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A MULTI-REGION COMPUTATIONAL GENERAL EQUILIBRIUM MODEL OF THE UNITED STATES, USED FOR SUB-NATIONAL TAX POLICY ANALYSIS

by

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE DOCTOR OF PHILOSOPHY

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April, 1996
Abstract

A Multi-Region Computational General Equilibrium Model of the United States, Used for Sub-National Tax Policy Analysis

by

Michael F. Williams

In my thesis I construct a four-region, four-product, three-factor, two income class applied general equilibrium model of the United States, which I use to examine several issues in sub-national tax incidence. Each of the four regions is an aggregate of several states. Within each region four products are produced; one is interregionally traded, one is not traded, one is provided by the region's government, and the last is provided by the national government. Each of the four products requires capital, skilled labor, and unskilled labor for its production. These factors are supplied by two types of households, Rich and Poor, who differ in their relative factor endowments and in their ability to relocate among regions (Rich may be mobile; Poor are immobile). Each household consumes each of the four products. Federal and regional governments tax households, firms, and products.
A benchmark equilibrium is established in which product and factor markets clear and in which Rich households have no incentive to relocate among regions. I then simulate several tax policy changes. In the first group of simulations, a single region's tax rates are (separately and unilaterally) increased, with the revenue used to fund additional government spending. One conclusion drawn from these simulations is that household utilities fall in any region which unilaterally increases any of its tax instruments. Interestingly, however, the business capital tax is the least "painful" way for a regional government to unilaterally increase its tax revenue. In the second group of simulations, a regional government unilaterally eliminates its household taxes, replacing the lost revenue by increasing its business capital taxes. In these simulations, household utilities generally increase in the region that eliminates its household taxes, while utilities decrease in other regions. This result is especially robust for regions which are net capital importers--those regions in which producers use more capital than their regions' residents own. Sensitivity analysis reveals that my simulation results are fairly robust, even when important parameter estimates (such as elasticities of substitution in production and consumption) are varied.
ACKNOWLEDGEMENTS

Those few who peruse the following pages will learn more about my benefactors than about my limited talents in economics. If they find some small economic insight winding through these pages, then it was guided by the knowledge and wisdom of Dr. George Zodrow. If they see a tiny bud of competent computational technique, then the seed was sown by Dr. Richard Young.

Those who know me may marvel that thesis has actually been completed. This miracle owes much to the angelic assistance of Ms. Joy Bryant, Ms. Patsy Williams, and Ms. Vera Wallis, to the steadfast guidance of Dr. Robert Zozus, and to the valuable suggestions and encouragement of Dr. Robert Stein.

Above all, I express my most profound thanks to Dr. Peter Mieszkowski. It was he who recruited me to Rice University. His exuberant lectures inspired me into the field of public economics. His ideas form the foundation of this thesis. His comments, suggestions, corrections, and knowledge support the structure of this thesis. His unending patience, his robust encouragement, his tireless assistance, and his friendship gave me the capacity to complete this thesis when I believed that the task was beyond my power. Good fortune found me when I found a mentor as extraordinary as Dr. Mieszkowski. I owe him a sum of gratitude too large to ever repay.
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1. Introduction

In the thirty years since Arnold Harberger first examined the incidence of a corporation income tax using a general equilibrium model,¹ economists have increasingly relied upon general equilibrium analyses of tax incidence, in order to capture the important economic effects of taxes in areas of the economy well beyond their area of initial statutory assessment. General equilibrium tax analysis is especially useful when examining a federal economy in which sub-national (i.e. state or local) governments have independent tax-levying authority, such as the United States economy; indeed, in a seminal work Peter Mieszkowski (1972), using a general equilibrium framework, turned the accepted view of property tax incidence on its head by illustrating how a locally-assessed property tax can have far-reaching national effects.

In recent years some economists have developed "computational general equilibrium," or "CGE" models that can give precise numerical estimates of the effects of changes in tax policy. Perhaps the best known of these CGE models was principally developed by John Shoven and John Whalley² and has been used to analyze potential changes in United States government tax policies. Other CGE models, including one developed by Mutti and Morgan³ divide the economy into several geographic regions, in order to more accurately analyze the potential economic effects of a sub-national government altering its tax policy.

This dissertation, using as a foundation the theoretical work of Harberger and Mieszkowski, and building upon the applied work of Shoven and Whalley and other authors, presents a computational general equilibrium model of a federal economy that improves upon previous CGE models. The model can be used to analyze the incidence of both nationally levied and sub-nationally levied taxes, and can distinguish between regional

¹ See, for example, Harberger (1962).
² See, for example, Shoven and Whalley (1972).
³ See, for example, Mutti, Morgan, and Partridge (1988).
effects of tax policy changes (for example, an increase in the utilities of one region's residents) and national effects (for example, a change in the national average return to labor). Highlighted below are the major features of the model:

--Two types of households exist, Rich and Poor, differentiated by their factor endowments.

--Four types of products (Goods, Services, Regional Government Goods, and Federal Government Goods) are produced using differing production technologies.

--The economy is divided into four geographic regions (Northeast/Midwest, Texas, South, and West). Some households and some products can be interregionally mobile.

--Within each region is a government with independent fiscal powers. A national government also exists, with fiscal powers over all regions.

The model is made operational using 1988 U.S. economic data (some of which must be calibrated to fit into the model), and using certain important estimated parameters which have been derived from other sources. The operational model is then used to analyze the effects of tax policy changes that I believe to be of current interest to policy makers:

1. Various regionally-levied taxes are unilaterally raised in a region, in order to fund additional government expenditures in that region.

2. Regionally-levied taxes on business capital are changed in a region, and the tax revenue gained or lost is offset by a change in household income taxes in the region.
Analysis of tax change #1 above indicates that in general, household utilities fall in a region which unilaterally increases any of its revenue-raising tax instruments. Analysis of tax change #2 indicates that in general, household utilities increase in a region that replaces revenue gained from a household tax with revenue gained from a tax on business capital. In both tax changes, the mobility assumption concerning Rich households has significant effects upon the simulation results. Sensitivity analysis reveals that the results are somewhat sensitive to the elasticity of substitution values chosen for the production and household sectors. Policy changes #1 and #2 are extensively analyzed in chapters 8, 9, and 10 of this dissertation.

The dissertation is organized as follows:

Chapter 2 presents the theoretical foundations of my multi-region CGE model, including expositions of Arnold Harberger’s general equilibrium analysis of corporate income tax incidence and Peter Mieszkowski's analysis of property tax incidence. Their analyses indicate the necessity of using general equilibrium (versus partial equilibrium) tax incidence analysis when examining major tax policy changes in a multi-good, multi-region federal economy.

Chapter 3 explains the fundamental workings of the computer algorithm necessary to make general equilibrium models operational. As a working example, a simple one-region, two-good, two-factor, two household CGE model is presented and used to examine a simple alteration in tax policy. The theoretical underpinnings of the computer algorithm, as originally presented by Herbert Scarf and other authors, are also explained.

Chapter 4 reviews the current research relevant to my dissertation, including CGE tax incidence analysis by: Ballard, Fullerton, Shoven, and Whalley; Kimbell and Harrison; Morgan, Mutti, and Partridge; and Jones and Whalley. The chapter explores these

---

4 See, for example, Scarf (1981).
analyses' structure, strengths, and weaknesses, and indicates enhancements that will be adapted into my CGE model.

Chapter 5 presents my CGE model in its mathematical detail, including precise specifications for household behavior, firm behavior, and government behavior, as well as specific conditions for equilibrium. Precision is required in order for the model to be computational—that is, to facilitate the model's solution via computer algorithm—as well as to garner precise numerical information (e.g. utility levels) characterizing the effects of tax policy changes.

Chapter 6 presents the real world 1988 U.S. economic data used to conform the model to represent the modern U.S. economy. Data are gathered to characterize consumption patterns, household income, factor payments, production patterns, tax revenues, and other important economic variables. Data sources include the U.S. Department of Commerce, the U.S. Department of Labor, and the Internal Revenue Service. Chapter 6 also includes estimates of utility function and production function parameters, such as elasticities of substitution, required along with the data to conform the model to the modern United States economy. These estimates are derived from econometric studies independent of this thesis.

Chapter 7 adapts, or calibrates the empirical data to conform with the mathematical rigidities of the model. In other words, the mathematical form of the economy does not match the exact form of the U.S. economy, in such areas as international trade and capital markets, so that raw U.S. data relating to these markets are incompatible with the mathematical model. Data must be adjusted, for example, to ensure in the CGE model that factor payments equal factor incomes, that budget and trade deficits are zero, and that gross national product equals national income. In essence, the 1988 U.S. economy, with its thousands of households, firms, and governments, must be
sculpted to fit into a rigid four-region, four-good, five-government equilibrium mathematical model.

The calibrated data and the econometric estimates, once "fit" into the model, provide a reference, or benchmark equilibrium representative of the 1988 U.S. economy. Simulations are then undertaken in chapter 8 to analyze the two types of tax changes mentioned previously in this introduction. Specifically, in the first portion of chapter 8, a region's various tax instruments are unilaterally and separately increased, while government expenditures are increased to maintain budget balance. In the second portion of chapter 8, all regions' household income tax rates are changed, with the change in revenue offset by a change in business capital taxes. In all cases, the alterations result in new, counterfactual equilibria which, when compared to the benchmark equilibrium, reveal the incidence of the tax policy changes.

Chapters 9 analyzes the robustness of the results obtained in the simulations performed in chapter 8. The first part of chapter 9 examines how sensitive the results are to an important elasticity of substitution in production. The second part of the chapter examines how sensitive the results are to an important utility function parameter. Finally, the last part of the chapter contends that the model's amalgamation of land and capital into one input does not drastically hinder the model's analytic power.

Chapter 10 attempts to synthesize and generalize the dissertation results as much as is possible, though one must take care to avoid broad generalizations garnered from specific CGE tax policy simulations. The last portion of chapter 10 contains suggested avenues for future research using my CGE model, and also suggests how the CGE model might be altered in order to study other economic issues. Chapter 11 is a brief conclusion. Appendices follow chapter 11, containing tables, my computer program, and symbols used in chapters 5-10. Finally, a list of references completes the thesis.
2. Theoretical Foundations of the Model

This chapter presents the major findings of two articles which serve as theoretical foundations of my general equilibrium model. The first article, a seminal work by Arnold Harberger (1962), analyzes the incidence of a corporation income tax in a general equilibrium setting. Harberger reaches the strong conclusion that in the United States economy (of the 1950s) capitalists bear roughly the full burden of the federal corporation income tax, whether their capital is used in the corporate or non-corporate sector. The second article, authored by Peter Mieszkowski (1972), examines the incidence of a locally-assessed property tax within a multi-location general equilibrium setting. Mieszkowski demonstrates that the property tax, by reducing the national average net return to capital, is largely borne by capitalists; in addition, "excise" effects induced by local differences in property tax rates also affect consumers, laborers, and landowners on a sub-national level. Both Mieszkowski's and Harberger's works demonstrate that a general equilibrium (versus a partial equilibrium) approach is a virtual necessity when examining changes in tax policy of large magnitudes.

In his 1962 article "The Incidence of the Corporation Income Tax," Arnold Harberger develops a simple two-good, two-factor, one-household, one-region general equilibrium model of the U.S. economy in which he examines the incidence of the federal corporation income tax. His model has the following characterizations of production, consumption, the government, and equilibrium:

**Production:** There are two production sectors in the economy, "corporate" and "non-corporate." Each sector produces a unique type of good according to production functions which exhibit constant returns to scale and constant elasticities of factor substitution, and which require two inputs--capital and labor. The producers earn zero profits. Total national supplies of capital and labor are fixed.

**Consumption:** Demand for the two types of goods is (implicitly) derived from a
homothetic constant elasticity of substitution utility function.

**Government:** The government levies a tax assessed on the capital earnings of the corporate sector. The revenue derived from the tax is, in effect, redistributed for private consumption.

**Equilibrium** occurs when net rates of return to capital are equalized between production sectors, when wages are equalized between production sectors, when full employment of factors occurs, and when the government's budget is balanced.

The model is depicted mathematically in a series of nine differential equations. The equations indicate how the economy would react if its initial equilibrium were disturbed. The mathematical model is presented below.

1. \[ \frac{dx}{x} = E(dp_x - dp_y) \]

This equation expresses the incremental demand for the corporate good ("x") as a function of the price elasticity of demand for x ("E"), the price of x ("p_x"), and the price of the non-corporate good y ("p_y").

2. \[ \frac{dx}{x} = f_L(dL_x/L_x) + f_K(dK_x/K_x) \]

This equation expresses the incremental supply of x, where \( f_K \) and \( f_L \) are the initial equilibrium cost shares of capital and labor, respectively, allocated in the production of x. \( L_x \) and \( L_y \) indicate the amount of labor and capital, respectively, initially used in the production of x.

3. \[ \frac{dK_y}{K_y} - \frac{dL_y}{L_y} = S_y(dp_K - dp_L) \]

Quantities are defined so that all prices in the initial equilibrium are unity.
This equation shows how a change in the relative use of capital and labor in producing \( y \) depends upon: the elasticity of factor substitution in \( y \) ("\( S_y \"\)); the price of capital ("\( p_K \"\)); and the price of labor ("\( p_L \"\)).

\[
(4) \quad \frac{dK_y}{K_x} - \frac{dL_y}{L_x} = S_x(dp_K + T - dp_L)
\]

This equation is similar to (3) above, except that "T," the per unit corporate tax, is added to the (net) price of capital.

\[
(5) \quad dK_y = -dK_x \\
(6) \quad dL_y = -dL_x
\]

These equalities follow from the assumption of fixed, inelastic national factor supplies.

\[
(7) \quad dp_X = f_L dp_L + f_K(dp_K + T) \\
(8) \quad dp_Y = g_L dp_L + g_K dp_K
\]

These are first-order approximations that ensure that the zero-profit competitive assumption holds. ("\( g_L \"\) and "\( g_K \"\) are the initial equilibrium cost shares of labor and capital, respectively, in producing \( y \).)

\[
(9) \quad dp_L = 0
\]

This equation fixes the price of labor as the numeraire.

Harberger's economy is completely characterized by these nine equations. (Note also that money is neutral in his model.)
The incidence of the corporation income tax is found by solving this system of equations for $dP_K$. As $dP_K$ increases, the burden of the corporation income tax falls increasingly upon capital owners (as opposed to labor owners). Harberger derives an equation for $dP_K$:

\begin{equation}
(10) \quad dP_K = T[Ef_K(.) + S_X(\text{'})] / \left[ E(g_K - f_K)(\text{'}') - S_Y - S_X(\text{'})] \right]
\end{equation}

where \( . \) = \( K_X/K_Y - L_X/L_Y \)
\( \text{'} \) = \( f_L K_X/K_Y - f_K L_X/L_Y \)

In order to derive a numerical approximation of $dP_K$, estimates of $E$, $f_K$, $g_K$, $K_X/K_Y$, $L_X/L_Y$, $S_X$, and $S_Y$ are needed. Harberger demonstrates, using estimates of these variables garnered from U.S. economic data, that capitalists bear roughly 100% of the burden of an incremental increase in corporation income taxes, regardless of whether their capital is employed in the corporate or non-corporate production sector.

This general equilibrium result differs markedly from the results of previous partial equilibrium analyses, demonstrating the pitfalls of undertaking partial equilibrium tax incidence analysis. Harberger's article further shows that general equilibrium models are capable of producing specific numerical estimates of tax incidence, fostering the now-popular use of large-scale, complex CGE models.

Despite the significant advances achieved by Harberger's model, its relative simplicity limits its analytic power. It cannot, for example, model with accuracy the effects of taxes levied by sub-national governments. A multi-region general equilibrium model could better examine the implications of allowing sub-national governments wide-ranging tax authority. Peter Mieszkowski, in his 1972 article "The Property Tax: An Excise Tax or a Profits Tax?" constructs such a multi-region model, which he uses to
examine property tax incidence.

Here are some of the important qualities of Mieszkowski's model:

--Within each region two types of goods are produced under competitive conditions: the "home" good, which is only consumed within the region, and the "export" good, which may be consumed in any region.

--Each good is produced with a constant returns to scale technology that requires three inputs: capital, labor, and land. The inputs are fixed in national supply and can be used in the production of either home or export goods. In addition, capital is perfectly mobile among regions; labor is interregionally mobile, with some restrictions.

The property tax is considered a regional tax on reproducible capital. Mieszkowski demonstrates that given the conditions of his model, a property tax levied at a uniform national rate across regions will reduce the net return to capital by the amount of the tax; under such a system the property tax is borne entirely by capitalists. Mieszkowski further shows that under more realistic conditions, i.e. when property tax rates vary across regions, that the net return to capital falls, on average, by the amount of the tax. Here again, the "national" incidence of the property tax is that it is borne entirely by capitalists.

When property tax rates vary among regions, however, the aforementioned national effects are joined with regional "excise" effects. The varying tax rates generate a non-uniform redistribution of capital among regions, as capital relocates to equalize its net rate of return across regions. Thus within a region, relative gross goods prices and factor prices may differ from the national 'average,' possibly pushing some of the property tax burden onto laborers, landowners, and consumers. Mieszkowski analyzes these potential excise effects by setting up a six-equation model of a single region, as follows:

\[(1) \ X = f_1(L,K,R)\]
Equation (1) depicts the region's linearly homogeneous production function of the single composite good ("X"), requiring as inputs labor ("L"), capital ("K"), and land ("R").

(2) \( X = f_2(p_X) \)

This demand equation allows the demand for X to vary with its price ("p_X").

(3) \( K = f_3(w,r,T,X) \)
(4) \( L = f_4(w,r,T,X) \)

These factor demand equations indicate that the demands for capital and labor within the region each depend upon the wage ("w"), the rental price of land ("r"), the property tax rate ("T"), and the production level of X.

(5) \( L = f_5(w) \)

This equation indicates that the supply of labor to this region depends upon the wage offered in the region.

(6) \( p_X X = wL + rR + (p_K + T)K \)

Equation (6) is the zero profit condition, where \( p_K \) is the net price of capital.

Mieszkowski uses this model to investigate how, within a single region, the property tax may be shifted to laborers, landowners, and consumers. Therefore, he derives representations of \( dw/dT \), \( dr/dT \), and \( dp_X \).
\[
\frac{dw}{dT} = \frac{(f_k E_X - f_k(a_k a_R k))(a_{LR} a_{RR}) + (a_{LK} a_{RK})(f_k(a_K a_R X) - E_X f_R)}{(f_k(a_{KL} a_{RL}) + f_L E_L E_X f_L)(a_{LR} a_{RR})}
\]

\[
\frac{dr}{dT} = \frac{[(f_k E_X - f_k(a_k a_R k))(a_{LL} a_{RL} E_L) + (a_{RK} a_{LK})(f_k(a_{KL} a_{RL}) + f_L E_L E_X f_L)]}{[(f_k(a_{KL} a_{RL}) + f_L E_L E_X f_L)(a_{LR} a_{RR})]}
\]

\[
\frac{dL_X}{d} = f_k dT + f_L dL + f_R dR
\]

\(f_k, f_L, \text{and } f_R\) are the original share of capital, labor, and land, respectively, used in the production of \(X\). \(E_L\) is the wage elasticity of supply of labor. \(E_X\) is the price elasticity of demand for \(X\). The \(a_{ij}\)s are the Allen elasticities of substitution between factors \(i\) and \(j\).

The above equations indicate that the welfare of laborers and landlords within a particular region may be affected by a change in the region's property tax rate.

Mieszkowski distinguishes between two types of effects:

--The "factor substitution" effect: Here, an increase in the region's property tax rate, by increasing gross business capital costs, causes producers to shift their factor use away from capital and into labor and land, thereby benefiting laborers and landowners.

--The "output" effect: Here, the increased gross capital costs increase the price of good \(X\). Consumer demand for \(X\) falls, and production decreases accordingly. The drop in production reduces the demand for both land and labor, reducing the factor rewards of laborers and landlords.

