions of factor taxes.

Household Disposable Incomes

(5-4)
$$y_h^d = y_h - \sum_{g \in G} t_{gh} a_h^w - \sum_{g \in G} \tau_{gh}^h a_h + \sum_{g \in G} a_h \tau_{hg}^{pc} \quad \forall h \in H$$

GAMS: YD(H) =E= Y(H) - SUM(GI, PIT(GI,H)) * HW(H) - SUM(G, TAUH(G,H) * HH(H)) + SUM(G, TP(H,G) * HH(H));

Description: Household disposable income is a function of gross household income remaining after all taxes have been paid and transfer payments received. PIT and TAUH are personal income taxes and household taxes other than pit respectively. TP are transfer payments.

Household Savings

(5-1)
$$s_h = y_h^d - \sum_{i \in I} c_{ih} p_i \left(1 + \sum_{g \in GS} \tau_{gi}^c\right) \quad \forall h \in H$$

GAMS: S(H) =E= YD(H) - SUM(I, P(I) * CH(I,H) * (1 + SUM(GS, TAUC(GS,I))));

Description: Saving is defined as disposable income minus consumption.

5.2 Producers

A firm produces outputs from the most effective combination of inputs, including labor and capital in order to maximize profit. The functional form chosen for producers is a Constant Elasticity of Substitution (CES) for primary factors of production, and fixed-shares for intermediate inputs. Therefore, factors form value added by a CES process and intermediate goods are used in fixed proportion to output.

Value Added Price Calculation

(5-2) $$p_i^{va} = p_i^d - \sum_{i' \in I} \alpha_{i'i} p_i \left(1 + \sum_{g \in GS} \tau_{gi'}^v \right) \qquad \forall\, i \in I$$

GAMS: PVA(I) =E= PD(I) - SUM(J, AD(J,I) * P(J) * (1 + SUM(GS, TAUV(GS,J))));

Description: This equation and its left-hand side variable are calculating conveniences. The share of domestic price remaining for the payment of factors is calculated as the residual of selling price, less payments for intermediate goods—including sales/use taxes imposed on intermediates. This simplifies the form of the factor demand equations. Since intermediate goods are in fixed proportion to output, their shares of costs do not form a direct part of the profit maximizing use of various intermediates, that is, there is no substitution between intermediate goods, nor between intermediates and factors in TRAIN.

Rental Rates

(5-3) $$\bar{r}_{fi}^r = r_{fi} r_f^a \left(1 + \sum_{g \in GF} \tau_{fgi}^x \right) - \frac{\sum_{g \in GN} t_{gn}^f t_i}{u_{fi}^d} \qquad \forall\, i \in I$$

GAMS: RREQ(F,I).. RR(F,I) =E= R(F,I) * RA(F) * (1 + SUM(GF, TAUFX(GF,F,I))) - SUM(GF, FITC(F,GF) * ITC(I)) / FD(F,I);

Description: Rental rates, including taxes are calculated by sector-, and economy-wide factor rental rates, tax rates of factors, and investment of tax credits.

Factor Demand

(5-4) $$u_{fi}^d = \bar{u}_{fi}^d \frac{q_i}{\bar{q}_i} \left(\frac{\bar{r}_{fi}^r p_i^{va}}{r_{fi}^r \bar{p}_i^{va}} \right)^{\sigma_i} \qquad \forall\, i \in I, f \in F$$

GAMS: FDEQ(F,I).. FD(F,I) =E= FD10(F,I) * DS(I) / DS10(I) * ((RR10(F,I) * PVA(I)) / (RR(F,I) * PVA10(I))) ** SIGMA(I);

Description: Factor demand functions are calculated by taking the first derivative of the profit function with respect to each factor demand variable—holding prices and other factor demands constant. SIGMA denotes elasticities of substitution in production.

5.3 Unit Cost

(5-9) $$p_i^{va} = \bar{p}_i^{va} \left(\sum_{f \in F} \alpha_i \left(\frac{r_i^r}{\bar{r}_i^r} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \qquad \forall\, i \in I$$

GAMS: PCEQ(I).. PVA(I) =E= PVA10(I) * SUM(F, ALPHA(F,I) * (RR(F,I) / RR10(F,I)) ** (1 - SIGMA(I))) ** (1 / (1 - SIGMA(I)));

Description: Since the profit maximizing condition for competitive markets is price equal to marginal cost, the unit cost function derived from first order condition of the cost function, is the value added price.