In addition, a portion of the tax increase may be shifted forward to consumers in the form of a higher price for \(X\). The excise effects of the property tax within a single region are a combination of the output effect, the factor substitution effect, and the price
effect. Generally speaking, laborers and landlords will be worse off in the region if:

1. **Capital-labor and capital-land substitution is difficult.** This tempers benefits from the factor substitution effect and exacerbates harm from the output effect.

2. **The price elasticity of demand for X is high.** This increases the harm from the output effect.

3. **Labor and land have difficulty moving among regions.** If labor is highly mobile interregionally, then it may escape from the harmful output effect. Since land is immobile, it cannot avoid any reduction in its rate of return by relocating.

Finally, consumers are relatively worse off when the price elasticity of demand for X is low. Mieszkowski finds, using reasonable production function and demand parameter values, that a property tax increase within a single region is shifted partially onto laborers, landowners, and consumers in the region, with consumers and landowners bearing the larger burden shares.² (Nationally, these excise effects are offset by gains in other regions.)

Mieszkowski's findings indicate the importance of properly modeling sub-nationally-levied taxes in a general equilibrium framework; mistakes can occur if these types of taxes are aggregated into national averages. The article also provides a logical structure for analyzing the incidence of sub-nationally-levied taxes; this framework is used extensively in chapters 8 and 9, in my sub-national tax incidence analysis.

Both the Mieszkowski and Harberger articles reveal the importance of performing tax incidence analysis using a general equilibrium approach. Several economists have built upon the two mainly theoretical articles, and constructed complex CGE models which have been used to ascertain the impact of both nationally levied and sub-nationally levied

² It is somewhat artificial (though necessary in Mieszkowski's article) to distribute tax burdens among single factor owners and consumers, since in reality an individual tends to be both a consumer and a multiple-factor owner. A better indicator of tax burdens would be to measure the change in an individual's utility caused by a tax change. My CGE model takes the utility comparison approach.
taxes in the real world. Computer solution techniques have become necessary because the algebraic solution of these disaggregated models is virtually impossible. Chapter 3 introduces a simple computational general equilibrium model.
3. A Simple Computational General Equilibrium Model

This chapter formulates, solves, and analyzes a simple two-good, two-production-factor, one-region, one person CGE model of a fictitious economy. Careful exposition of this simple model will facilitate later exposition of my more complex model by illustrating the specifications, data, computer techniques, and methodology required of most CGE models. In addition, this chapter explicates some of the problems encountered in adapting a real-world economy into a CGE setting. The model developed in this chapter is similar to Harberger's 1962 model, and has the following general qualities:

**Production Sector:** Two goods, X and Y, are produced, using separate technologies. Each technology requires inputs of capital, K, and labor, L.

**Household Sector:** One utility-maximizing household, H, is endowed with a fixed supply of capital and labor, which it supplies inelastically to the production sector. The household garners utility by consuming the goods X and Y.

**Government Sector:** A government may gain revenue by taxing capital in one of the production sectors. The government uses any tax revenue to provide transfer payments to the household.

In order for this general model to be transformed into a CGE model, specific equilibrium conditions must be imposed. In this model, they are:

i) Producers earn zero profits.

ii) Demand equals supply for goods X and Y.

iii) Demand equals supply for factors K and L.

iv) The household exhausts its income.

v) Government revenue equals government expenditure.

In addition, computational techniques require precise mathematical behavioral specifications for the production sector, the household sector, and the government sector.

---

1 Table 3.1 contains a list of the mathematical variables used in this chapter.
In this model, the specifications are as follows:

**Production sector:** X and Y are produced in cost-minimizing fashion according to the following constant returns to scale Cobb-Douglas production functions:

1. \[ X_S = AL_X^{-b} K_X^{1-b} \]
2. \[ Y_S = CL_Y^{-d} K_Y^{1-d} \]

where \( X_S \) and \( Y_S \) are the quantities of X and Y produced, respectively. \( L_X \) and \( L_Y \) are the quantities of labor used in the production of X and Y, respectively. \( b \) and \( d \) are the cost shares of labor used in producing X and Y, respectively. \( K_X \) and \( K_Y \) are the quantities of capital used in the production of X and Y, respectively.

**Household Sector:** The utility-maximizing household will allocate its factor endowments to production sectors X and Y so that the net rate of return it receives per unit of capital is equal in both X and Y, and so that the net per unit return from labor is equal in both X and Y. This allocation ensures that disposable income is maximized:

3. \[ p_{kx} = p_{ky} = p_k \]
4. \[ p_{lx} = p_{ly} = p_l \]

where \( p_{kx} \) and \( p_{ky} \) are the net per unit returns to capital in sectors X and Y, respectively. \( p_{lx} \) and \( p_{ly} \) are the net per unit returns to labor in sectors X and Y, respectively. \( p_k \) and \( p_l \) are the net per unit returns to capital and labor. (This notation merely indicates that the returns are equal across sectors.)

The household consumes goods X and Y according to a Cobb-Douglas utility function:

5. \[ U = F X_H^{i} Y_H^{1-i} \]
where U is the utility of the household, F is a scale parameter, \( X_h \) and \( Y_h \) are the quantities of \( X \) and \( Y \), respectively, consumed by the household, and \( j \) is the cost share of \( X \) in the household's budget.

**Government Sector:** The government may levy a tax at rate \( t \) on the value of capital used in producing good \( y \), gaining revenue \( T \). Any tax revenue is redistributed to the household as a transfer payment, \( R \). Thus government revenue is expressed:

\[
T = tp_kK_y = R
\]

Data are now required to precisely specify the production functions and the utility function, and to determine the precise tax rate on capital in sector \( Y \); that is, data are needed to obtain numerical estimates of \( A, b, C, d, F, j, \) and \( t \). This data, combined with the behavioral specifications, *calibrates* the model for computer solution of its equilibrium.

For example, suppose the following data are gathered from this fictitious economy's \( X \) production sector, in a "benchmark" period when the tax rate \( t \) is zero:

\[
X_s = 100 \quad K_X = 75 \quad L_X = 25
\]

where units of \( X, K, \) and \( L \) are defined in the benchmark period so that:

\[
p_X = \$1 \ (p_X \text{ is the price of } X), \ p_k = \$1, \ p_l = \$1
\]

Given the above data, the production function in the \( X \) sector can now be rewritten:

\[
100 = A25^{b751-b}
\]
Using equation (1') and the behavioral assumption of cost minimization, a numeric value for $b$ can now be determined:

$$b = \text{cost share of labor in the production of } X$$
$$= \frac{p_I L_X}{p_I L_X + p_K K_X}$$
$$= \frac{25}{(25 + 75)} = .25$$

Combining the value of $b$ and equation (1'), the numeric value for $A$ can be determined as follows: Rewriting (1')

$$100 = A25 \cdot 75^{1-.25} = A \cdot 59.6$$

Rearranging: $A = 100/59.6 = 1.7$

The production technology in sector $X$ has now been precisely determined. That is, for any values of $L_X$ and $K_X$:

$$(1'') \quad X_S = 1.7L_X^{25} K_X^{75}$$

This production function will be used in the computer solution algorithm to help determine how conditions in sector $X$ change when a tax is imposed on capital in sector $Y$.

In similar fashion, the production technology in sector $Y$ can be precisely determined. Suppose that the following data represent sector $Y$ in the no-tax benchmark period:

---

*For clarity, numeric estimates are rounded off in this chapter. Precise estimates are used in the computer algorithm displayed in table 3.1.*
\[ \begin{align*} Y_s &= 50 & K_y &= 25 & L_y &= 25 \end{align*} \]

where units of \( Y \), \( K \), and \( L \) are defined in the benchmark period so that:

\[ p_Y = $1 \,(p_Y \text{ is the price of } Y), \, p_K = $1, \, p_L = $1 \]

Given the above data, the production function in the \( Y \) sector can now be rewritten:

\( (2') \) \[ 50 = C25^{d}25^{1-d} \]

Using equation \( (2') \) and the behavioral assumption of cost minimization, a numeric value for \( d \) can now be determined:

\[ d = \text{cost share of labor in the production of } Y \]
\[ = \frac{p_LY}{(p_LY + p_KY)} \]
\[ = \frac{$25}{($25 + $25)} = .5 \]

Combining the value of \( d \) and equation \( (2') \), the numeric value for \( C \) can be determined as follows: Rewriting \( (2') \)

\[ 50 = C25^{.5}75^{1-.5} = C^{.25} \]

Rearranging: \[ C = \frac{50}{25} = 2 \]

The production technology in sector \( Y \) has now been precisely determined. That is, for any values of \( K_y \) and \( L_y \):
\( (2^\prime) \quad Y_s = 2L_y 5K_y 5 \)

This production function will be used in the computer solution algorithm to help determine how conditions in sector \( Y \) change when a tax is imposed on capital in sector \( Y \).

A similar procedure can be used to precisely specify the utility function in this economy. Suppose, for example, that the following data represent the household's consumption and utility level in the no-tax benchmark:

\[ U = 1 \quad X_h = 100 \quad Y_h = 50 \]

where \( U \) has been normalized to equal 1 in the benchmark, and where units of \( X \) and \( Y \) are measured so that \( p_x = $1 \) and \( p_y = $1 \). Now equation (3) can be rewritten:

\( (3^\prime) \quad 1 = F100 \cdot 501-j \)

To calculate \( j \), recall that utility maximization requires that:

\[ j = \text{share of disposable income spent on good } X \]

\[ = p_x X_h / (p_x X_h + p_y Y_H) \]

\[ = $100 / $150 = .67 \]

The estimate for \( j \), along with equation (3'), can now be used to obtain a numerical estimate for \( F \). Substituting the value for \( j \) into (3'):

\[ 1 = F100 \cdot 67.50 \cdot 33 \cdot 79.4 = 79.4F \]

Rearranging: \( F = 1/79.4 = .0126 \)
The utility function has now been completely specified; that is, for any $X_h$ and $Y_h$,

\[(3'') \quad U = 0.0126X_h^{67}Y_h^{33}\]

The final calibration step is to calculate $t$, the tax rate on capital in sector $Y$. In this economy, this calculation is simple, since the tax does not exist in the benchmark period. Therefore:

\[ t = 0 \quad T = 0 \quad R = 0 \]

The fictitious economy can now be summarized by equations (1"), (2"), (3"), and $t = 0$. These have all been calibrated to be consistent with the behavioral specifications imposed upon the economy, and with the data given. In essence, the data have acted as identifying restrictions which have determined the numerical values for the unknown parameters in the production functions and the utility function. But in order for this economy to be in equilibrium, it must satisfy equilibrium conditions (i)-(v). As shown below, all of the conditions are satisfied.\(^3\) For ease of exposition, benchmark data are reproduced in table 3.2.

Equilibrium condition (i) requires that producers earn zero profits. This condition can be restated mathematically:

\[
\begin{align*}
    p_x X_S - (p_k K_x + p_l L_x) &= 0 \\
    p_y Y_S - [(1+t)p_k K_y + p_l L_y] &= 0
\end{align*}
\]

\(^3\) Since I have created the fictitious data to satisfy the equilibrium conditions, I am not surprised that they are satisfied. Difficulty arises with real world data, however, because one must assume that an equilibrium exists, even when it does not. Thus real-world data must often be adapted to fit the equilibrium conditions. See chapter 7.
Substituting from the sector $X$ benchmark data,

$$p_X X_S = $100 \quad \text{and} \quad p_K K_X + p_L L_X = $100$$

and from sector $Y$ data,

$$p_Y Y_S = $50 \quad \text{and} \quad (1+t)p_K K_Y + p_L L_Y = $50$$

so that equilibrium condition (i) is satisfied.

Condition (ii) requires that demand equals supply of $X$, and demand equals supply of $Y$. Mathematically, the requirement is for

$$X_h = X_S \quad \text{and} \quad Y_h = Y_S.$$

A glance at the data in table 3.2 reveals that

$$X_h = X_S = 100 \quad \text{and} \quad Y_h = Y_S = 50$$

so that condition (ii) is indeed satisfied.

Equilibrium condition (iii) requires that capital supply equals capital demand, and that labor supply equals labor demand. In other words, the requirement is for

$$K = K_X + K_Y \quad \text{and} \quad L = L_X + L_Y$$

Again, a glance at the data in table 3.2 reveals that

$$K = 50 = K_X + K_Y \quad \text{and} \quad L = 100 = L_X + L_Y$$

so that condition (iii) is also satisfied.

Condition (iv) requires that the household exhausts its income. Mathematically, it requires
\[ p_x X_h + p_y Y_h = p_k K + p_l L + R \]

Substituting values from table 3.2 shows that:
\[ p_x X_h + p_y Y_h = $100 + $50 = $150 \quad \text{and} \quad p_k K + p_l L + R = $50 + $100 + $0 = $150 \]

Since household income and expenditures both equal $150, condition (iv) is satisfied.

Finally, condition (v) requires that the government's budget is balanced. This condition obviously holds, since both tax revenue and transfer payments are zero.

Since conditions (i)-(v) all hold, we have created an economy in "benchmark equilibrium." Generally speaking, given the data values and behavioral specifications, producers have no desire to alter their output levels or their factor demand levels, the household has no desire to alter its consumption bundle or its pattern of factor supply, and the government has a balanced budget. Barring any change in behavioral specifications, the economy is in a steady-state, with prices remaining constant and the household receiving utility = 1.

Suppose, however, that the behavioral specifications in this economy were altered slightly; specifically, suppose that the government were to levy its tax on capital in sector Y at a non-zero rate. In order for this new or "counterfactual" economy to be in equilibrium, we would expect, aside from the obvious increase in the government's budget, that production levels, factor demands, factor supplies, and consumption bundles might be different from those in the benchmark equilibrium, since the new tax would probably cause a reallocation of resources among production sectors, and a change in relative prices. Economists' intuition may also suggest that household utility would be reduced below its benchmark level in this counterfactual equilibrium, since the non-zero capital tax in sector Y would drive a wedge between opportunity costs in production and consumption.

We can test the effects of a proposed change in tax policy such as the one
suggested by comparing our benchmark equilibrium to a computer-synthesized counterfactual equilibrium which incorporates the augmented tax rate on sector Y capital. That is, we shall determine, given a new behavioral specification for our government of $t = .5$, how economic conditions are altered from $t = 0$ in order to maintain equilibrium conditions (i)-(v). By comparing economic conditions in the benchmark equilibrium with economic conditions in the computer-synthesized counterfactual equilibrium, we shall determine the impact of the tax change.

At the end of this chapter is displayed the computer algorithm which is used to arrive at a counterfactual equilibrium representing our fictitious economy in which producer and household behavior is specified precisely as in the benchmark equilibrium, but government behavior is altered so that capital income in sector Y is taxed at a fifty percent rate. Intuitively, the algorithm finds the counter factual equilibrium in the following progression of eight steps:

(Step 1A) The tax rate is set at $t = .5$

(Step 1B) The price of labor is established as the invariant numeraire, $p_l = 1$.

(Step 2A) The counterfactual equilibrium value of the transfer payment, $R$, is estimated.

(Step 2B) The counterfactual equilibrium value of the net price of capital, $p_k$, is estimated.

(Step 3) The value of $p_l$ (set in step 1B) and the value of $p_k$ (set in step 2B) are used to estimate cost-minimizing factor demands per unit of output in the $X$ and $Y$ production sectors. For example, the demands for capital and labor per unit of output in sector $X$ is estimated by solving the following minimization problem:
minimize \quad p_Lx_1 + p_Kx_1

subject to \quad 1.7Lx_1^{.25}Kx_1^{.75} = 1

where \(Lx_1\) is the cost-minimizing amount of labor used in \(X\) production.
\[Lx_1 = .59 \left( \frac{(25p_k)/(75p_L)}{} \right)^{3/4}\]
\[Kx_1 = .59 \left( \frac{(25p_k)/(75p_L)}{} \right)^{1/4}\]

Similarly, numerical estimates for sector \(Y\)'s per unit factor demand for labor \((L_y1)\) and capital \((K_y1)\) can also be determined.

(Step 4) The zero profit equilibrium condition (i) is assumed to hold. Given this assumption, information from steps 1, 2, and 3 is used to derive numerical estimates of goods prices \(p_x\) and \(p_y\) as follows:
\[p_x = p_Lx_1 + p_Kx_1 \quad \quad p_y = p_Ly_1 + (1+t)p_Ky_1\]

This step ensures that equilibrium condition (i), the zero profit condition, is satisfied in the counterfactual equilibrium.

(Step 5) We now have sufficient information to estimate household demand for goods \(X\) and \(Y\). This demand is estimated by solving the following utility maximization problem:

maximize \quad .0126X_h^{.67}Y_h^{.33}

subject to \quad p_LX_h + p_KY_h = p_XX_h + p_YY_h

Solution of the maximization problem gives us the following estimates of \(X_h\) and \(Y_h\):
\[X_h = .67[(p_LX_h + p_KY_h) / p_X]\]
\[Y_h = .33[(p_LX_h + p_KY_h) / p_Y]\]

To derive numerical estimates of \(X_h\) and \(Y_h\) from the above equations, we use values of \(p_L, p_K, p_X, p_Y, R, L\) and \(K\) from previous steps in the computer algorithm. The values of \(p_L\) and \(p_K\) are from steps 1 and 2. The values of \(p_X\) and \(p_Y\) are from step 4. The value of \(R\) is from step 2. \(L\) and \(K\) are fixed at the preset behavioral specifications that \(L = 100\) and \(K = 50\).
This step ensures that equilibrium condition (iv), the "exhaustion of household income" condition, is satisfied.

(Step 6) We assume that production sectors X and Y provide exactly enough output to satisfy household demand; that is, we assume:

\[ X_S = X_h \quad \text{and} \quad Y_S = Y_h \]

Combining this assumption with the behavioral specification of homothetic constant returns to scale production functions in sectors X and Y, we can estimate total demand for capital, \( K_X + K_Y \), and total demand for labor, \( L_X + L_Y \), in the economy as follows:

\[ K_X + K_Y = X_h K_{X1} + Y_h K_{Y1} \]
\[ L_X + L_Y = X_h L_{X1} + Y_h L_{Y1} \]

Values for \( X_h \) and \( Y_h \) are from step 5. Values for \( L_{X1}, L_{Y1}, K_{X1}, \) and \( K_{Y1} \) are from step 4. These numerical estimates, substituted into the above equations, provide numerical estimates for total labor demand and total capital demand.

This step ensures that equilibrium condition (ii) is satisfied; that is, demand equals supply of X, and demand equals supply of Y.

The computer algorithm has thus far guaranteed that equilibrium conditions (i), (ii), and (iv) hold for the counterfactual economy. It now checks to see if conditions (iii) and (v) also hold.

(Step 7) Check: (a) \( K_X + K_Y = K \)?

(b) \( R = (1+.5) p_k K_Y \)?

If (a) does not hold, then condition (iii) is violated, and the counterfactual economy is not in equilibrium. In this case, the algorithm revises its estimate of \( p_k \) from the original estimate made in step 2. For example, if the demand for capital exceeds its supply (i.e.
$K_x + K_y > K$) then the estimate of $p_k$ is increased.

If (b) does not hold, then condition (v) is violated, and again the counterfactual economy is not in equilibrium. In this case, the algorithm revises its estimate of $R$ from the original estimate in step 2. For example, if the transfer payment falls short of government revenue then the estimate for $R$ is increased.

(Step 8) If either equality (a) or (b) from step seven does not hold, then the algorithm returns to step 2, replacing the former estimates of $p_k$ and $R$ with the revised estimates derived in step 7. Then steps 3 through 8 are repeated.

The computer algorithm is therefore an iterative procedure; with each iteration, estimates of $p_k$ and $R$ are refined so that eventually, (a) and (b) hold to within a reasonable degree of accuracy, and the counterfactual economy is in equilibrium, with equilibrium conditions (i)-(v) all satisfied.

After economic equilibrium is established, the algorithm then calculates counterfactual economic data which act as forecasts of economic conditions if a 0% tax on capital in sector $Y$ were replaced with a 50% tax on capital in sector $Y$. The data indicate how prices, output, consumption, factor usage, government revenue, and household utility would change if the tax were imposed. Finally, the algorithm calculates the equivalent variation measure of the dollar loss in household utility.

Table 3.3 displays economic data in the no-tax benchmark equilibrium alongside the computer-forecasted data for the counterfactual 50% tax equilibrium. As expected, the 50% tax imposed on capital used in sector $Y$ has depressed the net return to capital economy-wide. The higher gross cost of capital faced by sector $Y$ has caused a reduction in its use of capital; capital has fled from the sector into sector $X$ in an effort to avoid the tax. In addition, the increased cost of capital in sector $Y$ has caused an increase in the

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4 Using Walras' Law, if conditions (a) and (b) are met in step 7 then it follows that $L_x + L_y = L$. 
price of Y; consequently, the household consumes less of good Y and more of good X. Finally, the efficiency of the economy has been reduced, since the tax has caused a distortion in the Pareto optimal allocation of resources; this distortion results in a loss of utility to the household equivalent to about 1% of her original income.

This simple example illustrates conceptually how CGE simulation models are used to evaluate the effects of a change in tax policy. Much of the methodology illustrated here has been incorporated into my more complex model, to be expounded in chapter 5 of this dissertation. In general, for real world applications, an existing economy is modeled using behavioral specifications similar to those used in this chapter. The specifications are then calibrated using empirical data in order to satisfy conditions for equilibrium. This benchmark equilibrium is then altered to simulate the tax policy change that the researcher wishes to examine. A computer algorithm projects a counterfactual equilibrium, and the two equilibria are compared to predict the effects of the change in tax policy.

Certain problems can arise, however, when the modeler attempts to "fit" a real-world economy into a rigid CGE model. The model must be computable; complex economic activities must therefore be modeled in relatively simple mathematical form. Furthermore, all computer algorithms have limited capabilities; these limitations restrict the modeler's choice of mathematical representations of economic activities. Finally, the real-world data available to the researcher may be inconsistent with the equilibrium conditions required of the model, or key data may not exist; therefore, compromises between tractability and reality are inevitable.

Despite these difficulties, many economists have developed quite intricate CGE models which incorporate much of the methodology expounded in this chapter. To be sure, these real-world CGE models are more intricate than the simple model used in this chapter, with the intricacies developed in order to examine particular economic issues. My model shares many of the qualities of these other CGE models. The next chapter
reviews some other CGE models, indicates their qualities which I shall adapt into my model, and introduces some extensions which make my model particularly powerful in examining the effects of sub-nationally levied taxes.
4. Some Computational General Equilibrium Models: A Review

This chapter reviews some CGE models which, unlike the model presented in the last chapter, have been used to evaluate real-world tax policies. Examined will be models developed by: John Shoven and John Whalley; Larry Kimbell and Glenn Harrison; John Mutti, William Morgan, and Mark Partridge; and Rich Jones and John Whalley. Each model will be described according to its characteristics in each of the following four areas:

1. Regional Structure. Explores how many geographic regions exist in each model.

2. Behavioral Specifications. Examines how households, firms, and governments function within each model, i.e. patterns of production, consumption, government finances and expenditures.

3. Mobility. Examines the extent by which goods, factors of production, and people may relocate (whether among geographic regions or production sectors) in each model.

4. Equilibrium Conditions. Describes the conditions necessary for equilibrium in each model.

After describing each model, I shall highlight the qualities of each which will be incorporated into my CGE model, and discard elements of each which I believe are either unrealistic or obfuscating. My model, to be described in the next chapter, is a compendium of many of the qualities of the four models examined here, combined with a few of my own extensions, which are mentioned at the end of this chapter.

One of the earlier CGE models was developed by Shoven and Whalley (1972) and has been expanded upon by Ballard, Fullerton, Shoven, and Whalley (1985a, 1985b) and other authors. The model has been used to examine many important issues in United States tax policy. It has the following qualities:

Regional Structure: There exists one region, the United States, an open economy.
Behavioral Specifications: Nineteen producer goods each requires primary inputs of labor and capital, and intermediate inputs of other producer goods. Value-added from capital and labor in each of the nineteen sectors is represented by a constant returns to scale ("CRS"), constant elasticity of substitution ("CES") production technology. A fixed coefficient input-output matrix determines the per-unit quantities of intermediate goods required in each sector. Each good can be traded on the world market. Producers minimize costs.

The nineteen producer goods are transformed into fifteen consumer goods with a fixed coefficient matrix. Twelve consumer groups, differentiated by their income levels, demand the fifteen consumer goods along with "savings" and "leisure," according to linearly homogeneous nested CES utility functions. Consumption is limited by the consumer groups' capital income, labor income, and transfer payment income.

One government levies taxes on U.S. consumers and producers. The government provides transfer payments and publicly-provided goods according to its own utility function, in such a fashion as to maintain government utility at a constant level regardless of changes in tax policy.

Mobility: Capital and labor are fully mobile among production sectors; they are internationally immobile. Any consumer may consume any of the consumer goods (subject to budget limitations).

Equilibrium Conditions:

(i) Producers earn zero profits.

(ii) Consumer purchases plus savings exhaust their income.

(iii) National income equals national expenditures.

(iv) Demand equals supply for factors of production.

(v) Domestic + foreign demand for domestic goods equals domestic supply.

(vi) The current account is in balance.
In developing this model, Shoven and Whalley have pioneered many of the calibration techniques necessary to fit real-world data into a CGE model, and have found functional forms (e.g. nested CES linearly homogeneous production and utility functions) which facilitate the model's computer solution. I have adopted many of these techniques and functional forms in the development of my model.

Shoven and Whalley's CGE model achieves a level of complexity in modeling producers' and households' behavior which is virtually unmatched in the economics CGE literature, with high levels of disaggregation in both the number of consumer groups and the number of goods. Interestingly, however, only one region (the U.S.) and one government exist in their model. A multi-region, multi-government model would more realistically reflect the federal nature of the United States, and could capture the Mieszkowski-type excise effects of taxation (as mentioned in chapter 2). These excise effects can be extremely important, especially when examining issues of horizontal equity, since similar individuals residing in different regions may not be similarly affected by a change in one region's tax policy.

Another problem with modeling the economy as spatially compact is that important issues regarding factor mobility may be missed. Of particular concern is the ability of labor in Shoven and Whalley's model to move freely among all production sectors in the economy; in the real world, geographic distances (e.g. commuting costs) may hamper such perfect mobility. A multi-region model can more realistically restrict laborers to work only in their region of residence. Such restrictions may alter the welfare implications of a change in national tax policy vis-à-vis Shoven and Whalley's model, since workers in a multi-region model could be limited in their ability to avoid a tax by shifting their labor to a production sector outside of their region of residence.

Finally, Shoven and Whalley's model illustrates the often encountered trade-off between a model's realism and its analytic power. Their model's high level of
disaggregation and its depictions of labor-leisure choices, consumption-savings patterns, and international trade all allow the model to represent the U.S. economy with an amount of realism far greater than simpler models such as the model presented in the last chapter. Yet the complexity of the model clouds its usefulness in analyzing the step-by-step effects of a change in tax policy; instead, the model becomes more of a "black box" in which the end results of a tax policy change become known, but the process by which the results were obtained is shrouded. It is therefore perhaps best to structure a model with sufficient complexity to usefully examine the problem of interest to the modeler, while simultaneously avoiding unnecessary adornments which hamper its analytic strength. In Shoven and Whalley's model, an aggregate national government allows them to examine national effects of tax policy changes with reasonable analytic power, but inhibits their examination of excise effects induced by sub-nationally levied taxes.

Kimbell and Harrison (1984) provide a framework which would remedy the neglect of excise effects in spatially compact CGE models. They develop computer techniques and methods of behavioral specification which facilitate construction of multi-region CGE models. Of particular interest is their "factor price revision rule"—a computer technique which substantially reduces computational solution time. This rule, which involves raising or lowering factor prices according to excess factor demands and elasticities of factor substitution, has been incorporated into my computer solution algorithm. Kimbell and Harrison use their techniques to develop a two-region CGE model of the U.S. which they use to examine the effects of reducing capital taxation in California. Their model has the following qualities:

1. **Regional Structure:** There are two regions of the United States: California and the

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1 Kimbell and Harrison develop the model principally to demonstrate the empirical applicability of their techniques. Thus their model's simplicity (and vagueness) does not necessarily reflect any shortcomings or limitations of the authors' techniques; rather, I believe that the model is kept simple to avoid undo confusion for the reader.
Rest of the United States ("ROUS"). There is no international trade.

**Behavioral Specifications:** Within each region ten goods are produced, each requiring primary inputs of capital and/or labor, and intermediate inputs of other goods. The precise mathematical depiction of producer behavior is unspecified. Producers minimize costs.

Within each region there exists one household, which consumes the ten goods and supplies capital and labor to producers. The precise mathematical depiction of household behavior is unspecified.

National, state, and local governments levy taxes on capital and possibly on other goods and factors. Governments use the money to purchase public goods. The precise mathematical depiction of government behavior is unspecified.

**Mobility:** Capital and labor are intersectorally mobile; capital is also inter-regionally mobile, while labor is inter-regionally immobile. Households and the government may only consume goods produced in their region of residence (e.g. a Californian may not consume a grapefruit grown in ROUS).

**Equilibrium Conditions:**

(i). Producers earn zero profits.

(ii). Household expenditures equal net household income.

(iii). Gross regional income equals gross regional expenditures.

(iv). Demand equals supply of goods.

(v). Demand equals supply of factors of production.

This model is simpler than Shoven and Whalley's model in its depiction of the government sector, the household sector, and the external sector; indeed, since only one household per region of the economy is allowed, vertical equity implications of tax policies are impossible to examine. However, the model's multi-government, multi-region formulation enables it to capture excise effects of sub-national taxes. Still, a further
division of the United States into more than two regions may more accurately depict empirical U.S. conditions, since Kimbell and Harrison's ROUS regional government actually comprises thousands of state and local governments in forty-nine states.

The model's depiction of labor mobility is diametrically opposite to that of Shoven and Whalley, since labor is mandated to remain perpetually in its region of origin. Indeed, the Kimbell-Harrison model in many respects resembles an international trade model in which legislative constraints prohibit international labor migration. A more realistic model of a federation such as the United States might strike some middle ground between the Shoven-Whalley and Kimbell-Harrison models, allowing for partial mobility of laborers among regions.

Finally, Kimbell and Harrison make a rather peculiar assumption regarding the demand for goods within a region. Producers in one region may import goods from the other region and use them as intermediate inputs, yet a household can only consume goods in its own region.² This inconsistency can be remedied by allowing interregional trade of goods for both producers and consumers.

Mutti, Morgan, and Partridge (1986) use a somewhat different approach in their six-region, three factor, seven good model of the United States, which they use to examine how regional taxes affect the region of location of production factors and economic activity.³ The model has the following qualities:

Regional Structure: The United States is divided into six regions. There is no foreign trade.

Behavioral Specifications: Seven goods are produced within each region, requiring

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² This might make sense if goods imported from the other region by producers were used as "inputs" and transformed into a locally-produced retail good (e.g. if a California retailer bought wholesale ROUS grapefruit and sold them to Californians as local grapefruit), but such is not the case in this model.

³ See also Mutti, Morgan, and Partridge (1989), which examines property tax incidence in a CGE framework reminiscent of Mieszkowski (1972).
inputs of capital, labor, and land, which are used in a cost-minimizing fashion according to a CRS, nested CES production function.

Within each region the seven goods are consumed according to a regional nested CES linearly homogeneous utility function. Each region maximizes its utility, constrained by regional income which it derives from its factor income and its tax receipts.

Six regional governments and one federal government levy taxes on goods and factors. In addition the regional government produces one of the seven goods, the quantity of which varies as regional income varies. The Federal government also provides one of the seven goods—a fixed quantity of a pure public good.

Mobility: Capital and labor are intersectorally and inter-regionally mobile; however, a "household" always pays any taxes on capital earnings in its original region of residence. Land is only partially intersectorally mobile and is inter-regionally immobile.

Three goods are traded among regions; four are non-traded and may not be consumed outside their region of production.

Equilibrium Conditions:
(i). Regional income equals regional expenditure.
(ii). Real wages are equalized among regions.
(iii). Demand equals supply of goods.
(iv). Demand equals supply of production factors.
(v). Producers earn zero profits.
(vi). Government budgets are balanced.

This model's higher level of regional disaggregation gives it more analytical power to examine how taxes affect interregional factor locations and terms of trade than the Kimbell and Harrison model. However, the model's design limits its ability to measure household utility in a meaningful way, especially if one desires to simulate how the utility
of a representative household would change if an economy's prevailing tax structure were altered. Indeed, the economic concept of a "household" is difficult to define in this model.

One might define a household as a supplier of factors of production. In the Mutti-Morgan-Partridge ("MMP") framework, factor suppliers can be separated into capitalists, laborers, and landowners. If households are defined in this manner, then one must be able to measure the consumption patterns of each of the three types of households in order to measure their utility. Unfortunately, in the MMP framework this type of measurement is impossible; only aggregate regional consumption can be determined. In other words, since both consumption patterns and factor incomes cannot be determined for capitalists, laborers, and landowners, it is impossible to determine their utility.

Although the utilities of individual capitalists, laborers, and landowners cannot be determined in the MMP model, aggregate regional utility can be derived, since both aggregate regional expenditures and aggregate regional incomes are known for a given benchmark situation. Regrettably, this utility measure is not tantamount to a measure of household utility, if one wishes to compare the utility of identical households under different tax regimes, because the characteristics of the region change as the tax regime is changed. Most markedly, the region's endowment of labor would be altered under a new tax regime due to the inter-regional mobility of labor; one would not expect an individual household's labor endowment to act similarly. (Indeed, a simple act of migration would probably neither augment nor diminish a household's labor endowment). Thus changes in regional utility are not necessarily related to changes in household utility.

Aside from its inability to measure changes in household utility, the model also has

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4 Also, it would be somewhat arbitrary to separate households into these three classifications, since in reality many people are endowed with more than one type of production factor.

5 The MMP model was not designed to measure individual utility, but rather, I believe, to measure inter-regional factor flows and changes in regional value-added resulting from changes in tax policy; for these purposes, the model acts well. I mention the inability to measure household utility because such measurement is essential for purposes of my analysis in later chapters.
a peculiar depiction of capitalists' mobility. While capital is inter-regionally mobile, capital owners are inter-regionally immobile. They must, in perpetuity, pay taxes on their capital earnings in their original region of residence, regardless of any changes in tax policy. This characterization of capitalists seems especially strange, considering that laborers are free to move to any region which they desire; indeed, the characterization precludes any migrating household from jointly supplying both capital and labor to the factor markets.\(^6\)

There are a few other shortcomings in the MMP model. For example, it restricts the demand elasticity of substitution between private goods and public goods to be zero. It also does not allow the regionally-supplied public good to exhibit any non-rival or non-excludable characteristics. But perhaps the model's most serious shortcoming is its mathematical form. It depicts the U.S. economy mathematically with a series of linear differential equations. Casual empiricism suggests that the U.S. economy is not linear in form; therefore any numerical estimates derived from the MMP model may be inaccurate, especially for "large" changes in tax policy.\(^7\)

Jones and Whalley (1988) avoid such mathematical missteps with their nonlinear, six region, thirteen good, three factor CGE model of Canada, which they use to compare how Canadian provinces would fare under various tax regime changes.\(^8\) They depict household mobility using assumptions about location preferences which rely heavily upon the unique provincial loyalty of the Canadian populace; these assumptions would less accurately model the location preferences of Americans in a multi-region U.S. CGE framework. Jones' and Whalley's model has the following characteristics:

**Regional Structure:** There exist six regions of the Canadian economy. Canada

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\(^6\) The mobility restriction on capitalists was probably imposed to create a regional lump-sum tax; that is, if capitalists cannot move to avoid a tax increase, then a household tax on a fixed endowment of capital becomes a lump-sum tax.

\(^7\) See Shoven and Whalley (1977) for a full discussion.

\(^8\) See also Jones and Whalley (1989) and Jones and Whalley (1991) which use the same model to examine other tax policy issues in Canada.
trades goods with the rest of the world.

**Behavioral Specifications:** Within each region thirteen goods are produced, each requiring primary inputs of labor and capital, or labor and natural resources. In addition, each good may require intermediate inputs of the other twelve goods. Producers minimize costs; their technology is represented by CRS nested CES production functions.

Each "region" demands the thirteen goods according to a regional linearly homogeneous nested CES utility function, where the "region" maximizes utility subject to its regional income. Regional income includes the factor income of residents of the region, as well as tax receipts of the regional government and net transfer payments to the region from the federal government.

Six regional governments each provides a rival and excludable good in an amount desired by the "region," collects taxes and provides lump sum payments to the region. A federal government collects taxes, redistributing them to the six regions.

**Mobility:** Most of the thirteen goods are traded among regions and the rest of the world. Capital is partially mobile among production sectors and fully mobile among regions in Canada; it may also be internationally mobile. Natural Resources are immobile among regions, and only partially mobile among production sectors.

Households are partially inter-regionally mobile, according to the following characteristics: Each household has a measurable affinity to reside in the region in which it is located in the benchmark equilibrium; the amount of this affinity varies among individuals within each region. Thus a region's residents can be classified by the intensity of their desire to remain within their home region. Households with "strong" provincial allegiances will probably not relocate as a result of a tax change, whereas households with "weak" allegiances may relocate to other regions. (Even after households relocate, their regional preferences remain unchanged in perpetuity from their original desires.)

**Equilibrium Conditions:**
(i) Demand equals supply of goods.

(ii) Demand equals supply of factors of production.

(iii) Producers earn zero profits.

(iv) The current account is in balance.

(v) Government budgets are balanced.

The mathematical structure and calibration techniques employed by Jones and Whalley in their model are markedly similar to those of Shoven's and Whalley's model; the Jones-Whalley model, however, has been formulated to examine some of the interregional equity issues unique to the federal structure and history of Canada. Indeed, some of the model's structure cannot be readily adapted into a U.S. CGE model.

The model assumes, for example, that every Canadian citizen is different—that each is born with a different and unforgettable desire to remain in her home region. This assumption may work well for a Canadian model, especially when considering the dual French-British history of that nation, but it does not seem as fitting an assumption for the more homogeneous United States. Furthermore, while the assumption works well in examining how various regions are affected by changes in tax policy, it obscures issues relating to interpersonal equity, since individuals differ not only in their factor endowments but also in their location desires.

There are a few other unusual qualities to Jones' and Whalley's model. For example, they make the strong assumption that regional tax rates on capital earnings are the same in every region, and they assume that the federal government provides no goods to Canadians. In general, their model illustrates once again the difficulties of designing a generic CGE model which can be applied to any economy in any situation; this model and the previous models described in this chapter reveal the necessity that the CGE modeler formulate his model with priorities dependent upon his areas of interest.
Fortunately, however, the CGE models described above are sufficiently general to provide considerable economies of scale to my model-making endeavor. Many of the important characteristics of these models are maintained in my multi-region U.S. CGE model. These characteristics include: the general mathematical form of the Shoven and Whalley model and its calibration techniques; a variation of the computer solution algorithm suggested by Kimbell and Harrison; and the multi-region nature of the Mutti-Morgan-Partridge and the Jones and Whalley models. These desirable traits are extended in five important areas in order to complete my model:

1. **A Choice for Household Mobility.** In my model, Rich households can be considered either mobile among regions or immobile. The "immobile" assumption may be more appropriate for shorter time periods; the "mobile" assumption may be more accurate for long time periods. Poor households, however, are interregionally immobile.

2. **Direct Measurement of Household Utilities.** Rather than relying upon some measure of regional income or regional utility or changes in specific factor rewards as an indicator of tax incidence, my model directly measures the change in utility of individuals within the economy resulting from a change in tax policy. This method allows direct measurement of excess burdens, and direct horizontal equity comparisons.

3. **Two Types of Households Exist.** This allows vertical equity considerations to be examined. Further, it allows for heterogeneous regional populations, allowing an examination of the interactions between different types of households who have different types and amounts of factor endowments.