Intermediate Demand

(5-10) $$v_i = \sum_{i' \in I} \alpha_{ii'} q_{i'} \qquad \forall\, i \in I$$

GAMS: V(I) =E= SUM(J, AD(I,J) * DS(J));

Description: In all industries, intermediate goods are in fixed shares of production. This is a standard assumption in CGE models and provides a major simplification and size reduction to the model.

Factor Income

(5-11) $$y_f = \bar{y}_f + \sum_{i \in I} \Omega_f r_{fz} r_f^a u_{fz}^d - \sum_{i \in I} \Omega_f \bar{r}_{fz} \bar{r}_f^a \bar{u}_{fz}^d \qquad \forall f \in F$$

GAMS: YFEQ(F).. Y(F) =E= Y10(F) + SUM(Z, OMEGA(F,Z)*R(F,Z) * RA(F) * FD(F,Z)) - SUM(Z, OMEGA(F,Z)*R10(F,Z) * RA10(F) * FD10(F,Z));

Description: This is a simple calculation device to gather all payments to factors from sectors and from governments. The weights in OMEGA quantify the sensitivity of Nebraska household income to factor income earned in Nebraska. It is assumed that residents directly receive 95% of all income earned in Nebraska. The remainder goes to out-of-state households. For capital income, OMEGA is equal to the share of proprietor's income in total non-labor income.

5.4 Trade

TRAIN uses the share equation from Armington's CES formulation for foreign trade. A first order condition of utility maximization of the Armington formulation has been implemented.

Export Demand

(5-12) $$e_i = \bar{e}_i \left[p_i^d \div \bar{p}_i^w \div \left(1 + \sum_{g \in G} \tau_{gi}^m \right) \right]^{\eta_i^e} \qquad \forall i \in I$$

GAMS: CX(I) =E= CX0(I) * (PD(I) / PW0(I) / (1 + SUM(G, TAUM(G,I)))) ** ETAE(I);

Description: Export demand for domestic production is a simple function of observed exports and the relationship between domestic and world prices. As domestic prices rise in relation to world prices, exports fall. TAUM is import duty tax rates, and ETAE are export price elasticities.

Domestic Shares

(5-13) $$d_i = \bar{d}_i \left[p_i^d \div \bar{p}_i^w \div \left(1 + \sum_{g \in G} \tau_{gi}^m \right) \right]^{\eta_i^d} \qquad \forall i \in I$$

GAMS: D(I) =E= D0(I) * (PD(I) / PW0(I) / (1 + SUM(G, TAUM(G,I)))) ** ETAD(I);

Description: The domestic share of domestic consumption adjusts in ways similar to that of exports, with the relationship to relative prices. Imports and domestic production are not perfect substitutes in the minds of consumers, firms, governments and investors. ETAD are import price elasticities.

Import Demand

(5-14) $$m_i = (1 - d_i) x_i \qquad \forall i \in I$$

GAMS: M(I) =E= (1 - D(I)) * DD(I);

Description: Imports, given the domestic share function above, are simply the share of domestic consumption that is not supplied by domestic sources. The shares are determined in the preceding equations.

Aggregated Prices

(5-15) $$p_i = d_i p_i^d + (1 - d_i)\bar{p}_i^w \left(1 + \sum_{g \in G} \tau_{gi}^m\right) \quad \forall\, i \in I$$

GAMS: P(I) =E= D(I) * PD(I) + (1 - D(I)) * PW0(I) * (1 + SUM(G, TAUM(G,I)));

Description: This equation simply defines an aggregate price level as a weighted average of domestic (Nebraska) prices and ROW (Non-Nebraska) prices.

Net Capital Inflow

(5-16) $$z = \sum_{i \in I} m_i \bar{p}_i - \sum_{i \in I} e_i p_i^d$$

GAMS: NKI =E= SUM(I, M(I) * PW0(I)) - SUM(I, CX(I) * PD(I));

Description: This equation keeps track of capital flows. The net of outflows as imports less exports is set to equal inflows.

5.5 Investment

For investment, TRAIN adopts a "supply of capital" equation that gives the supply of capital to Nebraska as a function of the difference between rates of return in Nebraska and the rest of the world. Steady state investment is that level required maintaining the capital stock.