4. **Labor is Divided into "Skilled" and "Unskilled" Types.** In previous models, skilled workers differed from unskilled workers only by their larger endowment of the homogeneous factor of production, labor. This modeling assumption suggests a fixed-proportion substitutability between skilled and unskilled workers in any production process (given a certain class of production function). This unrealistic characteristic can
markedly change the results of multi-region general equilibrium simulations, since it suggests that the population makeup is irrelevant to a region's production—only the total amount of production factors is relevant.

5. **Regional Governments Can Provide Congested Public Goods.** Government services such as education, police protection, and highway construction are only partially rivalrous and excludable. In my model, an increase in the population of a region, given a fixed amount of government service provision, can only slightly reduce the per capita consumption of government services within the region.

6. **Regions of Different Size Can Exist.** Recent theoretic literature has suggested that the effects of a sub-national tax depend to some extent upon the size of the taxing jurisdiction. My model has small, medium-sized, and large regions, and can "test" this theory.

The six extensions presented above have been chosen to capture some of the important tax policy issues involved with regional tax differentials. For example, the burden of an increase in a personal income tax may "unfairly" fall on those who cannot relocate to escape the tax; the introduction of mobility and of non-identical households will allow my model to test such contentions. The possible inclusion of a congested public good may offer some indication of relocation externalities and of optimal regional size. And the assumptions of labor and population heterogeneity suggest that households, in the location decision process, must not only consider the tax/expenditure policies of regions, but also consider whether the production technologies of regions are relatively rewarding to their type of labor skill. Thus the six extensions enhance the richness of CGE models in exploring these and other issues. Chapter 5 unveils my model in its full mathematical detail, and illustrates how its construction is a combination of the best of the four CGE

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9See Wheaton (1994), for example.
models presented here, shed of their obfuscating detail, with the addition of new features. The result is a CGE model tailored to be both realistic and analytically powerful in its representation of regional tax policy issues.
5. The Model

This chapter presents my multi-region CGE model of the United States in its full mathematical detail. The model contains several enhancements which augment its analytic power vis-à-vis previous CGE models; the enhancements include the ability to logically and precisely measure household utility in a multi-region context, the ability to model Rich households as either mobile or immobile, and the separation of labor into two types. In order to maintain the model's tractability and analytic power, certain simplifying assumptions are also made; most important are simplifications of international transactions, government budgeting processes, and household labor-leisure and consumption-savings decisions.

Throughout the model's exposition, full explanations will be offered concerning my choices of mathematical and verbal specifications of producer behavior, household behavior, government behavior, the regional structure of the model, the mobility of products and factors, and the equilibrium conditions. Once fully developed, the model is ready to be fit with real-world U.S. economic data to represent the modern U.S. economy in benchmark equilibrium.

Table 5.1 outlines the major qualities of the model. The full model is expounded below.\(^1\)

The Model

The Nation

There exists one nation, the United States, or "U.S," in isolation (i.e. no foreign trade). The U.S. is divided into four regions: the Northeast/Midwest (or "N"), Texas (or "M"), the South (or "S"), and the West (or "W"). Each region is an aggregation of many and localities.

\(^1\) Appendix C at the end of this thesis contains a list of symbols used in the mathematical depiction of my model. These symbols supersede those used in chapter 3, and will be used throughout the remainder of this thesis (except in the computer solution algorithm displayed in the appendix B).
Explanation: International trade is omitted and the number of regions is kept relatively low in order to maintain the analytic power of the model. While an open economy and higher levels of regional disaggregation may offer greater realism, these characteristics also increase the "black box" nature of the model. Since my goal is not only to achieve numerical results from computer simulations but also to carefully interpret the results, it is prudent to maintain the simplicity of the regional and international structure of the model, while retaining enough complexity to be able to capture the important excise effects that sub-national taxes have on regional patterns of production and location choice.

The four regions as chosen parallel the U.S. Bureau of Economic Analysis' state and regional depiction of the United States. Model calibration is facilitated by this choice. Within each region, the state and local governments' fiscal behavior is reasonably homogeneous, so that amalgamating these governments into one regional government is reasonably justifiable.

Production

There are four production sectors within each region. Each production sector produces one product. The four types of products are: "Goods" (or "G"), "Services" (or "V"), "Regional Public Goods" (or "R"), and "Federal Public Goods" (or "F"). Each type of product is an aggregation of many real-world products.

Explanation: The number of products is kept small in order to maintain the analytic power of the model; while realism suggests a higher level of disaggregation, such disaggregation would substantially hinder a careful analysis of computer simulations. The myriad of U.S. products are aggregated into four groups in order to separate these products by the nature of their production technologies. The "Goods" grouping, for example, contains manufactured products and other goods which use a certain production
technology, whereas "Services" contains financial and other services whose technology differs from the "Goods" sector. In the public sector, "Regional Public Goods" are separated from "Federal Public Goods" because the types of goods and services provided by state and local governments, such as education and public safety, differ markedly from the types of goods and services provided by the Federal government, such as military goods.

"Goods" and "Services" are private in nature; that is, they are rival and excludable. "Regional Public Goods" can be only partially rival and excludable; that is, they can be congested public goods. "Federal Public Goods" can also be modeled as congested public goods or pure public goods.

Explanation: Since "Goods" and "Services" are sold on the open market, it is highly likely that they have private goods characteristics. Externalities such as pollution, which would drive a wedge between private and social costs, are not considered in this model.

The depiction of "Regional Public Goods" as congested public goods is more contentious. Seminal articles by Borcherding and Deacon (1972) and Bergstrom and Goodman (1973) suggest that local public goods do not exhibit any attributes of publicness. However, recent articles by Oates (1988) and Edwards (1990) contend that the results obtained in these seminal works are attributable to econometric misspecification; once this misspecification is corrected, both Oates and Edwards maintain that local public goods may indeed have public good characteristics.

Given this debate, I have developed my CGE model to be able to depict Regional Public Goods as either private in nature, partially non-rivalrous and non-excludable, or fully non-rivalrous and non-excludable. This choice can be made by changing one mathematical variable in the model. In model calibration in chapter 7 and in computer
simulations in chapters 8 and 9, I have chosen to treat Regional Public Goods as completely rivalrous and excludable.

The same option exists in my model's depiction of "Federal Public Goods:" they can be private in nature, or they can be treated as congested public goods, or they can be treated as pure public goods. In chapters 7, 8 and 9, I treat them as completely non-rivalrous and non-excludable.

"Goods" may be traded interregionally while "Services," "Regional Public Goods" and "Federal Public Goods" are non-traded.

**Explanations:** It will become evident in the next chapter by those readers with knowledge of Bureau of Economic Analysis ('BEA') data that some of the products which I consider "Goods" are interregionally non-traded, while some "Services" are traded. This unfortunate circumstance results from the high level of aggregation of the model and the form of the BEA data utilized, and is a consequence of sacrificing complexity for analytic strength.

The depiction of "Regional Public Goods" and "Federal Public Goods" as non-traded is probably fairly realistic.

The Armington assumption\(^2\) is employed, so that similar Goods produced in different regions are not perfect substitutes. For example, Goods produced in the Northeast/Midwest are not perfect substitutes for Goods produced in the South. This assumption is tantamount to assuming that sixteen distinct products are produced in the U.S: four Goods, four Services, four Regional public goods, and four Federal public goods.

**Explanation:** Since cross-hauling of similar products interregionally is a

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\(^2\)See Armington (1969)
characteristic of U.S. interstate trade patterns, the Armington assumption seems reasonable for traded goods. This assumption also facilitates computer solution of the model (although only a modest modification to my model and to my computer solution algorithm would be required to eliminate the Armington assumption).

Production within each sector takes place according to a constant returns to scale technology represented by a nested CES production function requiring three inputs: "capital" (or "CAP"), "skilled labor" (or "SKIL"), and unskilled labor (or "UNSKIL").

Explanation: Constant returns to scale is assumed in order to facilitate solution by computer algorithm. While production of certain products in the U.S. almost certainly exhibits increasing returns to scale, the degree of aggregation in the model may subsume those products sufficiently to justify the CRS assumption.

The nested CES functional form is chosen for two major reasons. First, the nested CES function is the most versatile form of production function which is compatible with the computer solution algorithm developed in later chapters of this thesis. From a realism standpoint, more flexible functional forms, such as transcendental logarithmic or other variable elasticity of substitution production functions, may be desirable, but these functional forms are extremely difficult to incorporate into a computer solution algorithm.

Second, and perhaps coincidentally, there is little empirical data characterizing production processes using the more sophisticated functional forms, whereas a reasonable amount of literature has estimated CES production functions for various industries. Therefore, data constraints also preclude the use of more complex production functions.

The three factors of production were chosen to allow for a sufficient degree of diversity to examine how tax policies affect factor prices and factor supplies to various production sectors. "Capital" has been separated from labor because real-world business-type taxes often differ substantially depending upon whether labor is used in production,
or some other input is used. Also, household-type taxes may vary depending upon the source of factor incomes, labor or otherwise.

Labor has been divided into two types to help determine the degree to which regional population heterogeneity results from production input requirements. Without diverse types of labor, Tiebout-type\(^3\) multi-region models suggest that households would tend to stratify into homogeneous regions based upon their demands for regionally-provided public goods. However, if both skilled and unskilled labor are required in the process, a countervailing tendency exists; that is, both skilled and unskilled households may tend to reside in the same region in order to maximize their returns to labor. Thus my assumption of a heterogeneous labor force is consistent with the existence of heterogeneous localities in the United States.

Thought was given to including land as a production input. However, land is an important input in only a few industries, and data on land returns are poor. As a result, land was omitted from the model.

Intermediate production was omitted to maintain the analytic strength of the model.

Mathematically, Goods production in the Northeast/Midwest is represented by:

\[
G_N = A_G b_G LABOR_GN (eG-1)/eG + (1-b_G) CAP_GN (eG-1)/eG \ eG/(eG-1)
\]

"G_N" represents the quantity of Goods produced in the Northeast/Midwest. "A_G" is the scale parameter in Goods production. "b_G" is the distribution parameter in Goods production. "LABOR_GN" is the bundle of skilled and unskilled labor used to produce Goods in the Northeast/Midwest. "CAP_GN" is the amount of capital used to produce

\(^3\) See Tiebout (1956)
Goods in the Northeast/Midwest. "eG" is the elasticity of factor substitution between capital and the skilled-unskilled labor bundle. A closer dissection of "LABOR\textsubscript{GN}" reveals:

\[ \text{LABOR}_{\text{GN}} = A_L[c_G \text{SKIL}_{\text{GN}}(e_{GL}-1)/e_{GL} + (1-c_G)\text{UNSKIL}_{\text{GN}}(e_{GL}-1)/e_{GL}] e_{GL}/(1-e_{GL}) \]

"A\textsubscript{L}" is a scale parameter, "c\textsubscript{G}" is a distribution parameter in Goods production. "SKIL\textsubscript{GN}" is the amount of skilled labor used in Goods production in the Northeast/Midwest. "UNSKIL\textsubscript{GN}" is the amount of unskilled labor used in Goods production in the Northeast/Midwest. "e_{GL}" is the elasticity of factor substitution between skilled labor and unskilled labor in Goods production.

Goods production in the South, Texas, and West are represented by:

\[ \text{GS} = A_G[b_G \text{LABOR}_{\text{GS}}(e_{G-1})/e_{G} + (1-b_G)\text{CAP}_{\text{GS}}(e_{G-1})/e_{G}] e_{G}/(e_{G-1}) \]
\[ \text{GM} = A_G[b_G \text{LABOR}_{\text{GM}}(e_{G-1})/e_{G} + (1-b_G)\text{CAP}_{\text{GM}}(e_{G-1})/e_{G}] e_{G}/(e_{G-1}) \]
\[ \text{GW} = A_G[b_G \text{LABOR}_{\text{GW}}(e_{G-1})/e_{G} + (1-b_G)\text{CAP}_{\text{GW}}(e_{G-1})/e_{G}] e_{G}/(e_{G-1}) \]

where

\[ \text{LABOR}_{\text{GS}} = A_L[c_G \text{SKIL}_{\text{GS}}(e_{GL}-1)/e_{GL} + (1-c_G)\text{UNSKIL}_{\text{GS}}(e_{GL}-1)/e_{GL}] e_{GL}/(1-e_{GL}) \]
\[ \text{LABOR}_{\text{GM}} = A_L[c_G \text{SKIL}_{\text{GM}}(e_{GL}-1)/e_{GL} + (1-c_G)\text{UNSKIL}_{\text{GM}}(e_{GL}-1)/e_{GL}] e_{GL}/(1-e_{GL}) \]
\[ \text{LABOR}_{\text{GW}} = A_L[c_G \text{SKIL}_{\text{GW}}(e_{GL}-1)/e_{GL} + (1-c_G)\text{UNSKIL}_{\text{GW}}(e_{GL}-1)/e_{GL}] e_{GL}/(1-e_{GL}) \]

The strong assumption is made that the elasticities of substitution, e\textsubscript{G} and e\textsubscript{GL}, are identical among Goods producers in all regions. This assumption is necessary because of the dearth of information in the U.S. concerning production technologies of differing regions. However, the scale parameters, A\textsubscript{G} and A\textsubscript{L}, and the distribution parameters, b\textsubscript{G}...
and \( c_G \), may vary among Goods producers in different regions. Thus Goods-producing technology varies across regions, consistent with the Armington assumption.

Production of Services in the economy is represented similarly to the Goods sector:

\[
\begin{align*}
V_N &= A_V [b_V LABOR_{VN}(e^V-1)/e^V + (1-b_V)CAP_{VN}(e^V-1)/e^V] e^V/(e^V-1) \\
V_S &= A_V [b_V LABOR_{VS}(e^V-1)/e^V + (1-b_V)CAP_{VS}(e^V-1)/e^V] e^V/(e^V-1) \\
V_M &= A_V [b_V LABOR_{VM}(e^V-1)/e^V + (1-b_V)CAP_{VM}(e^V-1)/e^V] e^V/(e^V-1) \\
V_W &= A_V [b_V LABOR_{VW}(e^V-1)/e^V + (1-b_V)CAP_{VW}(e^V-1)/e^V] e^V/(e^V-1)
\end{align*}
\]

where

\[
\begin{align*}
LABOR_{VN} &= A_L [c_V SKIL_{VN}(e^{VL}/e^{VL}) + (1-c_V)UNSKIL_{VN}(e^{VL}/e^{VL})] e^{VL}/(1-e^{VL}) \\
LABOR_{VS} &= A_L [c_V SKIL_{VS}(e^{VL}/e^{VL}) + (1-c_V)UNSKIL_{VS}(e^{VL}/e^{VL})] e^{VL}/(1-e^{VL}) \\
LABOR_{VM} &= A_L [c_V SKIL_{VM}(e^{VL}/e^{VL}) + (1-c_V)UNSKIL_{VM}(e^{VL}/e^{VL})] e^{VL}/(1-e^{VL}) \\
LABOR_{VW} &= A_L [c_V SKIL_{VW}(e^{VL}/e^{VL}) + (1-c_V)UNSKIL_{VW}(e^{VL}/e^{VL})] e^{VL}/(1-e^{VL})
\end{align*}
\]

Symbols are defined similarly to those of the Goods sector.\(^4\) As in the Goods sector, elasticities of factor substitution are identical across regions, while scale parameters and distribution parameters may vary across regions.

Production of Regional Public Goods is similarly represented:

\[
\begin{align*}
R_N &= A_R [b_R LABOR_{RN}(e^{R}/e^{R}) + (1-b_R)CAP_{RN}(e^{R}/e^{R})] e^{R}/(e^{R}) \\
R_S &= A_R [b_R LABOR_{RS}(e^{R}/e^{R}) + (1-b_R)CAP_{RS}(e^{R}/e^{R})] e^{R}/(e^{R}) \\
R_M &= A_R [b_R LABOR_{RM}(e^{R}/e^{R}) + (1-b_R)CAP_{RM}(e^{R}/e^{R})] e^{R}/(e^{R}) \\
R_W &= A_R [b_R LABOR_{RW}(e^{R}/e^{R}) + (1-b_R)CAP_{RW}(e^{R}/e^{R})] e^{R}/(e^{R})
\end{align*}
\]

\(^4\) See appendix C for a complete list of symbols and their definitions.
where
\[
\begin{align*}
\text{LABOR}_{RN} &= A_L c_R [\text{SKIL}_{RN} (e_{RL}-1)/e_{RL} + (1-c_R) \text{UNSKIL}_{RN} (e_{RL}-1)/e_{RL}] e_{RL}/(1-c_{RL}) \\
\text{LABOR}_{RS} &= A_L c_R [\text{SKIL}_{RS} (e_{RL}-1)/e_{RL} + (1-c_R) \text{UNSKIL}_{RS} (e_{RL}-1)/e_{RL}] e_{RL}/(1-c_{RL}) \\
\text{LABOR}_{RM} &= A_L c_R [\text{SKIL}_{RM} (e_{RL}-1)/e_{RL} + (1-c_R) \text{UNSKIL}_{RM} (e_{RL}-1)/e_{RL}] e_{RL}/(1-c_{RL}) \\
\text{LABOR}_{RW} &= A_L c_R [\text{SKIL}_{RW} (e_{RL}-1)/e_{RL} + (1-c_R) \text{UNSKIL}_{RW} (e_{RL}-1)/e_{RL}] e_{RL}/(1-c_{RL})
\end{align*}
\]

Symbols are defined similarly to those of the Goods sector. As in the Goods sector, elasticities of factor substitution are identical across regions, while scale parameters and distribution parameters may vary across regions.

Finally, production of Federal Public Goods is similarly represented:
\[
\begin{align*}
F_N &= A_F [b_F \text{LABOR}_{FN} (e_{F}-1)/e_{F} + (1-b_F) \text{CAP}_{FN} (e_{F}-1)/e_{F}] e_{F}/(e_{F}-1) \\
F_S &= A_F [b_F \text{LABOR}_{FS} (e_{F}-1)/e_{F} + (1-b_F) \text{CAP}_{FS} (e_{F}-1)/e_{F}] e_{F}/(e_{F}-1) \\
F_M &= A_F [b_F \text{LABOR}_{FM} (e_{F}-1)/e_{F} + (1-b_F) \text{CAP}_{FM} (e_{F}-1)/e_{F}] e_{F}/(e_{F}-1) \\
F_W &= A_F [b_F \text{LABOR}_{FW} (e_{F}-1)/e_{F} + (1-b_F) \text{CAP}_{FW} (e_{F}-1)/e_{F}] e_{F}/(e_{F}-1)
\end{align*}
\]

where
\[
\begin{align*}
\text{LABOR}_{FN} &= A_L c_F [\text{SKIL}_{FN} (e_{FL}-1)/e_{FL} + (1-c_F) \text{UNSKIL}_{FN} (e_{FL}-1)/e_{FL}] e_{FL}/(1-c_{FL}) \\
\text{LABOR}_{FS} &= A_L c_F [\text{SKIL}_{FS} (e_{FL}-1)/e_{FL} + (1-c_F) \text{UNSKIL}_{FS} (e_{FL}-1)/e_{FL}] e_{FL}/(1-c_{FL}) \\
\text{LABOR}_{FM} &= A_L c_F [\text{SKIL}_{FM} (e_{FL}-1)/e_{FL} + (1-c_F) \text{UNSKIL}_{FM} (e_{FL}-1)/e_{FL}] e_{FL}/(1-c_{FL}) \\
\text{LABOR}_{FW} &= A_L c_F [\text{SKIL}_{FW} (e_{FL}-1)/e_{FL} + (1-c_F) \text{UNSKIL}_{FW} (e_{FL}-1)/e_{FL}] e_{FL}/(1-c_{FL})
\end{align*}
\]

Symbols are once again defined similarly to those in the other production sectors. And again, the distribution parameter and the elasticities of substitution may vary among regions.