Gross Investment by Sector of Destination

(5-17) $$n_i = k_i \delta_i \quad \forall\, i \in I$$

GAMS: N(I) =E= KS(I) * DEPR;

Description: Because the model describes steady state behavior, investment demand is the investment required to maintain the capital stock. Investment demand is determined by the demand for capital and depreciation rates.

Predicted Gross Investment by Sector of Source

(5-18) $$p_i \left(1 + \sum_{g \in GS} \tau_{gi}^n\right) c_{in} = \sum_{j \in I} \beta_{ij} n_i \quad \forall i \in I$$

GAMS: P(I) * (1 + SUM(GS, TAUN(GS,I))) * CNW(I) =E= SUM(J, CCM(I,J) * N(J));

Description: This equation generates investment demand for each sector's output from estimates of investment by sector of origin using shares from the CCM.

Desired Capital Stock

(5-19) $$k_i = \bar{k}_i \left(\frac{r_{ki}}{\bar{r}_{ki}} \right)^{\eta_i} \quad \forall i \in I$$

GAMS: KS(I) =E= KS0(I) * (R('CAPIT',I) / R0('CAPIT',I)) ** ETAI(I);

Description: The desired capital stock adjusts to the difference between current and the initial return to capital.

Residential Investment

(5-20) $$c_{in}^R = \bar{c}_{in}^R \sum_{h \in H} y_h^d / \sum_{h \in H} \bar{y}_h^d \quad \forall i \in I$$

GAMS: CHH(I) =E= CHH0(I)*((SUM(H,YD(H))/SUM(H,YD0(H)))**ETAH);

Description: The demand for residential investment spending depends on total household disposable income.

Actual Level of Investment by Sector of Source

(5-21) $$c_{in} = \bar{c}_{in} + (c_{in}^p - \bar{c}_{in}^p) + (c_{in}^R - \bar{c}_{in}^R) \quad \forall i \in I$$

GAMS: CN(I) =E= CNIMP(I)+CNW(I)-CN0(I)+CHH(I)-CHH0(I);

Description: The levels of investment predicted by TRAIN differ somewhat from the levels reported by those used in our SAM. To minimize the impact of this discrepancy, we use the initial values given by our SAM and use TRAIN only to predict *changes* in the investment by source. The level of investment is thus the initial level plus the predicted change in investment by industry and the predicted change in residential investment by households.

Calculated Investment Tax Credit

(5-5) $$t_i^P = n_i \tau_i^n \theta_i \quad \forall i \in I$$

GAMS: ITCTEQ(I).. ITCT(I) =E= N(I) * ITCR(I) * ITCE(I) ;

Description: The predicted level of the investment tax credit is a function of tax rates and the share of qualifying firms multiplied by the predicted level of investment

Actual Level of Investment Tax Credit

(5-23) $t_i = \bar{t}_i + (t_i^P - \bar{t}_i^P) \;\; \forall i \in I$

GAMS: ITC(I) =E= ITC0(I) + ITCT(I) - ITCT0(I);

Description: The levels of the investment tax credit predicted by TRAIN differ somewhat from the levels reported. To minimize the impact of this discrepancy, TRAIN calculates *changes* in the investment tax credit and adjusts the reported initial values accordingly.

5.6 Labor Supply

Labor Supply

(5-24)
$$\frac{a_h^w}{a_h} = \frac{\bar{a}_h^w}{\bar{a}_h} \left(\frac{r_L^a}{\bar{r}_L^a} \right)^{\eta_h^{LS}} \left(\frac{\sum_{g \in GI} \bar{t}_{gh}}{\sum_{g \in GI} t_{gh}} \right)^{\eta_h^{PIT}} \left(\frac{\sum_{g \in G} \frac{\bar{w}_{h'g}}{\bar{p}_h}}{\sum_{g \in G} \frac{w_{h'g}}{p_h}} \right)^{\eta_h^w} \quad \forall h \in H$$

GAMS: HW(H) / HH(H) =E= HW0(H) / HH0(H) * ((RA('L') / RA0('L')) / (CPI(H) / CPI0(H))) ** ETARA(H) * (SUM(GI, PIT(GI,H)) / SUM(GI, PIT0(GI,H))) ** ETAPIT(H) * (SUM(G, TP(H,G) / CPI(H)) / SUM(G, TP0(H,G) / CPI0(H))) ** ETATP(H);

Description: The household labor supply equation is a function of the existing labor supply, the change in statewide wage rates between periods, the change in taxes between periods, and the change in transfer payments when not working. Each household responds according to a constant set of elasticities, but the elasticities vary across household sectors. High-income households have higher elasticities with respect to wages and taxes, but are not responsive to transfer payments. Low-income households have lower elasticities with respect to wages and taxes and higher responsiveness to transfer payments.

Migration and Population

(5-25)
$$a_h = \bar{a}_h \cdot \pi + \bar{a}_h^i \left(\frac{y_h^d}{a_h} \div \frac{\bar{y}_h^d}{\bar{a}_h} \div \frac{p_h}{\bar{p}_h} \right)^{\eta_h^{yd}} \left(\frac{a_h^n}{a_h} \div \frac{\bar{a}_h^n}{\bar{a}_h} \right)^{\eta_h^u} - \bar{a}_h^o \left(\frac{\bar{y}_h^d}{\bar{a}_h} \div \frac{y_h^d}{a_h} \div \frac{\bar{p}_h}{p_h} \right)^{\eta_h^{yd}} \left(\frac{\bar{a}_h^n}{\bar{a}_h} \div \frac{a_h^n}{a_h} \right)^{\eta_h^u} \quad \forall h \in H$$

GAMS: HH(H) =E= HH0(H) * NRPG(H) + MI0(H) * ((YD(H) / HH(H)) / (YD0(H) / HH0(H)) / (CPI(H) / CPI0(H))) ** ETAYD(H) * ((HN(H) / HH(H)) / (HN0(H) / HH0(H))) ** ETAU(H) - MO0(H) * ((YD0(H) / HH0(H)) / (YD(H) / HH(H)) / (CPI0(H) / CPI(H))) ** ETAYD(H) * ((HN0(H) / HH0(H)) / (HN(H) / HH(H))) ** ETAU(H);

Description: The population for each household type is a function of existing population, the natural rate of population growth, and net migration. Net migration depends upon after tax incomes and that household's fraction of non-working members. Working population depends on the after-tax return to labor. Total population is a function of the changing attractiveness of Nebraska as measured by real after-tax earnings changes and employment prospects.

Number of Non-Working Households

(5-26) $a_h^n = a_h - a_h^w \quad \forall h \in H$

GAMS: HN(H) =E= HH(H) - HW(H);

Description: The number of non-working households is simply the count of that household's population, minus those with jobs.

5.7 Taxation and Government

TRAIN treats all federal spending and transfers as exogenous. Modeling the possible dependence of federal transfers on Nebraska income is currently beyond the scope of the model. The model treats most state spending as endogenous. The exception is unemployment and disability payments which are taken to be exogenous. State spending units are assumed to spend all special funds allocated to them. The model does not impose a balanced budget. However, if tax revenues rise or fall, they are simply reflected in surpluses or deficits on the General Fund Balance, which accounts for about 75% of all expenditures. This strategy allows tracing the budget implications of alternative policies.

TRAIN assumes that local governments operate under a balanced budget. Specifically, local government units spend—either through transfers to individuals or through purchases of goods and services—all of the funds allocated to them. Local property taxes are taken to be exogenous, but other local revenue including transfers from state government are explicitly modeled. All local spending is endogenous and responds in a manner to ensure local budgets balance.

Household Personal Income Taxes

(5-27)

$$t_{gh} a_h^w = \bar{t}_{gh} \bar{a}_h^w \tau_{gh}^c + \tau_{gh}^m \left\{ (y_h - \bar{y}_h) - \left(\sum_{g'} \alpha_{gg'}^{\tau} (a_h^w t_{gh} - \bar{t}_{gh} \bar{a}_h^w) \tau_{gh}^i \right) \right\}$$

$$\forall g \in GI,\ h \in H$$

GAMS: PIT(GI,H)*HW(H) =E= PIT0(GI,H)*HW0(H)*TAXCVC(GI,H) + MTR(GI,H)*(Y(H)-Y0(H)-SUM(GI1, ATAX(GI1,GI)* (HW(H) * PIT(GI1,H)-HW0(H) *PIT0(GI1,H))) *TAXPI(GI,H));

Description: The personal income tax equation represents a linear approximation of the personal income tax code. Total personal income tax (PIT) payments are equal to taxes per working household times the number of working households. The model constructs PIT as equal to the initial level plus the marginal tax rate times the change in income minus the marginal tax rate times the increase in deductions from payment of other income taxes.