Each producer is a price-taker and minimizes the average cost of producing each
good. For example, the Goods producer in the Northeast/Midwest minimizes:

\[(P_{\text{CAPGN}})(C_{\text{APG}N1})+(P_{\text{SKILGN}})(S_{\text{KILGN}1})+(P_{\text{UNSKILGN}})(U_{\text{NSKILGN}1})\]

"\(P_{\text{CAPGN}}\)" is the price of capital taken by the Goods producer in the Northeast/Midwest gross of her business capital taxes and corporation income taxes; "\(P_{\text{SKILGN}}\)" and "\(P_{\text{UNSKILGN}}\)" are similarly defined for skilled and unskilled labor, respectively. "\(C_{\text{APG}N1}\)" is the amount of capital used to produce 1 unit of Goods in the Northeast/Midwest; "\(S_{\text{KILGN}1}\)" and "\(U_{\text{NSKILGN}1}\)" are similarly defined for skilled labor and unskilled labor, respectively.

This cost-minimizing behavior, coupled with the CES technology, allows the factor demands per unit of output in the Northeast/Midwest Goods sector to be derived. These factor demands are:

\[
C_{\text{APG}N1} = A^{-1}\left[\frac{bG[(1-bG)PLABORGN/(bGPCAPGN)]^{1-eG}+(1-bG)eG/(1-eG)}{eG/(1-eG)}\right]
\]
\[
S_{\text{KILGN}1} = \left\{(1-cG)\left[cG^{UNSKILGN}/(cG^{SKILGN})\right]^{1-eGL}+(cG)eGL/(1-eGL)\right\}
\]
\[
U_{\text{NSKILGN}1} = \left\{cG[(1-cG)P_{\text{SKILGN}}/(cG^{UNSKILGN})]^{1-eGL}+(1-cG)eGL/(1-eGL)\right\}
\]

where

\[
PLABORGN = [cG^{PSKILGN}^{1-eGL}+(1-cG)P_{\text{UNSKILGN}}(1-eGL)]^{1/(1-eGL)}
\]

The cost-minimizing behavior and per-unit factor demand equations for the other production sectors are depicted similar to those above. For example, the remaining Goods-producing sectors (in the South, Texas, and West, respectively), costs are minimized as follows:
\[(PCAPGS)(CAPGS1)+(PSKILGS)(SKILGS1)+(PUNSKILGS)(UNSKILGS1)\]
\[(PCAPGM)(CAPGM1)+(PSKILGM)(SKILGM1)+(PUNSKILGM)(UNSKILGM1)\]
\[(PCAPGW)(CAPGW1)+(PSKILGW)(SKILGW1)+(PUNSKILGW)(UNSKILGW1)\]

Per-unit factor demand equations in the South's Goods sector are:

\[CAPGS1=AG^{-1}\left(\frac{bG\left((-1-bG)PLABORGGS\right)}{bG\left(PCAPGS\right)}\right)^{1-eG+(1-bG)}\frac{eG}{(1-eG)}\]
\[SKILGS1=\left(\frac{(1-cG)(cGPUNSKILGS)}{(1-cG)PSKILGS}\right)^{1-eGL+cG}\frac{eGL}{(1-eGL)}\]
\[UNSKILGS1=(cG\left((-1-cG)PSKILGS\right))^{1-eGL+(1-cG)}\frac{eGL}{(1-eGL)}\]

In the Texas Goods sector:

\[CAPGM1=AG^{-1}\left(\frac{bG\left((-1-bG)PLABORGM\right)}{bG\left(PCAPGM\right)}\right)^{1-eG+(1-bG)}\frac{eG}{(1-eG)}\]
\[SKILGM1=\left(\frac{(1-cG)(cGPUNSKILGM)}{(1-cG)PSKILGM}\right)^{1-eGL+cG}\frac{eGL}{(1-eGL)}\]
\[UNSKILGM1=(cG\left((-1-cG)PSKILGM\right))^{1-eGL+(1-cG)}\frac{eGL}{(1-eGL)}\]

In the West Goods sector:

\[CAPGW1=AG^{-1}\left(\frac{bG\left((-1-bG)PLABORGW\right)}{bG\left(PCAPGW\right)}\right)^{1-eG+(1-bG)}\frac{eG}{(1-eG)}\]
\[SKILGW1=\left(\frac{(1-cG)(cGPUNSKILGW)}{(1-cG)PSKILGW}\right)^{1-eGL+cG}\frac{eGL}{(1-eGL)}\]
\[UNSKILGW1=(cG\left((-1-cG)PSKILGW\right))^{1-eGL+(1-cG)}\frac{eGL}{(1-eGL)}\]

where

\[PLABORGGS = [cG\left(PSKILGS\right)^{1-eGL}+(1-cG)PUNSKILGS^{(1-eGL)}]^{1/(1-eGL)}\]
\[PLABORGM = [cG\left(PSKILGM\right)^{1-eGL}+(1-cG)PUNSKILGM^{(1-eGL)}]^{1/(1-eGL)}\]
\[PLABORGW = [cG\left(PSKILGW\right)^{1-eGL}+(1-cG)PUNSKILGW^{(1-eGL)}]^{1/(1-eGL)}\]

Symbols are defined similarly to those in the Northeast/Midwest Goods sector.

The per-unit factor demand equations for Services, Regional Public Goods, and
Federal Public Goods are derived in similar fashion to those shown above. These derivations are omitted from this thesis to avoid redundancy. All of the factor demand equations will appear in the computer algorithm which will be used to solve the model for counterfactual equilibria.

**Households**

There exists a constant national population of identical rich households (or "Rich"), each of which is endowed with a fixed amount of capital (or "RICH\_CAP") and skilled labor (or "RICH\_S\_KIL"). There also exists a constant national population of identical poor households (or "Poor"), each of which is endowed with a fixed amount of capital (or "POOR\_CAP") and unskilled labor (or "POOR\_unskil").

**Explanation:** Households are separated into two income classes according to their labor abilities and the size of their capital endowments. This separation seems reasonable, since empirically in the United States people tend to earn progressively more income as their level of educational attainment increases, and richer people tend to control more capital than poorer people.

The division of income classes is limited to two, rich and poor, in order to maintain the analytic power of the model.\(^5\)

Rich and poor supply their factors of production inelastically to the production sectors in the economy.

**Explanation:** This assumption eliminates the possibility that household taxation affects the labor-leisure choices of households through income and substitution effects.

While such effects may exist in the real world,\(^6\) to include these effects in a multi-region

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\(^5\)In later chapters, I create "hypothetical" households whose income sources varies; this aids in tax incidence analysis.

\(^6\)See, for example, Beck (1979)
model would complicate the analysis of regional tax policy. Consider, for example, a scenario in which a regional government replaces its business-type taxes with an equal-yield personal income tax. In the real world, a household within that region might respond either by moving out of the region, or by remaining in the region while reducing (or increasing) her work effort. Thus the migration effects of regional tax changes are intertwined with labor-leisure tradeoff effects. In order to avoid this complication in the model, it is assumed that changes in taxes do not affect labor supplies, allowing the labor-leisure effects to be suppressed,\textsuperscript{7} so that migration effects become more transparent.

The household population is distributed among the four regions of the U.S. Each household must supply her labor endowment in the region in which she resides. She may supply her capital endowment in any region.

\textbf{Explanation:} Commuting costs and geographic distances between regions preclude people in the real world from working far from their residence. Therefore, the assumption that households must work in their region of residence is justified.\textsuperscript{8}

Since a person need not be physically present to supply her capital endowment in production, it is accurate to model households as being able to supply capital wherever they wish.

Rich and poor households have identical preferences.

\textbf{Explanation:} Some economists suggest that household preferences vary by income class,\textsuperscript{9} implying, perhaps, that due to innate or societal circumstances rich people in their formative years develop preferences different from the poor. This author, however, does

\textsuperscript{7} Some studies have found that primary wage-earners will not substantially alter their work effort when their marginal personal income tax rates are altered. See, for example, Atkinson and Stiglitz (1982).

\textsuperscript{8} Richard Young has suggested that modern telecommunications technology is increasingly allowing workers to supply their labor over long distances to other geographic regions. Conceivably then, the model's regional labor supply assumption may become obsolete in the distant future.

\textsuperscript{9} See, for example, Henderson (1984).
not wish to bring these issues of class preference stratification into the model. Instead, I wish to focus on how differences in factor endowments between classes (especially differences in labor skills) affect migration, population patterns, and household utilities. Therefore, consistent with the American ideal of a classless society, the assumption is made that everyone in the United States has the same preference structure.

Households gain utility from consuming products according to a nested linearly homogeneous CES utility functions. Each household maximizes her utility, constrained by her disposable income and by the products available in her region of residence.

**Explanation:** The utility functions are of the linearly homogeneous variety to facilitate computer solution of the model; this form allows total regional demands for products to be easily determined by aggregating regional product demand into one aggregate utility function.

The utility functions are of the CES variety for reasons similar to the CES choice for the production functions; that is, CES functions allow for computer solution of the model, and also conform to real-world data limitations.

A representative household's utility function is a follows:

\[ U_H = d_1^{1/i_1} \text{PRIV}_H^{(i_1-1)/i_1} + (1-d_1)^{1/i_1} \text{PUBL}_H^{(i_1-1)/i_1} \frac{i_1}{i_1(i_1-1)} \]

"\( U_H \)" is the utility of a representative household. "\( d_1 \)" is a distribution parameter. "\( \text{PRIV}_H \)" is a nested bundle of Goods and Services consumed by the household. "\( \text{PUBL}_H \)" is a nested bundle of Federal Public Goods and Regional Public Goods consumed by the household. "\( i_1 \)" is the elasticity of substitution between \( \text{PRIV}_H \) and \( \text{PUBL}_H \).
A closer look at $\text{PUBL}_H$ and $\text{PRIV}_H$ reveals:

$$\text{PRIV}_H = [d_2^{1/i2} \text{GOOD}_H(i2-1)/i2 + (1-d_2)^{1/i2} V_H(i2-1)/i2] j^{1/i2}/(i2-1)$$

$$\text{PUBL}_H = [d_3^{1/i3} (R/(\text{POOR} + \text{RICH}))j(i3-1)/i3 + (1-d_3)^{1/i3} F(i3-1)/i3] j^{1/i3}/(i3-1)$$

"$d_2$" and "$d_3$" are distribution parameters. "$i2$" is the elasticity of substitution between Goods and Services. "$i3$" is the elasticity of substitution between Regional Public Goods and Federal Public Goods. "$\text{GOOD}_H$" is the amount of a bundle of goods from different regions consumed by the household. "$V_H$" is the amount of services consumed by the household. "$R$" is the total amount of Regional Public Goods produced in the region in which the household resides. "$\text{POOR} + \text{RICH}$" is the total household population of the region in which the household resides. "$j$" is a fraction between zero and one; it measures the level of congestion of the Regional Public Good. "$F$" is the total amount of (pure) Federal Public Goods produced in the nation.

A closer look at $\text{GOOD}_H$ reveals:

$$\text{GOOD}_H = [d_4^{1/i4} \text{GOOD}_N(i4-1)/i4 + d_5^{1/i4} \text{GOOD}_S(i4-1)/i4 +$$

$$d_6^{1/i4} \text{GOOD}_M(i4-1)/i4 + d_7^{1/i4} \text{GOOD}_W(i4-1)/i4]$$

"$d_4,$" "$d_5,$" "$d_6$" and "$d_7$" are distribution parameters whose sum equals 1. "$i4$" is the elasticity of substitution between Goods produced in different regions. "$\text{GOOD}_N$" is the household's consumption of Goods made in the Northeast/Midwest. "$\text{GOOD}_S$" is the household's consumption of Goods made in the South. "$\text{GOOD}_M$" is the household's consumption of Goods made in Texas. "$\text{GOOD}_W$" is the household's consumption of Goods made in the West.

Households' utility-maximizing consumption decisions do not affect the amount of Federal Public Goods or Regional Public Goods they receive.
Explanation: Under certain circumstances this assumption may not be realistic; for example, if in the real world households were to consume large amounts of private schooling, then governments may reduce their outlays for public schooling. However, I believe this assumption to be reasonably accurate in most cases; Federal and State governments, in particular, seem to suffer from a degree of inertia which precludes any response to consumption decisions of households.

Given the above assumption, a household's utility-maximizing consumption choice reduces to allocating its disposable income among North Goods, South Goods, Texas Goods, West Goods, and Services. Since nested CES functions are strictly separable, the mathematical representation of this maximization process is straightforward. At the first stage, a representative household maximizes:

$$PRIV_H = \left[ d_2 \frac{1}{i_2} \frac{GOOD_H}{i_2} + (1-d_2) \frac{1}{i_2} \frac{V_H}{i_2} \right] \left[ 1 + \frac{1}{i_2} \right]$$

A typical Rich household faces the following budget constraint:

$$RICHTRAN + (PRICHCAP)(RICHCAP) + (PRICHSKIL)(RICHSKIL) = (PGOOD)(RICHGOOD) + (PVH)(RICHVH)$$

"RICHTRAN" is the transfer payment received by a Rich household. "PRICHCAP" is the Rich return on capital net of taxes. "RICHCAP" is the capital endowment of the rich household. "PRICHSKIL" is the Rich wage net of taxes. "RICHSKIL" is the Rich household's endowment of labor. "PGOOD" is a price index of North Goods, South Goods, Texas Goods, and West Goods. "RICHGOOD" is the Rich household's consumption of the aforementioned goods. "PVH" is the price of services gross of retail
sales taxes. "RICHVH" is the Rich household's consumption of Services.

A closer look at PGOODH reveals:

\[ PGOODH = (d_4P_{GNH}^{(1-i_4)} + d_5P_{GSH}^{(1-i_4)} + d_6P_{GMH}^{(1-i_4)} + d_7P_{GWH}^{(1-i_4)} \]

"P_{GNH}," "P_{GSH}," "P_{GMH}," and "P_{GWH}" are the prices of North Goods, South goods, Texas Goods, and West Goods, respectively, gross of retail sales taxes.

A Poor household faces the following budget constraint:

\[ POORTRAN + (P_{POORCAP})POORCAP + (P_{POORUNSKIL})POORSKIL = (PGOODH)POORGOODH + (PVH)POORVH \]

Symbols are defined similarly to those in the Rich budget constraint above.

Solution of the utility maximization problem for a rich household reveals the following product demand functions:

\[ RICHVH = \]
\[ [(1-d_2)[RICHTRAN+(PRICHCAP)(RICHCAP)+(PRICHSKIL)(RICHSKIL)]/\]
\[ (PVH^{i_2}[d_2PGOODH^{1-i_2}+(1-d_2)PVH^{1-i_2}]) \]

\[ RICHGOODH = \]
\[ [d_2[RICHTRAN+(PRICHCAP)(RICHCAP)+(PRICHSKIL)(RICHSKIL)]/\]
\[ (PGOODH^{i_2}[d_2PGOODH^{1-i_2}+(1-d_2)PVH^{1-i_2}]) \]

\[ RICHGNH = [d_4(RICHGOODH)(PGOODH)]/[P_{GNH}^{i_4}(PGOODH)] \]
RICH_{GSH} = \frac{d_5(RICH_{GOODH})(PGOODH)}{[PGSH^{i_4}(PGOODH)]}
RICH_{GMH} = \frac{d_6(RICH_{GOODH})(PGOODH)}{[PGMH^{i_4}(PGOODH)]}
RICH_{GWH} = \frac{d_7(RICH_{GOODH})(PGOODH)}{[PGWH^{i_4}(PGOODH)]}

"RICH_{GNH}" is the Rich household's demand for North Goods.
"RICH_{GSH}" is the Rich household's demand for South Goods.
"RICH_{GMH}" is the Rich household's demand for Texas Goods.
"RICH_{GWH}" is the Rich household's demand for West Goods.

These demand equations will be used in the computer solution algorithm to help solve for counterfactual equilibria. Also required are demand equations for poor households. They are as follows:

POOR_{VH} = \frac{[(1-d_2)[POOR_{TRAN}+(POOR_{CAP})(POOR_{CAP})+(POOR_{SKIL})(POOR_{SKIL})]]}{[PVH^{i_2}[d_2^{2}PGOODH^{1-i_2}+(1-d_2)PVH^{1-i_2}]]}

POOR_{GOODH} = \frac{[d_2[POOR_{TRAN}+(POOR_{CAP})(POOR_{CAP})+(POOR_{SKIL})(POOR_{SKIL})]]}{[PGOODH^{i_2}[d_2^{2}PGOODH^{1-i_2}+(1-d_2)PVH^{1-i_2}]]}

POOR_{GHN} = \frac{[d_4(POOR_{GOODH})(PGOODH)]}{[PGNH^{i_4}(PGOODH)]}
POOR_{GSH} = \frac{[d_5(POOR_{GOODH})(PGOODH)]}{[PGSH^{i_4}(PGOODH)]}
POOR_{GMH} = \frac{[d_6(POOR_{GOODH})(PGOODH)]}{[PGMH^{i_4}(PGOODH)]}
POOR_{GWH} = \frac{[d_7(POOR_{GOODH})(PGOODH)]}{[PGWH^{i_4}(PGOODH)]}

"POOR_{GNH}" is the POOR household's demand for North Goods.
"POORGSH" is the POOR household's demand for South Goods.

"POORGMH" is the POOR household's demand for Texas Goods.

"POORGWH" is the POOR household's demand for West Goods.

These equations are also necessary to run computer simulations of tax policy.

Governments

There exists one national government which levies taxes on household labor income, household capital income, corporation income, business labor income, and business capital income.

Explanation: Major revenue sources of the United States federal government include the OASDI tax, the personal income tax, and the corporation income tax. These and other personal and corporate taxes will be modeled as household-type or business-type taxes on capital or labor. Federal ad valorem taxes will be omitted from the model, to maintain tractability. The revenue received from these sources is relatively small.

The national government disperses transfer payments to individuals and also provides them with Federal Public Goods, spending a fixed, never-changing proportion of tax receipts on each.

Explanation: I believe this assumption to be as realistic as any other in describing the behavior of the federal government. The vast majority of the U.S. government's tax receipts go into the general revenue fund (including so-called targeted taxes such as OASDI); tax increases are usually not associated with an increase in any particular area of the budget, but rather fund general expenditures. Therefore, I believe that it is reasonable to assume that an increase or reduction in federal tax receipts will not by itself change the composition of federal expenditures. In my model, then, the proportion of expenditures of the national government spent on transfer payments and Federal Public Goods will be the
same in the benchmark and counterfactual equilibria.

Within each region there exists a regional government, which derives tax revenue from the capital and labor income of households residing in the region, from the capital and labor income of businesses located in the region, from corporation income, and from ad valorem taxes on Goods and Services produced in the region.

**Explanation:** Each regional government in my model will be a compendium of U. S. state and local governments. The major revenue sources of these governments—individual income taxes, ad valorem taxes, property taxes, and corporation income taxes—can be adequately modeled as business-type taxes, household-type taxes, corporation income taxes, or sales taxes.

Each regional government provides Regional Public Goods and transfer payments to households in the region, spending a forever constant proportion of revenues on each.

**Explanation:** As with the national government above, I do not believe that any correlation exists between the level of a sub-national government's tax revenue and the allocation of that revenue among alternate expenditures (i.e. transfer payments versus Regional Public Goods). Therefore the assumption seems reasonable that the proportion of government revenue spent on transfer payments vs Regional Public Goods remains the same in the benchmark and counterfactual equilibria.

**Household Mobility**

In the benchmark period Rich households residing in different regions of the nation will have the same utility levels.

**Explanation:** Recent econometric literature has supported the theory that mobile households in the long run have sufficient information to locate their residence in an area
which maximizes their utilities; however, since each mobile household undertakes this location choice, the long run equilibrium would suggest that Rich household utilities are equalized across geographic areas.\textsuperscript{10}

The high degree of aggregation of goods and households in my model makes it impossible for it to capture entirely the utility-equalizing effect. Therefore, in the benchmark equilibrium, a percentage measurement of the disparities in utilities among Rich households of various regions will be made. Then, shift parameters will be employed to equalize the utilities of Rich households interregionally.

Rich household utility may be modeled in two possible ways in my model:

1) After a tax change, Rich households relocate to re-equalize their utilities.

2) Rich households do not change their region of residence after a tax change.

**Explanation:** One could consider each of the two options above as acting sequentially; assumption (2) may be more accurate for the short term while assumption (1) may be more accurate for the long term. It is possible, for example, that a Rich household may not relocate initially as a result of a tax change, due to factors such as job, family, and incomplete information. However, in the long term it is possible that if tax policy were changed from the benchmark period so that regional Rich utility disparities temporarily existed, then Rich households in poorer regions would eventually relocate to the better off regions, and would slowly close the utility gaps among regions so that eventually, in the counterfactual equilibrium, the utility disparities would disappear.

Poor households are regionally immobile.

**Explanation:** In the real world, workers with minimal job skills have great difficulty searching for better jobs in other areas of the country. Unskilled jobs in other regions are

\textsuperscript{10}See Feldstein and Valiant (1994) for an analysis.
rarely advertised in local media, nor is it easy to discover the real wage rates that unskilled jobs pay in other areas. The only real option in the real world for unskilled workers searching for a job in another region is to take a substantial risk, and spend a large percentage of their income to move to another region, and hope that they can find a better job there. This risk is a huge obstacle—large enough so that I believe that my assumption of immobile Poor households is realistic.

Since Poor households are immobile, the utilities of Poor households may differ among regions.

Explanation: This is fairly obvious. If, for example, Poor households in the Northeast/Midwest were forced to pay a substantial increase in their taxes, then they could not relocate to avoid the tax. As a result, Poor households' utilities in the Northeast/Midwest would probably be reduced relative to their counterparts' utilities in other regions.

Equilibrium Conditions

1. Factor Markets Clear.

This condition requires that the demand for skilled labor equals its supply in each region; that the demand for unskilled labor equals its supply in each region; and that the national demand for capital equals its national supply.

For skilled labor, the condition can be expressed mathematically as follows:

\[
\begin{align*}
\text{SKIL}_{GN} + \text{SKIL}_{VN} + \text{SKIL}_{RN} + \text{SKIL}_{FN} &= \text{RICH}_{N} \times \text{RICH}_{SKIL} \\
\text{SKIL}_{GS} + \text{SKIL}_{VS} + \text{SKIL}_{RS} + \text{SKIL}_{FS} &= \text{RICH}_{S} \times \text{RICH}_{SKIL} \\
\text{SKIL}_{GM} + \text{SKIL}_{VM} + \text{SKIL}_{RM} + \text{SKIL}_{FM} &= \text{RICH}_{M} \times \text{RICH}_{SKIL} \\
\text{SKIL}_{GW} + \text{SKIL}_{VW} + \text{SKIL}_{RW} + \text{SKIL}_{FW} &= \text{RICH}_{W} \times \text{RICH}_{SKIL}
\end{align*}
\]
"RICH_N" is the population of Rich households in the Northeast/Midwest. "RICH_S."
"RICH_M," and "RICH_W" are similarly defined.

For unskilled labor, the condition is expressed:

\[ \text{UNSKIL}_{GN} + \text{UNSKIL}_{VN} + \text{UNSKIL}_{RN} + \text{UNSKIL}_{FN} = \text{POOR}_N \times \text{POOR}_{UNSKIL} \]
\[ \text{UNSKIL}_{GS} + \text{UNSKIL}_{VS} + \text{UNSKIL}_{RS} + \text{UNSKIL}_{FS} = \text{POOR}_S \times \text{POOR}_{UNSKIL} \]
\[ \text{UNSKIL}_{GM} + \text{UNSKIL}_{VM} + \text{UNSKIL}_{RM} + \text{UNSKIL}_{FM} = \text{POOR}_M \times \text{POOR}_{UNSKIL} \]
\[ \text{UNSKIL}_{GW} + \text{UNSKIL}_{VV} + \text{UNSKIL}_{RW} + \text{UNSKIL}_{FW} = \text{POOR}_W \times \text{POOR}_{UNSKIL} \]

"POOR_N" is the population of POOR households in the Northeast/Midwest. "POOR_S."
"POOR_M," and "POOR_W" are similarly defined.

Finally, for capital the equilibrium condition is expressed:

\[ \text{CAP}_{GN} + \text{CAP}_{VN} + \text{CAP}_{RN} + \text{CAP}_{FN} + \text{CAP}_{GS} + \text{CAP}_{VS} + \text{CAP}_{RS} + \text{CAP}_{FS} + \text{CAP}_{GM} + \text{CAP}_{VM} + \text{CAP}_{RM} + \text{CAP}_{FM} + \text{CAP}_{GW} + \text{CAP}_{VV} + \text{CAP}_{RW} + \text{CAP}_{FW} = \text{POOR}_W \times \text{POOR}_{CAP} + \text{RICH}_W \times \text{RICH}_{CAP} + \text{POOR}_N \times \text{POOR}_{CAP} + \text{RICH}_N \times \text{RICH}_{CAP} + \text{POOR}_S \times \text{POOR}_{CAP} + \text{RICH}_S \times \text{RICH}_{CAP} + \text{POOR}_M \times \text{POOR}_{CAP} + \text{RICH}_M \times \text{RICH}_{CAP} \]

2. Private Products Markets Clear

This condition requires that the national demand for Goods (which are inter-regionally traded) equals the national supply of Goods, and that the demand for Services (which are non-traded) equals the supply of Services in each region of the nation.

For Northeast/Midwest Goods, the condition is expressed:
\[ \text{RICH}_N \times \text{RICH}_{GNHN} + \text{RICH}_S \times \text{RICH}_{GNHS} + \text{RICH}_M \times \text{RICH}_{GNHM} + \]
\[ \text{RICH}_W \times \text{RICH}_{GNHW} + \text{POOR}_N \times \text{POOR}_{GNHN} + \text{POOR}_S \times \text{POOR}_{GNHS} + \]
\[ \text{POOR}_M \times \text{POOR}_{GNHM} + \text{POOR}_W \times \text{POOR}_{GNHW} = G_N \]

"RICH\text{\textsubscript{GNHN}}" is the amount of Northeast/Midwest Goods consumed by 1 Rich household living in the Northeast/Midwest. "RICH\text{\textsubscript{GNHS}}" is the amount of Northeast/Midwest Goods consumed by 1 household living in the South. "RICH\text{\textsubscript{GNHM}}" is the amount of Northeast/Midwest Goods consumed by 1 household living in the Texas. "RICH\text{\textsubscript{GNHW}}" is the amount of Northeast/Midwest Goods consumed by 1 household living in the West. "POOR\text{\textsubscript{GNHN}}," "POOR\text{\textsubscript{GNHS}}," "POOR\text{\textsubscript{GNHM}}," and "POOR\text{\textsubscript{GNHW}}" are defined similarly for Poor households.

For South Goods, the condition is:
\[ \text{RICH}_N \times \text{RICH}_{GSHN} + \text{RICH}_S \times \text{RICH}_{GSHS} + \text{RICH}_M \times \text{RICH}_{GSHM} + \]
\[ \text{RICH}_W \times \text{RICH}_{GSHW} + \text{POOR}_N \times \text{POOR}_{GSHN} + \text{POOR}_S \times \text{POOR}_{GSHS} + \]
\[ \text{POOR}_M \times \text{POOR}_{GSHM} + \text{POOR}_W \times \text{POOR}_{GSHW} = G_S \]

For Texas Goods:
\[ \text{RICH}_N \times \text{RICH}_{GMHN} + \text{RICH}_S \times \text{RICH}_{GMHS} + \text{RICH}_M \times \text{RICH}_{GMHM} + \]
\[ \text{RICH}_W \times \text{RICH}_{GMHW} + \text{POOR}_N \times \text{POOR}_{GMHN} + \text{POOR}_S \times \text{POOR}_{GMHS} + \]
\[ \text{POOR}_M \times \text{POOR}_{GMHM} + \text{POOR}_W \times \text{POOR}_{GMHW} = G_M \]

For West Goods:
\[ \text{RICH}_N \times \text{RICH}_{GWHN} + \text{RICH}_S \times \text{RICH}_{GWHS} + \text{RICH}_M \times \text{RICH}_{GMHW} + \]
\[ \text{RICH}_W \times \text{RICH}_{GWHW} + \text{POOR}_N \times \text{POOR}_{GWHN} + \text{POOR}_S \times \text{POOR}_{GWHS} + \]
\[ \text{POOR}_M \times \text{POOR}_{GWHM} + \text{POOR}_W \times \text{POOR}_{GWHW} = G_W \]
Symbols are defined similarly to the Northeast/Midwest Goods equilibrium.

For Services, the equilibrium is expressed:

\[
\begin{align*}
RICH_N \times RICH_{VHN} + \text{POOR}_N \times \text{POOR}_{VHN} & = V_N \\
RICH_S \times RICH_{VHS} + \text{POOR}_S \times \text{POOR}_{VHS} & = V_S \\
RICH_M \times RICH_{VHM} + \text{POOR}_M \times \text{POOR}_{VHM} & = V_M \\
RICH_W \times RICH_{VHW} + \text{POOR}_W \times \text{POOR}_{VHW} & = V_W \\
\end{align*}
\]

"RICH_{VHN}" is consumption of Services in the Northeast/Midwest by a Rich household.
"RICH_{VHS}" is consumption of Services in the South by a Rich household. "RICH_{VHM}" is consumption of Services in the Texas by a Rich household. "RICH_{VHW}" is consumption of Services in the West by a Rich household. "POOR_{VHN}," "POOR_{VHS}," "POOR_{VHM}," and "POOR_{VHW}" are defined similarly for Poor households.

3. Producers Earn Zero Profits

Producers of Goods and Services set their price equal to their average costs of production. Mathematically,

\[
\begin{align*}
P_{\text{NETGN}} & = (P_{\text{CAPGN}})(\text{CAPGN}) + (P_{\text{SKILGN}})(\text{SKILGN}) \\
& \quad + (P_{\text{UNSKILGN}})(\text{UNSKILGN}) \\
P_{\text{NETGS}} & = (P_{\text{CAPGS}})(\text{CAPGS}) + (P_{\text{SKILGS}})(\text{SKILGS}) \\
& \quad + (P_{\text{UNSKILGS}})(\text{UNSKILGS}) \\
P_{\text{NETGM}} & = (P_{\text{CAPGM}})(\text{CAPGM}) + (P_{\text{SKILGM}})(\text{SKILGM}) \\
& \quad + (P_{\text{UNSKILGM}})(\text{UNSKILGM}) \\
P_{\text{NETGW}} & = (P_{\text{CAPGW}})(\text{CAPGW}) + (P_{\text{SKILGW}})(\text{SKILGW}) \\
& \quad + (P_{\text{UNSKILGW}})(\text{UNSKILGW})
\end{align*}
\]
\[ P_{NETVN} = (P_{CAPVN})(CAP_{VN!}) + (P_{SKILVN})(SKIL_{VN!}) + (P_{UNSKILVN})(UNSKIL_{VN!}) \]
\[ P_{NETVS} = (P_{CAPVS})(CAP_{VS!}) + (P_{SKILVS})(SKIL_{VS!}) + (P_{UNSKILVS})(UNSKIL_{VS!}) \]
\[ P_{NETVM} = (P_{CAPVM})(CAP_{VM!}) + (P_{SKILVM})(SKIL_{VM!}) + (P_{UNSKILVM})(UNSKIL_{VM!}) \]
\[ P_{NETVW} = (P_{CAPVW})(CAP_{VW!}) + (P_{SKILVW})(SKIL_{VW!}) + (P_{UNSKILVW})(UNSKIL_{VW!}) \]

"P_{NETGN}" is the price of Northeast/Midwest Goods net of retail sales taxes. "P_{NETGS}" is the price of South Goods net of retail sales taxes. "P_{NETGM}" is the price of Texas Goods net of retail sales taxes. "P_{NETGW}" is the price of West Goods net of retail sales taxes. "P_{NETVN}" is the price of Northeast/Midwest Services net of retail sales taxes. "P_{NETVS}" is the price of South Services net of retail sales taxes. "P_{NETVM}" is the price of Texas Services net of retail sales taxes. "P_{NETVW}" is the price of West Services net of retail sales taxes.

4. Governments Budgets Balance

This equilibrium condition may not be very realistic, given the bevy of government deficits in the United States over the past twenty years. But it is a necessary condition for equilibrium; since in this model there are not any consumer savings, producer profits or savings, or foreign sector, government budgets must balance in order for national product to equal national expenditures.

Mathematically, for the Northeast/Midwest Regional government the equilibrium condition is:
\[
RICH_N \times RICH_{TRANN} + POOR_N \times POOR_{TRANN} + R_N \times P_{RN} = \\
T_{CAPG} \times P_{NETC} \times CAP_G + TSKILG_N \times P_{NETSKILN} \times SKIL_GN \\
+ TUNSKILG_N \times P_{NETUNSKILN} \times UNSKIL_GN + \\
T_{CAPV} \times P_{NETC} \times CAP_V + TSKILV_N \times P_{NETSKILN} \times SKIL_VN \\
+ TUNSKILV_N \times P_{NETUNSKILN} \times UNSKIL_VN + \\
TRICH_{CAP} \times PH_{CAP} \times RICH_{CAP} + \\
TPOOR_{CAP} \times PH_{CAP} \times POOR_{CAP} + \\
TRICH_{SKIL} \times P_{RICHSKIL} \times RICH_{SKIL} + \\
TPOOR_{UNSKIL} \times P_{POORUNSKIL} \times POOR_{UNSKIL} \\
TGOODN \times [ P_{NETG} \times (RICH_{GNHN} + POOR_{GNHN}) ] + \\
P_{NETG} \times (RICH_{GNHN} + POOR_{GNHN}) + \\
P_{NETGM} \times (RICH_{GMHN} + POOR_{GMHN}) + \\
P_{NETGW} \times (RICH_{GWHN} + POOR_{GWHN}) + \\
TVN \times P_{NETV} \times (RICH_{VHN} + POOR_{VHN}) + \\
T_{CORPG} \times \left( \frac{(1/3 \times (P_{NETC} \times CAP_G) / (P_{NETC} \times CAP_{NAT}))}{T_{CORPG}} \right) + \\
T_{CORPG} \times \left( \frac{(1/3 \times (P_{NETSKILG_N} \times SKIL_GN)}{T_{CORPG} \times ((1/3 \times (P_{NETSKILG_N} \times SKIL_GN)}) + (P_{NETSKILG} \times SKIL_{GM}) + (P_{NETSKILGS} \times SKIL_{GS}) + (P_{NETSKILGW} \times SKIL_{GW}) + \\
+ T_{CORPG} \times \left( \frac{(1/3 \times (P_{NETUNSKILG_N} \times UNSKIL_GN)}{T_{CORPG} \times ((1/3 \times (P_{NETUNSKILG_N} \times UNSKIL_GN)}) + (P_{NETUNSKILG} \times UNSKIL_{GM}) + (P_{NETUNSKILGS} \times UNSKIL_{GS}) + (P_{NETUNSKILGW} \times UNSKIL_{GW}) \\
T_{CORPG} \times \left( \frac{(1/3 \times (P_G \times G_N)}{T_{CORPG} \times ((1/3 \times (P_G \times G_N)}) + (P_G \times G_M) + (P_GS \times G_S) + (P_{GW} \times G_W) \\
\right)
\]

\[ T_{\text{CORPVN}} \times \left( \left( \frac{1}{3} \times \left( P_{\text{NETCAP}} \times \text{CAP}_{\text{VN}} \right) \right) / \left( P_{\text{NETCAP}} \times \text{CAP}_{\text{NAT}} \right) \right) + \]

\[ T_{\text{CORPVN}} \times \left( \left( \frac{1}{3} \times \left( P_{\text{NETSKILVN}} \times \text{SKIL}_{\text{VN}} \right) \right) \right) \]

\[
\frac{(P_{\text{NETSKILVN}} \times \text{SKIL}_{\text{VN}}) + (P_{\text{NETSKILVM}} \times \text{SKIL}_{\text{VM}}) + (P_{\text{NETSKILVS}} \times \text{SKIL}_{\text{VS}}) + (P_{\text{NETSKILVW}} \times \text{SKIL}_{\text{VW}})}{\text{ }}
\]

\[ T_{\text{CORPRN}} \times \left( \left( \frac{1}{3} \times \left( P_{\text{NETCAP}} \times \text{CAP}_{\text{RN}} \right) \right) / \left( P_{\text{NETCAP}} \times \text{CAP}_{\text{NAT}} \right) \right) + \]

\[ T_{\text{CORPRN}} \times \left( \left( \frac{1}{3} \times \left( P_{\text{NETSKILRN}} \times \text{SKIL}_{\text{RN}} \right) \right) \right) \]

\[
\frac{(P_{\text{NETSKILRN}} \times \text{SKIL}_{\text{RN}}) + (P_{\text{NETSKILRM}} \times \text{SKIL}_{\text{RM}}) + (P_{\text{NETSKILRS}} \times \text{SKIL}_{\text{RS}}) + (P_{\text{NETSKILRW}} \times \text{SKIL}_{\text{RW}})}{\text{ }}
\]

\[ T_{\text{CORPRN}} \times \left( \left( \frac{1}{3} \times \left( P_{\text{NETUNSKILRN}} \times \text{UNSKIL}_{\text{RN}} \right) \right) \right) \]

\[
\frac{(P_{\text{NETUNSKILRN}} \times \text{UNSKIL}_{\text{RN}}) + (P_{\text{NETUNSKILRM}} \times \text{UNSKIL}_{\text{RM}}) + (P_{\text{NETUNSKILRS}} \times \text{UNSKIL}_{\text{RS}}) + (P_{\text{NETUNSKILRW}} \times \text{UNSKIL}_{\text{RW}})}{\text{ }}
\]

\[ + \]
\[ T_{\text{CORPRN}} \times \frac{\left( (1/3 \times (P_{\text{RN}} \times R_{\text{N}}) \right)}{\left( (P_{\text{RN}} \times R_{\text{N}}) + (P_{\text{RM}} \times R_{\text{M}}) + (P_{\text{RS}} \times R_{\text{S}}) + (P_{\text{RW}} \times R_{\text{W}}) \right)} +

T_{\text{CORPFN}} \times \frac{\left( (1/3 \times (P_{\text{NETCAP}} \times CAP_{\text{FN}}) \right)}{\left( (P_{\text{NETSKILFN}} \times SKIL_{\text{FN}}) + (P_{\text{NETSKILFN}} \times SKIL_{\text{FS}}) + (P_{\text{NETSKILFW}} \times SKIL_{\text{FW}}) \right)} +

T_{\text{CORPFN}} \times \frac{\left( (1/3 \times (P_{\text{NETUNSKILFN}} \times UNSKIL_{\text{FN}}) \right)}{\left( (P_{\text{NETUNSKILFN}} \times UNSKIL_{\text{FN}}) + (P_{\text{NETUNSKILFM}} \times UNSKIL_{\text{FM}}) + (P_{\text{NETUNSKILFS}} \times UNSKIL_{\text{FS}}) + (P_{\text{NETUNSKILFW}} \times UNSKIL_{\text{FW}}) \right)} +

T_{\text{CORPFN}} \times \frac{\left( (1/3 \times (P_{\text{FN}} \times F_{\text{N}}) \right)}{\left( (P_{\text{FN}} \times F_{\text{N}}) + (P_{\text{FM}} \times F_{\text{M}}) + (P_{\text{FS}} \times F_{\text{S}}) + (P_{\text{FW}} \times F_{\text{W}}) \right)}

\]

where

RICH\text{TRANN} = transfer payment to each Rich household
POOR\text{TRANN} = transfer payment to each Poor household
P_{\text{RN}} = average cost of producing the regional public good
T_{\text{CAPGN}} = Business tax rate on capital in Goods sector
P_{\text{NETCAP}} = Net of business tax per unit cost of capital
T_{\text{SKILGN}} = Business tax rate on skilled labor in Goods sect.
P_{\text{NETSKILN}} = Net per unit cost of skilled labor in region
\[ T_{UNSKILGN} = \text{Business tax rate on unskilled labor in Goods} \]
\[ P_{NETUNSKILN} = \text{Net per unit cost of unskilled labor in region} \]
\[ T_{CAPVN} = \text{Business tax rate on capital in Services sector} \]
\[ T_{SKILVN} = \text{Business tax rate on skilled labor in Services} \]
\[ T_{UNSKILVN} = \text{Business tax rate on unskilled labor in Services} \]
\[ T_{RICHCAPN} = \text{Tax rate on Rich household capital income} \]
\[ P_{HCAPN} = \text{Net price of capital received by the household} \]
\[ R_{ICHCAPN} = \text{Total capital owned by Rich in the region} \]
\[ T_{POORCAPN} = \text{Tax rate on Poor household capital income} \]
\[ POOR_{CAPN} = \text{Total capital owned by Poor in the region} \]
\[ T_{RICHSKILN} = \text{Household tax rate on skilled labor} \]
\[ P_{RICHSKILN} = \text{Skilled labor wage net of household taxes} \]
\[ R_{ICHSKILN} = \text{Total skilled labor in the region} \]
\[ T_{POORUNSKILN} = \text{Household tax rate on unskilled labor} \]
\[ P_{POORUNSKILN} = \text{Unskilled labor wage net of household taxes} \]
\[ POOR_{UNSKILN} = \text{Total unskilled labor in the region} \]
\[ T_{GOODN} = \text{Ad valorem tax on Goods} \]
\[ T_{VYN} = \text{Ad valorem tax rate on Services} \]
\[ T_{CORPYN} = \text{Corporate tax rate on Goods} \]
\[ T_{CORPVN} = \text{Corporate tax rate on Services} \]
\[ T_{CORPRN} = \text{Corporate tax rate on Regional Public Goods} \]
\[ T_{CORPFN} = \text{Corporate tax rate on Federal Public Goods} \]
\[ CAP_{NAT} = \text{National stock of capital} \]

(& other variables are defined similarly to those above. See appendix )

Regional government budget balance in the South, Texas, and West are similarly
expressed.