Government Income

(5-28)

$$y_g = \sum_{i \in I} \tau_{qgi}^x v_i p_i + \sum_{i \in I} \tau_{gi}^m m_i p_i^w + \sum_{i \in I} \sum_{h \in H} \tau_{qgi}^x c_{ih} p_i + \sum_{i \in I} \tau_{qgi}^x c_{in} p_i + \sum_{i \in I} \sum_{g' \in G} \tau_{qgi}^x c_{ig'} p_i$$
$$+ \sum_{i \in I} \sum_{f \in F} \tau_{gi}^x r_{fi} r_f^a u_{fi}^d + \sum_{g' \in G} \sum_{f \in F} \tau_{gi}^x r_{fg} r_f^a u_{fg'}^d + \sum_{h \in H} \tau_f^h y_f$$
$$+ \sum_{h \in H} \tau_{hg}^h a_h + \sum_{h \in H} t_{gh} a_h^w + \sigma_{gn} \left(- \sum_{i \in I} t_i \right) \Bigg|_{CABAC} \quad \forall g \in G$$

GAMS: Y(G) =E= SUM(I, TAUV(G,I) * V(I) * P(I)) + SUM(I, TAUM(G,I) * M0(I) * PW0(I)) + SUM((H,I), TAUC(G,I) * CH(I,H) * P(I)) + SUM(I, TAUN(G,I) * CN(I) * P(I)) + SUM((G1,I), TAUG(G,I) * CG(I,G1) * P(I)) + SUM((F,I), TAUFX(G,F,I) * RA(F) * R(F,I) * FD(F,I)) + SUM((F,G1), TAUFX(G,F,G1) * RA(F) * R(F,G1) * FD(F,G1)) + SUM(F, TAUFH(G,F) * Y(F)) + SUM(H, PIT(G,H)*HW(H)) + SUM(H, TAUH(G,H) * HH(H)) + SAM(G,'INVES') - FITC('CAPIT',G)*SUM(I, ITC(I));

Description: Government income is the sum of sales taxes collected from domestic consumption including intermediates, imports, household consumption, investment and governments, plus taxes on factor payments, plus taxes collected from households including income taxes and per household taxes, less investment tax credits.

Government Endogenous Purchases of Goods and Services

(5-29)
$$p_i\left(1+\sum_{g\in GS}\tau_{gi}^{g}\right)c_{ig} = a_{ig}\left(y_g + \sum_{g'\in G} b_{gg'} - \sum_{g'\in G} b_{gg'} - \sum_{h\in H} w_{hg} a_h - \bar{s}_g\right) \quad \forall i \in I, g \in GN$$

GAMS: P(I) * (1 + SUM(GS, TAUG(GS,I))) * CG(I,GN)=E= AG(I,GN) * (Y(GN) + SUM(G1, IGT(GN,G1)) - SUM(G1, IGT(G1,GN))- SUM(H, TP(H,GN) * HH(H)) - S0(GN));

Description: Endogenous government spending units are assumed to spend all of their net income. Their net income consists of tax revenues, plus inter-governmental transfers in, less inter-governmental transfers out, less transfer payments made from this unit, less the observed level of government savings in the original data. Spending is allocated across industrial sectors according to the shares in the original data.

Government Endogenous Rental of Factors

(5-30)
$$u_{fg}^{d} r_f^{a} r_{fg} = \alpha_{fg}\left(y_g + \sum_{g'\in G} b_{gg'} - \sum_{g'\in G} b_{gg'} - \sum_{h\in H} w_{hg} a_h - \bar{s}_g\right) \quad \forall f \in F, g \in GN$$

GAMS: FD(F,GN) * RA(F) * R(F,GN) =E= AG(F,GN) * (Y(GN) + SUM(G1, IGT(GN,G1)) - SUM(G1, IGT(G1,GN)) - SUM(H, TP(H,GN) * HH(H)) - S0(GN));

Description: The shares of government spending for factor rentals are applied to government incomes and set equal to nominal government factor rentals. Government factor taxes paid to other governments do not appear, as these are omitted from the share calculations.