Federal government budget balance is as follows:

\[
RICH \times RICHTRANF + POOR \times POORTRANF + F_N \times P_{FN} + F_S \times P_{FS} + F_M \times P_{FM} + F_W \times P_{FW} = \\
T_{CAPGF} \times P_{NETCAP} \times (CAP_{GN} + CAP_{GS} + CAP_{GM} + CAP_{GW}) + \\
T_{CAPVF} \times P_{NETCAP} \times (CAP_{VN} + CAP_{VS} + CAP_{VM} + CAP_{VW}) + \\
T_{UNSKILGF} \times [(P_{NETUNSKILN} \times UNSKIL_{GN})+ \\
(P_{NETUNSKILS} \times UNSKIL_{GS})+ \\
(P_{NETUNSKILM} \times UNSKIL_{GM})+ \\
(P_{NETUNSKILW} \times UNSKIL_{GW})]+ \\
T_{UNSKILVF} \times [(P_{NETUNSKILN} \times UNSKIL_{VN})+ \\
(P_{NETUNSKILS} \times UNSKIL_{VS})+ \\
(P_{NETUNSKILM} \times UNSKIL_{VM})+ \\
(P_{NETUNSKILW} \times UNSKIL_{VW})]+ \\
T_{SKILGF} \times [(P_{NETSKILN} \times SKIL_{GN})+(P_{NETSKILS} \times SKIL_{GS})+ \\
(P_{NETSKILM} \times SKIL_{GM})+(P_{NETSKILW} \times SKIL_{GW})]+ \\
T_{SKILVF} \times [(P_{NETSKILN} \times SKIL_{VN})+(P_{NETSKILS} \times SKIL_{VS})+ \\
(P_{NETSKILM} \times SKIL_{VM})+(P_{NETSKILW} \times SKIL_{VW})]+ \\
T_{CORPF} \times [P_{NETCAP} \times (CAP_{GN} + CAP_{GS} + CAP_{GM} + CAP_{GW}) + \\
P_{NETCAP} \times (CAP_{VN} + CAP_{VS} + CAP_{VM} + CAP_{VW}) + \\
(P_{NETUNSKILN} \times UNSKIL_{GN})+ \\
(P_{NETUNSKILS} \times UNSKIL_{GS})+ \\
(P_{NETUNSKILM} \times UNSKIL_{GM})+ \\
(P_{NETUNSKILW} \times UNSKIL_{GW})]+
\[
\begin{align*}
((\text{PNETUNSKILN} \times \text{UNSKILVN}) + \\
(\text{PNETUNSKILS} \times \text{UNSKILVS}) + \\
(\text{PNETUNSKILM} \times \text{UNSKILVM}) + \\
(\text{PNETUNSKILW} \times \text{UNSKILVW})) + \\
((\text{NETSKILN} \times \text{SKILGN}) + (\text{NETSKILS} \times \text{SKILGS}) + \\
(\text{NETSKILM} \times \text{SKILGM}) + (\text{NETSKILW} \times \text{SKILGW})) + \\
((\text{NETSKILN} \times \text{SKILVN}) + (\text{NETSKILS} \times \text{SKILVS}) + \\
(\text{NETSKILM} \times \text{SKILVM}) + (\text{NETSKILW} \times \text{SKILVW})) + \\
\text{T\text{RICHCAPF}} \times [(\text{PRICHCAPN} \times \text{RICHCAPN}) + (\text{PRICHCAPS} \times \text{RICHCAPS}) + \\
(\text{PRICHCAPM} \times \text{RICHCAPM}) + (\text{PRICHCAPW} \times \text{RICHCAPW})] + \\
\text{T\text{POORCAPF}} \times [(\text{POORCAPN} \times \text{POORCAPN}) + (\text{POORCAPS} \times \text{POORCAPS}) + \\
(\text{POORCAPM} \times \text{POORCAPM}) + (\text{POORCAPW} \times \text{POORCAPW})] + \\
\text{T\text{RICHSKILF}} \times [(\text{PRICHSKILN} \times \text{RICHSKILN}) + (\text{PRICHSKILS} \times \text{RICHSKILS}) + \\
(\text{PRICHSKILM} \times \text{RICHSKILM}) + (\text{PRICHSKILW} \times \text{RICHSKILW})] + \\
\text{T\text{POORUNSKILF}} \times [(\text{POORUNSKILN} \times \text{POORUNSKILN}) + \\
(\text{POORUNSKILS} \times \text{POORUNSKILS}) + \\
(\text{POORUNSKILM} \times \text{POORUNSKILM}) + \\
(\text{POORUNSKILW} \times \text{POORUNSKILW})] \\
\end{align*}
\]

where

\text{RICH} = \text{National Rich population} \\
\text{RICH\_TRANF} = \text{Federal transfer payment per Rich household} \\
\text{POOR} = \text{National Poor population} \\
\text{POOR\_TRANF} = \text{Federal transfer payment per Poor household} \\
\text{FN} = \text{Amount of Federal public good produced in Northeast/Midwest} \\
\text{FS} = \text{Amount of Federal public good produced in South}
$F_M =$ Amount of Federal public good produced in Texas
$F_W =$ Amount of Federal public good produced in West
$P_{FN} =$ Avg. cost of the Fed. public good in the Northeast/Midwest
$P_{FS} =$ Avg. cost of the Fed. public good in the South
$P_{FM} =$ Avg. cost of the Fed. public good in the Texas
$P_{FW} =$ Avg. cost of the Fed. public good in the West
$T_{CAPGF} =$ Federal tax on capital in Goods sector
$T_{CAPVF} =$ Federal tax on capital in Services sector
$T_{UNSKILGF} =$ Fed. tax on unskilled labor, Goods sector
$T_{UNSKILVF} =$ Fed. tax on unskilled labor, Services sector
$T_{SKILGF} =$ Fed. tax on skilled labor, Goods sector
$T_{SKILVF} =$ Fed. tax on skilled labor, Services sector
$T_{RICHCAPF} =$ Federal tax on Rich households' capital
$T_{POORCAPF} =$ Federal tax on Poor households' capital
$T_{RICHSKILF} =$ Federal tax on Rich Households' labor
$T_{POORUNSKILF} =$ Federal tax on Poor Households' labor
$T_{CORPF} =$ Federal corporation income tax rate

5. (This is an equilibrium condition only when Rich households are assumed to be inter-regionally mobile)

Rich Utilities are equalized among regions. This equilibrium condition was discussed previously in this chapter, in the section concerning household utility.

My model has now been completely mathematically specified. In this form, combined with some real-world U.S. economic data, it can be incorporated into my
computer solution algorithm. The next chapter displays the data necessary to achieve this incorporation.
6. Data and Estimation

This chapter presents the data from the 1988 United States which is used to make operational the mathematical model presented in chapter 5. To achieve that purpose specific information is needed to characterize production, household, and government activities within the economy. This information is used to calibrate the general mathematical forms of production and utility functions into specific numerical forms, and is also used to estimate prices, tax rates, and government expenditures. In this fashion, the operational CGE model will be prepared to undergo computer simulations which will give precise numerical estimates of tax incidence.

This chapter is organized as follows: First, a few definitions will be given characterizing the makeup of regions, production sectors, and households. Second, real world data will be used to generate information characterizing production processes (including: factor payments to skilled labor, unskilled labor, and capital, for each product produced in each region; and business taxes paid on skilled labor income, unskilled labor income, and capital income); household behavior (including: labor and capital endowments of Rich households and Poor households in each region; household taxes paid on factor endowments and product purchases in each region; government transfer payments received by Rich and Poor households in each region; and consumption of traded and non-traded goods by households in each region); and government activities (including: tax revenue received, and the composition of government expenditures, in each region, by the regional and federal government). This information will be used in chapter 7 to derive specific production functions and utility functions, and to determine other important variables; equivalently, sufficient information will be gathered in this chapter to provide specific numerical estimates for all of the variables listed in appendix C.

Often the requisite information for model calibration is not available from any raw data source (known to me); in these instances, this information will be estimated from
other data sources. Similarly, the restrictive nature of my model--e.g. combining thousands of sub-national governments into 4, combining thousands of products into four, and combining scores of tax types into several--requires that certain real-world data be 'massaged' to fit the model. Therefore, throughout this chapter, as production, household, and government information is gathered, I shall, for each piece of information, indicate: the information needed, the raw data used to get the needed information, and the process by which the needed information is extracted from the raw data.

Definitions

Regions:

The Northeast-Midwest region (or "Nor-Mid") comprises Maine, Vermont, Massachusetts, New Hampshire, Rhode Island, New York, New Jersey, Pennsylvania, North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana, and Ohio.

The South comprises Oklahoma, Arkansas, Louisiana, Kentucky, Tennessee, Mississippi, Alabama, Maryland, Delaware, the District of Columbia, West Virginia, Virginia, North Carolina, South Carolina, Georgia, and Florida.

The Texas region is the state of Texas.


Products:

Services parallel the U.S. Department of Commerce Bureau of Economic Analysis Standard Industrial Classification of Services industries.
Goods include the B.E.A. S.I.C. industries of: Farms, forestry and fisheries; Mining; Construction; Manufacturing; Transportation and public utilities; Wholesale and retail trade; and Finance, insurance, and real estate.

Regional Public Goods include goods and services provided directly by state and local governments.

Federal Public Goods include goods and services provided directly by the Federal government.

Skilled Labor is all labor except production labor, as defined by the U.S. Department of Labor.

Unskilled Labor is "production" labor, as defined by the U.S. Department of Labor.

Production Information

1. Needed: Value of the output of each product produced in each region.

Raw Data Used:

(a) Gross state product, classified by S.I.C. industry.


(b) State and local government expenditures on public welfare, unemployment compensation, and public employee retirement.


(c) State and local governments' total expenditures.

Source: Same as (b) above.

(d) State and local tax receipts from corporation income, personal income, property, and sales taxes.

Source: Same as (b) above.
(e) Federal government expenditures on social security, Medicare, income security, public
employee retirement and disability, and veterans retirement and disability.

(f) Federal government's total expenditures, minus net interest payments.
Source: Same as (e) above.

(g) Federal government's receipts from individual income taxes, corporation income taxes,
and social insurance taxes.
Source: Same as (f) above.

Estimation process:
Goods output for each region equals:
Sum of gross state products of S.I.C. Goods industries of states within each
region. (Information obtained directly from (a) above.)

Services output for each region equals:
Gross state products of the services S.I.C in states within each region.
(Information obtained directly from (a) above.)

Regional Public Goods output estimation procedure:
The equilibrium requirement in my CGE model that each regional government's
budget be balanced precludes the direct use of BEA gross state product figures for
Regional Public Goods, because in 1988 U.S. reality most sub-national government's
budgets were not balanced and because there are no intergovernmental transfer payments
allowed in my model. Instead, I shall estimate the percentage of the total tax receipts of
the sub-national governments within each region that are spent on transfer payments; the
remaining percentage of tax receipts will be the estimates for Regional Public Goods output in each region.

The estimate for the percentage of each regional government’s tax receipts spent on transfer payments is: \( (b) / (c) \) for sub-national governments in each region. Here are the numerical estimates for each region:

<table>
<thead>
<tr>
<th>Region</th>
<th>Revenue (m)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-Mid</td>
<td>48,452 / 333,231</td>
<td>= 0.14567</td>
</tr>
<tr>
<td>Texas</td>
<td>3,558 / 41,402</td>
<td>= 0.08594</td>
</tr>
<tr>
<td>South</td>
<td>16,165 / 167,949</td>
<td>= 0.09625</td>
</tr>
<tr>
<td>West</td>
<td>18,205 / 159,659</td>
<td>= 0.11402</td>
</tr>
</tbody>
</table>

Furthermore, for simplicity my CGE model does not incorporate every single revenue source of sub-national governments, but rather it uses only the revenue sources in (d) above plus revenue from unemployment compensation payroll taxes.\(^1\) It is the revenue from these sources only that I allocate between Regional Public Good output and regional transfer payments. Thus the estimate for a regional government’s spending on transfer payments is:

\[
\text{Percentage of regional government’s tax receipts spent on transfer payments} \\
\times \\
(d)
\]

Here are the estimates for each region: ($millions)

<table>
<thead>
<tr>
<th>Region</th>
<th>Estimate (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-Mid</td>
<td>0.14567 x 205,231 = 29,909</td>
</tr>
<tr>
<td>Texas</td>
<td>0.08594 x 13,974 = 1,201</td>
</tr>
<tr>
<td>South</td>
<td>0.09625 x 97,307 = 9,366</td>
</tr>
<tr>
<td>West</td>
<td>0.11402 x 92,205 = 10,513</td>
</tr>
</tbody>
</table>

Finally, Regional Public Goods output is estimated as:

---

\(^1\) I have arbitrarily assumed that government revenue from unemployment payroll taxes equals government expenditures on unemployment compensation. The data on unemployment expenditures is from (b) above.
(d) - regional government's transfer payment spending

Numerical estimates for Regional Public Goods output for each region are shown on a later page of this chapter.

Federal Public Goods output estimate:

As with regional public goods output, I cannot use direct BEA numbers here because of my CGE model's requirement that the Federal government's budget is balanced. Instead, I shall estimate the percentage of Federal government total expenditures that were spent on transfer payments, and allocate the remaining percentage to government purchases.

The estimate of the percent of Federal government expenditures spent on transfer payments is: \((e) \div (f) = \frac{490,000}{912,000} = .53728\)

Thus 1-.53728, or .46272 percent of Federal government expenditures are spent on Federal public goods.

In my model total Federal government expenditures are equal to Federal tax receipts from social insurance taxes, individual income taxes, and corporation income taxes--a total of 694.2 billion dollars. Therefore my national estimate for Federal public goods provision is: \(694,200 \times .46272 = 321,220\)

This amount must now be allocated among the four regions. To do this I estimate the percentage of total Federal contributions to gross national product allocated to states within each region by the BEA in (a) above. The estimate is:

Federal Government Contribution to Gross State Product in States Within Each Region

\[
\begin{align*}
\text{Total Federal Government Contribution to Gross National Product} & \end{align*}
\]
For each region, the estimates are:

- **Nor-Mid**: \(50,214 \div 184,233 = 0.27242\)
- **Texas**: \(8,415 \div 184,233 = 0.04565\)
- **South**: \(85,412 \div 184,233 = 0.46338\)
- **West**: \(40,192 \div 184,233 = 0.21886\)

The Numbers:

### #1: Value of Output of Each Product, by Region ($millions)

#### Nor-Mid
- **Goods** = 1,371,235
- **Services** = 332,642
- **Regional Public Good** = 175,323
- **Federal Public Good** = 87,999

#### Texas
- **Goods** = 214,105
- **Services** = 44,649
- **Regional Public Good** = 18,773
- **Federal Public Good** = 24,664

#### South
- **Goods** = 716,787
- **Services** = 158,300
- **Regional Public Good** = 82,024
- **Federal Public Good** = 138,257

#### West
- **Goods** = 604,324
- **Services** = 164,596
- **Regional Public Good** = 81,692
- **Federal Public Good** = 70,301.5

### #2. Needed: Value of output in each production sector in each region, net of regional sales taxes.

**Raw Data Used:**

(a) Estimates of gross value of output in each production sector in each region, taken from #1 above
(b) State and local sales tax collections.

Source same as (b) from #1 above.

Estimation Process:

Due to limitations of my CGE model, I assume that sales taxes are origin-based and collected from producers; this assumption is not realistic for the traded "Goods" output in each region, although for the non-traded "Services" output the assumption is sound. I further assume that Regional Public Goods and Federal Public Goods are untaxed, and that "Goods" and "Services" are taxed at the same rate. In each region these products are assumed taxed at the rate:

Sales tax collections of state and local governments within the region (from (b))

<table>
<thead>
<tr>
<th>Region</th>
<th>Value of goods output in the Region</th>
<th>Value of services output in the region (from #1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-Mid:</td>
<td>.0386812</td>
<td></td>
</tr>
<tr>
<td>Texas</td>
<td>.0491046</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>.0456023</td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>.0442842</td>
<td></td>
</tr>
</tbody>
</table>

For each region the estimates are: ($millions)

In each region, the total dollar amount of sales tax collections in the region are assigned to Goods and Services by multiplying these percentages by the value of output of Goods and Services. The estimates are:

<table>
<thead>
<tr>
<th>Region</th>
<th>Goods Sales Taxes</th>
<th>Services Sales Taxes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-Mid:</td>
<td>53,097</td>
<td>12,808</td>
</tr>
<tr>
<td>Texas</td>
<td>10,514</td>
<td>2,192</td>
</tr>
<tr>
<td>South</td>
<td>32,687</td>
<td>7,219</td>
</tr>
<tr>
<td>West</td>
<td>26,762</td>
<td>7,289</td>
</tr>
</tbody>
</table>
These estimates are now subtracted from the value of Goods and Services output in each region displayed in #1 above; the result are estimates for the value of output net of sales taxes. The numbers:

#2: Value of the Output of Each Product Net of Sales Tax Collections

**Nor-Mid**
- Goods = 1318138
- Services = 319834
- Regional Public Good = 175323
- Federal Public Good = 87999

**Texas**
- Goods = 203591
- Services = 42457
- Regional Public Good = 18773
- Federal Public Good = 24664

**South**
- Goods = 684105
- Services = 151075
- Regional Public Good = 82024
- Federal Public Good = 138257

**West**
- Goods = 577,562
- Services = 157,307
- Regional Public Good = 81,692
- Federal Public Good = 70,302

#3. Needed: Value of output of each product in each region, net of sales taxes, Regional government corporation income taxes, and Federal government corporation income taxes.

*Raw Data Used:*

(a) Estimate of the value of output of each product in each region net of sales taxes.

Source: Estimated in #2 above.

(b) State and local corporation income tax receipts.

Source: Same as #1 (b) above.
(c) Federal corporation income tax receipts.

    Source: Same as #1 (f) above.

    Estimation Process: First I shall estimate the dollar amount of state and local corporation income taxes paid by each production sector in each region. Next I shall estimate the dollar amount of federal corporation income taxes paid by each production sector in each region. Finally I shall subtract these two estimates from (a) above to get my estimate for # 3.