Government Savings

(5-31)
$$s_g = y_g - \sum_{i\in I} c_{ig} p_i\left(1+\sum_{g\in GS}\tau_{gi}^{g}\right) - \sum_{f\in F} u_{fg}^{d} r_{fg} r_f^{a}\left(1+\sum_{g'\in GF}\tau_{fg'i}^{x}\right) - \sum_{h\in H} w_{hg} a_{hg} - \sum_{g'\in G} b_{g'g} + \sum_{g'\in G} b_{gg'} \quad \forall g \in G$$

GAMS: S(G) =E= Y(G) - SUM(I, CG(I,G) * P(I) * (1 + SUM(GS, TAUG(GS,I)))) - SUM(F, FD(F,G) * R(F,G) * RA(F) * (1 + SUM(GF, TAUFX(GF,F,G)))) - SUM(H, TP(H,G) * HH(H)) - SUM(G1, IGT(G1,G)) + SUM(G1, IGT(G,G1));

Description: As with the household savings function, government saving becomes the residual from government income less government purchases of goods and services less government rental of factors less government welfare payments less net intergovernmental transfers paid.

Distribution of Tax Revenue to Spending Locations

(5-32) $b_{g'g} = \mu_{g'g} y_g \quad \forall g \in GI, g' \in G$

GAMS: IGT(G,GT) =E= TAXS(G,G) * Y(GT);

Description: Taxing units in our model distribute their receipts in two ways, transfers to spending units, and transfers to individuals. The intergovernmental transfer matrix, IGT, identifies which units are modeled this way. A tax destination shares matrix, TAXS, is established which identifies the shares of net taxes that are distributed to particular government units.

Endogenous Transfer Payments to Individuals

(5-33) $w_{hg} a_h = \overline{w}_{hg} \overline{a}_h \left(\sum_{g' \in G} b_{g'g} \right) \div \left(\sum_{g' \in G} \overline{b}_{g'g} \right) \quad \forall g \in GWN$

GAMS: TP(H,GWN) * HH(H) =E= TP0(H,GWN) * HH0(H) * SUM(G, IGT(GWN,G)) / SUM(G, IGT0(GWN,G));

Description: Endogenous transfer payments to individuals depend on the number of households and the transfers received from other governmental units.

<u>*5.8 Market Closure*</u>

Macroeconomic closure rules in a general equilibrium models specify the aggregate economic behavior that restores macro equilibrium when saving and investment are thrown out of balance by exogenous shocks.

Labor Market Clearing

(5-34) $\sum_{h \in H} a_h^w = \left(\sum_{i \in I} u_{Li}^d + \sum_{g \in G} u_{Lg}^d \right) \varepsilon$

GAMS: SUM(H, HW(H)) =E= SUM(Z, FD('L',Z)) * JOBCOR;

Description: This equation imposes the equality of supply and demand for labor. Supply is expressed in number of working households and demand is expressed in number of jobs. To correct any discrepancy, a constant correction factor is applied to demand.

Capital Market Clearing

(5-35) $u^s_{Ki} = u^d_{Ki} \quad \forall i \in I$

GAMS: KS(I) =E= FD('K',I);

Description: As with labor markets, capital markets are forced to clear, sector-by-sector.

Goods Market Clearing

(5-36) $q_i = x_i + e_i - m_i \quad \forall i \in I$

GAMS: DS(I) =E= DD(I) + CX(I) - M(I);

Description: Domestic demand is the sum of intermediate, consumer, government and investment demand. The right hand side of this function could have been incorporated into the functions below and into trade demand equations, but has been kept separate for simplifying and transparency reasons.

Definition of Domestic Demand

(5-37) $x_i = v_i + \sum_{h \in H} c_{ih} + \sum_{g \in G} c_{ig} + c_{in} \quad \forall i \in I$

GAMS: DD(I) =E= V(I) + SUM(H, CH(I,H)) + SUM(G, CG(I,G)) + CN(I);

Description: These equations ensure the balance between domestic production and demand for this production (domestic plus foreign demand, less imports).

Fix PIT for Non-Income Tax Units to Zero

(5-38) $t_{gh} = 0 \quad \forall h \in H, g \notin GI$

GAMS: PIT.FX(G,H)$(NOT GI(G)) = 0;

Description: These are ‘housekeeping’ equations to ensure that the mathematical programming solver does not create income taxes that do not reflect the institutional structure of governments.

Fix Inter-Governmental Transfers to Zero if not in Original SAM

(5-39) $b_{gg'} = 0 \quad \forall g, g' \in G \text{ where } \overline{b}_{gg'} = 0$

GAMS: IGT.FX(G,G1)$(NOT IGT0(G,G1)) = 0;

Description: These are 'housekeeping' equations to ensure that the mathematical programming solver does not create inter-governmental transfers that do not reflect the institutional structure of governments.

Fix Exogenous Inter-Governmental Transfers

(5-40) $b_{gg'} = \overline{b}_{gg'} \quad \forall g, g' \in G \text{ where defined}$

GAMS: IGT.FX(G,G1)$(IGTD(G,G1) EQ 2) = IGT0(G,G1);

Description: These represent payments to and from each level of government and from taxing authorities to spending authorities. Federal block grants are modeled this way.

Fix Exogenous Government Spending on Goods and Services

(5-41) $c_{ig} = \overline{c}_{ig} \quad \forall i \in I, g \in GX$

GAMS: CG.FX(I,GX) = CG0(I,GX);

Description: Some government units are modeled with endogenous spending and some as exogenous.

Fix Exogenous Government Rental of Factors

(5-42) $u^d_{fg} = \overline{u}^d_{fg} \quad \forall f \in F, g \in GX$

GAMS: FD.FX(F,GX) = FD0(F,GX);

Description: As with purchases of goods and services by some government units, discussed above, rental of factors are made endogenous for some governments and exogenous for others.

Fix Inter-Sector Wage Differentials

(5-43) $r_{Li} = \overline{r}_{Li} \quad \forall i \in I$

GAMS: R.FX('L',Z) = R0('L',Z);

Description: Inter-sectoral wage differentials are fixed to those calculated using employment and wage data in IMPLAN. Since households respond to the overall change in wages, only the economy-wide wage variable can change, not the sectoral wage differential.

Fix Government Rental Rates for Capital

(5-44) $r_{Kg} = \bar{r}_{Kg} \quad \forall g \in G$

GAMS: R.FX('K',G) = R0('K',G);

Description: Because government does not respond to a profit maximizing motivation, government rental rate for capital is held exogenous.

Fix Economy Wide Scalar for Capital

(5-45) $r_f^a = \bar{r}_f^a \quad \forall f \in F$

GAMS: RA.FX('K') = RA0('K');

Description: Since firms make their investment decision based on the change in their own sector return to capital, the economy-wide scalar is fixed.

Fix Exogenous Transfer Payments

(5-46) $w_{hg} = \overline{w}_{hg} \quad \forall h \in H, g \in GWX$

GAMS: TP.FX(H,GWX) = TP0(H,GWX);

Description: Transfer payment are exogenous, or are set to zero if they are zero in the original data, as below.

Fix Transfer Payments to Zero if Zero in Original Data

(5-47) $w_{hg} = 0 \quad \forall\ h \in H, g \in GWX \text{ where } \overline{w}_{hg} = 0$

GAMS: TP.FX(H,G)$(NOT TP0(H,G)) = 0;

Description: Transfer payments are set equal to zero if the initial data indicate no such payments.

6. SELECTED REFERENCES

Ballard, C. L., D. Fullerton, J. Shoven, and J. Whalley. 1985. *A General Equilibrium Model for Tax Policy Evaluation.* Chicago: University of Chicago Press.

Berck, P., E. Golan, and B. Smith. 1996. *Dynamic Revenue Analysis for California*. Sacramento: California Department of Finance.

Cushing, Matthew J., and Iksoo Cho. 1998. *Tax and Revenue Analysis in Nebraska*. Lincoln: Nebraska Legislature.

Keller, Wouter J. 1980. *Tax Incidence: A General Equilibrium Approach*. Amsterdam: North-Holland Publishing Company.

Kraybill, David S., Thomas G. Johnson, and David Orden. 1992. Macroeconomic imbalances: A multiregional general equilibrium analysis. *American Journal of Agricultural Economics* 74:726–36.

Shoven, John B., and John Whalley. 1972. A general equilibrium calculation of the effect of differential taxation of income from capital in the US. *Journal of Public Economics* 1:281–321.