    Estimating Regional Government Corporation income taxes paid by each production sector in each Region:

    (Digression): As you may recall from chapter 2, Arnold Harberger (1962) modeled the corporation income tax as a tax on the capital costs of firms; initially, I was prepared to do the same. Most U.S. sub-national governments which levy corporation income taxes, however, levy them with the following statutory assessment:

    \[
    T \cdot P \cdot \left( \frac{S_F}{S} + \frac{W_F}{W} + \frac{I_F}{I} \right) / 3
    \]

    where T is the corporation income tax rate, P is the accounting profits of the corporation, S_F is the corporation's sales within the geographic boundaries of the taxing fisc, S is the corporation's national sales, W_F is the corporation's wage costs for workers employed in the sub-national region, W is the corporation's national wage bill, I_F is the corporation's capital bill in the region, and I is the corporation's national capital payments bill.

    The economic incidence of this tax, T, is unclear and contentious. I therefore will refrain from including it solely as an increased capital cost to producers; instead I will model it as a separate cost of production. (See chapter 7). This step allows my model to be more "impartial" when examining the economic incidence of this tax. (End of digression.)
Summing the state and local corporation income tax receipts of sub-national governments within each region, the numbers for total Regional Government corporation income tax receipts are:

Nor-Mid: 13,003  Texas: 0
South: 3,971  West: 5,673

Each region's tax receipts must now be allocated to each of the four production sectors. Data (of which I am aware) that might help with this allocation are poor. I therefore make the following very brave assumptions:

1. Within each region the Goods and Services sectors pay the same proportion of their net of sales tax output to the Regional Government as corporation income taxes (in the benchmark year).

2. The "Regional Public Good" and "Federal Public Good" sectors within each region each pay a proportion of their (net) output as Regional corporation income taxes which is 25% as large as the Goods and Services sectors.²

<table>
<thead>
<tr>
<th>Regionally-Levied Corporation Income Tax Payments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nor-Mid</strong></td>
</tr>
<tr>
<td>Goods                                        = 9,987</td>
</tr>
<tr>
<td>Services                                     = 2,510</td>
</tr>
<tr>
<td>Regional Public Good                         = 338</td>
</tr>
<tr>
<td>Federal Public Good                          = 168</td>
</tr>
<tr>
<td><strong>Texas</strong></td>
</tr>
<tr>
<td>Goods                                        = 0</td>
</tr>
<tr>
<td>Services                                     = 0</td>
</tr>
<tr>
<td>Regional Public Good                         = 0</td>
</tr>
<tr>
<td>Federal Public Good                          = 0</td>
</tr>
</tbody>
</table>

² The casual observer might believe that governments do not pay corporation taxes to themselves. Since, however, governments often pay private firms to provide public goods, this portion of government goods provision would be subject to tax. The 25% portion (compared to 100% for private goods) that I assign to each of the Regional and Federal production sectors attempts to address this fact.
**South**
- Goods = 3,073
- Services = 670
- Regional Public Good = 87
- Federal Public Good = 141

**West**
- Goods = 4,239
- Services = 1,155
- Regional Public Good = 150
- Federal Public Good = 129

*Estimating Federal corporation income taxes paid by each production sector in each region:* I assume that each Goods and Services sector pays the same portion of its (net of sales tax) output in Federal corporation income taxes, regardless of the region in which it is located. I further assume that the Regional Public Good and Federal Public Good sectors pay a portion of their output 25% the size of the Goods and Services portion (in the benchmark period). Total Federal corporation income tax receipts of 61,300 million are divided among the production sectors adhering to these assumptions.

**Federally-Levied Corporation Income Tax Payments**

**Nor-Mid**
- Goods = 22296
- Services = 5412
- Regional Public Good = 742
- Federal Public Good = 372

**Texas**
- Goods = 3003
- Services = 688
- Regional Public Good = 77
- Federal Public Good = 72

**South**
- Goods = 12013
- Services = 2586
- Regional Public Good = 349
- Federal Public Good = 617
West
Goods = 9,770
Services = 2,661
Regional Public Good = 345
Federal Public Good = 297

Now I shall subtract Regionally-levied and Federally-levied corporation income taxes from the value of output of each product net of sales tax collections.

The Numbers:

#3: Value of Production Net of Sales and Corporation Income Taxes

Nor-Mid
Goods = 1,285,855
Services = 311,912
Regional Public Good 106,321 - 16,321 = 174,243
Federal Public Good 321,220 x .13533 = 87,459

Texas
Goods = 200,588
Services = 41,769
Regional Public Good 98,910 -13,587 = 18,696
Federal Public Good 321,220 x .13862 = 24,591

South
Goods = 669,020
Services = 147,819
Regional Public Good 111,281 - 10,484 = 81,588
Federal Public Good 321,220 x .50719 = 137,499

West
Goods = 577,562
Services = 157,307
Regional Public Good 92,205 - 10,513 = 81,692
Federal Public Good 321,220 x .21886 = 70,302

#4. Needed: Factor payments to labor, net of business taxes on labor, classified by region and product sector.

Raw Data Used:
(a) Total annual wages, classified by state and industry.
   (Includes only workers covered by unemployment compensation, i.e. not
   proprietors, soldiers, elected officials, etc.)

(b) State and local government employment and average
   earnings, classified by state.

(c) Federal expenditures on salaries and wages, classified by region.
   Source: Same as (b) above.

(d) Sum of Federal tax receipts from individual income taxes, corporation income taxes,
   and social insurance taxes.
   Source: U.S. Office of Management and Budget, Budget of the United States

(e) Total Federal Expenditures in 1988.
   Source: Same as (d) above.

(f) Sum of state and local governments' receipts from individual income taxes, property
   taxes, corporation income taxes, and sales taxes, plus unemployment benefits
   paid.

(g) State and local government's total government expenditures.
   Source: Same as above.

Estimation Process:

Labor payments by Goods sector, net of business tax, equal:

   Sum of wages paid in S.I.C. "goods" industries
Service sector net of business tax payments to labor equal:

Sum of wages paid in S.I.C. services industry.

Regional government net of business tax payments to labor estimate:

Here again, due to my artificially balanced regional government budgets (in which actual regional government expenditures have been reduced to equal regional government tax receipts), it is ill advised to use direct wage and salary numbers; instead, they need to be reduced by the same percentage that regional government expenditures have been reduced. In each region, labor payments by regional governments will be reduced to a percentage of actual labor payments. The reduced percentage is

\[
\frac{(f)}{(g)} \quad \text{for sub-national governments in each region.}
\]

The reduced percentages are:

<table>
<thead>
<tr>
<th>Region</th>
<th>Actual Expenditures</th>
<th>Reduced Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-Mid:</td>
<td>106,321 / 143,578</td>
<td>.72351</td>
</tr>
<tr>
<td>Texas:</td>
<td>98,910 / 143,744</td>
<td>.63710</td>
</tr>
<tr>
<td>South:</td>
<td>111,281 / 179,685</td>
<td>.59931</td>
</tr>
<tr>
<td>West:</td>
<td>92,205 / 136,676</td>
<td>.67462</td>
</tr>
</tbody>
</table>

Thus my estimated regional government payments to labor for each region will be the actual payments to labor multiplied by the percentages above, i.e.

\[
\text{[Regional government wages and salaries] } \times \left[ \frac{(f)}{(g)} \right]
\]

Federal government net of business tax payments to labor estimate:

Once again, actual Federal government payments to labor should be reduced by the same percentage that my balanced-budget Federal government expenditures have been reduced. For all regions, the reduced percentage will be:

\[
\frac{(f)}{(g)}
\]

\[3\] Unfortunately this reduction in labor payments will also reduce a household's labor endowment. This circumstance is unavoidable in my model.
(d) / (e) = \frac{694,200}{990,300} = .70100

Thus my estimated Federal government payments to labor in each region will be:

\[ \text{Federal payments to labor in the region} \times .70100 \]

The Numbers:

### Factor Payments to Labor Net of Business Taxes

#### Nor-Mid
- Goods = 612546
- Services = 175937
- Regional Public Good = 65,166 x .74051 = 95139
- Federal Public Good = 17,609 x .701 = 25820

#### Texas
- Goods = 77111
- Services = 20217
- Regional Public Good = 68,134 x .68810 = 9594
- Federal Public Good = 19,224 x .701 = 6916

#### South
- Goods = 312385
- Services = 86189
- Regional Public Good = 86,061 x .61931 = 43704
- Federal Public Good = 58,381 x .701 = 34009

#### West
- Goods = 257,092
- Services = 85,843
- Regional Public Good = 66,380 x .67462 = 44,781
- Federal Public Good = 30,679 x .701 = 21,506

#5. **Needed**: Division of net factor payments to labor (i.e. #4 above) into Skilled Labor and Unskilled Labor.

**Raw Data Used:**

(a) Raw data used to determine #4 above
(b) National average weekly hours, classified by S.I.C. industry.


(c) National number of production workers, classified by

    S.I.C. industry.

    Source: Same as (a) above.

(d) National average hourly earnings, classified by S.I.C. industry.

    Source: Same as (a) above.

*Estimation Procedure:*

First the percent of total labor earnings received by production workers in each production sector will be determined for the nation. These national percentages will be assumed to hold in each region of the nation.

For the Goods sector, the percent of labor payments received by production workers is: \(^4\)

Labor payments to production workers in "Goods" S.I.C.s

\[
\frac{\text{Total labor payments in "Goods" S.I.C.s}}{807,960 / 1,245,112} = .64891
\]

Thus approximately 65% of net labor payments will be allocated to production (Unskilled) workers in the Goods sector in each region. The remaining 35% will be allocated to non-production (Skilled) workers.

For the Services sector, the percentage is:

---

\(^4\) Since labor payments to production workers in the "Farms, Forestry, and Fisheries" S.I.C. are unavailable, I am ignoring that sector here.
Labor payments to production workers in "Services" S.I.C.

Total labor payments in "Services" S.I.C.

\[
\frac{278,456}{368,186} = 0.75629
\]

Thus roughly 76% of net labor payments will be allocated to production (Unskilled) workers in the Services sector in each region. The remaining 24% will be allocated to non-production (Skilled) workers.

There is insufficient data to directly calculate this percentage for Regional or Federal governments. Therefore, I am arbitrarily estimating the percentage as a weighted average of the Goods and Services percentages above. The estimate is:

\[
\frac{(807,960 + 278,456)}{(1,245,112 + 368,186)} = 0.67341
\]

Thus for each Regional and Federal production sector in each region, about 67% of net labor payments will be assigned to production workers, and 33% to non-production workers.

The Numbers: ($millions)

<table>
<thead>
<tr>
<th></th>
<th>unskilled</th>
<th>skilled</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nor-Mid</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goods</td>
<td>397487</td>
<td>215059</td>
</tr>
<tr>
<td>Services</td>
<td>133059</td>
<td>42878</td>
</tr>
<tr>
<td>Regional Public Good</td>
<td>64067</td>
<td>31072</td>
</tr>
<tr>
<td>Federal Public Good</td>
<td>17388</td>
<td>8432</td>
</tr>
<tr>
<td><strong>Texas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goods</td>
<td>50038</td>
<td>27073</td>
</tr>
<tr>
<td>Services</td>
<td>15290</td>
<td>4927</td>
</tr>
<tr>
<td>Regional Public Good</td>
<td>6461</td>
<td>3133</td>
</tr>
<tr>
<td>Federal Public Good</td>
<td>4657</td>
<td>2259</td>
</tr>
<tr>
<td>Region</td>
<td>Goods</td>
<td>Services</td>
</tr>
<tr>
<td>-------</td>
<td>---------</td>
<td>-----------</td>
</tr>
<tr>
<td>South</td>
<td>202638</td>
<td>65184</td>
</tr>
<tr>
<td>West</td>
<td>166,830</td>
<td>64,922</td>
</tr>
</tbody>
</table>

#6. *Needed*: Regional governments' business-type taxes on skilled labor income and unskilled labor income, classified by production sector.

*Raw Data Used:*

(a) Raw data used to determine #5 above.

(b) State unemployment benefits paid, classified by state.


*Estimation Procedure:*

I assume that the unemployment insurance payroll tax is the only business-type regional tax on labor. I also assume that the unemployment benefits paid equaled the taxes collected. I further assume that each production sector pays an amount of unemployment tax proportionate to its payments to labor. Finally I assume that the payroll tax is invariant to the type of labor--skilled or unskilled--being employed. None of these assumptions is entirely accurate.

The estimate of the business tax rate on labor income for each region is:

\[
\text{Sum of unemployment benefits paid, each state in region} \quad \frac{\text{Sum of total labor payments in region, net of business taxes}}{\text{}}
\]
In the Nor-Mid, this ratio is  

\[= .0077399\]

In Texas,  

\[= .0062633\]

In the South,  

\[= .0059453\]

In the West,  

\[= .0080959\]

Multiplying these tax rates by labor payments to skilled and unskilled labor in each production sector in each region gives us the estimates for Regional governments' business-type taxes on labor.

*The Numbers: ($millions)*

<table>
<thead>
<tr>
<th></th>
<th>unskilled</th>
<th>skilled</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nor-Mid</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goods</td>
<td>3078</td>
<td>1665</td>
</tr>
<tr>
<td>Services</td>
<td>1027</td>
<td>331</td>
</tr>
<tr>
<td>Regional Public Good</td>
<td>495</td>
<td>240</td>
</tr>
<tr>
<td>Federal Public Good</td>
<td>135</td>
<td>65</td>
</tr>
<tr>
<td><strong>Texas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goods</td>
<td>313</td>
<td>170</td>
</tr>
<tr>
<td>Services</td>
<td>96</td>
<td>31</td>
</tr>
<tr>
<td>Regional Public Good</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Federal Public Good</td>
<td>29</td>
<td>14</td>
</tr>
<tr>
<td><strong>South</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goods</td>
<td>1205</td>
<td>652</td>
</tr>
<tr>
<td>Services</td>
<td>388</td>
<td>125</td>
</tr>
<tr>
<td>Regional Public Good</td>
<td>175</td>
<td>85</td>
</tr>
<tr>
<td>Federal Public Good</td>
<td>136</td>
<td>66</td>
</tr>
<tr>
<td><strong>West</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goods</td>
<td>1,351</td>
<td>731</td>
</tr>
<tr>
<td>Services</td>
<td>526</td>
<td>169</td>
</tr>
<tr>
<td>Regional Public Good</td>
<td>244</td>
<td>118</td>
</tr>
<tr>
<td>Federal Public Good</td>
<td>117</td>
<td>56.5</td>
</tr>
</tbody>
</table>
#7. *Needed:* Federal government's business-type taxes on skilled labor and unskilled labor, classified by production sector and region.

*Raw Data Used:*

(a) Raw data used to determine #3 above.

(b) Employer contributions to OASI, DI, HI, SMI, and RR.


(c) Federal, state, and local government contributions to retirement.


*Estimation Procedure:*

I assume that all production sectors in each region pay the same percentage of net labor payments in Federal taxes, regardless of the region. I also assume that they pay the same percent regardless of the type of labor--skilled or unskilled--which they hire. I further assume that the Goods and Services sectors pay the same percent of labor payments as Federal taxes.

The estimate for the percent of net labor payments paid as Federal taxes in the Goods and Services sectors is

\[
\frac{\text{Sum of national employer payments to OASI, DI, HI, SMI, and RR}}{\text{Sum of national net factor payments to labor}} = \frac{131,288}{1,908,678} = 0.0687848
\]
For the Federal Public Goods sector, the estimate is

Payments to OASI,DI,HI,SMI,RR +Federal payments to pensions

\[
\frac{(131,288 + 23,972)}{1,908,678} = 0.08125
\]

For the Regional Public Goods sector, the estimate is

Payments to OASI,DI,HI,SMI,RR+Regional payments to pensions

\[
\frac{(131,288 + 28,122)}{1,908,678} = 0.0835185
\]

Multiplying net factor payments to skilled labor and unskilled labor in each sector in each region, by these percentages, provides the estimates of Federal business-type taxes paid on skilled labor and unskilled labor.

*The Numbers:*

*#7: Federal Government's Taxes on Skilled and Unskilled Labor*

<table>
<thead>
<tr>
<th>Nor-Mid</th>
<th>Unskilled</th>
<th>Skilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goods</td>
<td>27341</td>
<td>14793</td>
</tr>
<tr>
<td>Services</td>
<td>9152</td>
<td>2950</td>
</tr>
<tr>
<td>Regional Public Good</td>
<td>5351</td>
<td>2595</td>
</tr>
<tr>
<td>Federal Public Good</td>
<td>1412</td>
<td>686</td>
</tr>
<tr>
<td>Region</td>
<td>Goods</td>
<td>Services</td>
</tr>
<tr>
<td>-------------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td><strong>Texas</strong></td>
<td>3442</td>
<td>1052</td>
</tr>
<tr>
<td><strong>South</strong></td>
<td>13938</td>
<td>4484</td>
</tr>
<tr>
<td><strong>West</strong></td>
<td>11,475</td>
<td>4,466</td>
</tr>
</tbody>
</table>

#8. Needed: Payments to skilled and unskilled labor, gross of Federal and Regional business-type taxes, classified by production sector and region.

**Raw Data Used:**

(a) Raw data used in #5, #6, and #7 above.

**Estimation Procedure:**

The estimate for each production sector in each region is,

for skilled labor

Net payments to skilled labor +

Taxes paid to regional government for skilled labor +

Taxes paid to Federal government for skilled labor

For unskilled labor, the estimate is

Net payments to unskilled labor +

Taxes paid to regional government for unskilled labor +

Taxes paid to Federal government for unskilled labor
Note that the three components of my estimate of gross payments to labor are all
estimates themselves (as shown in earlier portions of this chapter).

The Numbers:

<table>
<thead>
<tr>
<th></th>
<th>Nor-Mid</th>
<th>Texas</th>
<th>South</th>
<th>West</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unskilled</td>
<td>Skilled</td>
<td>Unskilled</td>
<td>Skilled</td>
</tr>
<tr>
<td>Goods</td>
<td>427906</td>
<td>231517</td>
<td>53793</td>
<td>29105</td>
</tr>
<tr>
<td>Services</td>
<td>143238</td>
<td>46159</td>
<td>16437</td>
<td>5297</td>
</tr>
<tr>
<td>Regional Public Good</td>
<td>66913</td>
<td>33907</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Federal Public Good</td>
<td>18935</td>
<td>9183</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goods</td>
<td>53793</td>
<td>29105</td>
<td>7041</td>
<td>3415</td>
</tr>
<tr>
<td>Services</td>
<td>16437</td>
<td>5297</td>
<td>7041</td>
<td>3415</td>
</tr>
<tr>
<td>Regional Public Good</td>
<td>7041</td>
<td>3415</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Federal Public Good</td>
<td>5065</td>
<td>2456</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goods</td>
<td>217780</td>
<td>117829</td>
<td>32064</td>
<td>15550</td>
</tr>
<tr>
<td>Services</td>
<td>70055</td>
<td>22575</td>
<td>32064</td>
<td>15550</td>
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<tr>
<td>Regional Public Good</td>
<td>24899</td>
<td>12075</td>
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<td></td>
</tr>
<tr>
<td>Federal Public Good</td>
<td>24899</td>
<td>12075</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#9. Needed: Factor payments to capital gross of business taxes, classified by region and
production sector.

Raw Data Used:

(a) Raw data used for #3 and #8 above.

Estimation procedure:
For each production sector in each region, the estimate is

- Value of output in the sector net of sales and corporation income taxes
- Estimated gross labor payments in the sector

These two components of the estimate come directly from #3 and #8 above.

**The Numbers:**

### #9: Factor Payments to Capital Gross of Business Taxes

**Nor-Mid**
- Goods = 626432
- Services = 122515
- Regional Public Good = 70423
- Federal Public Good = 59341

**Texas**
- Goods = 117690
- Services = 20035
- Regional Public Good = 8241
- Federal Public Good = 17070

**South**
- Goods = 333409
- Services = 55189
- Regional Public Good = 33974
- Federal Public Good = 100525

**West**
- Goods = 286,695
- Services = 61,048
- Regional Public Good = 32,314
- Federal Public Good = 46,448

**#10. Needed:** Business capital taxes paid to regional governments, classified by region and production sector.

**Raw Data Used**

(a) Raw data used in #9 above.
(b) State and local government property tax receipts.


(c) Gross assessed value of taxable real property parcels

and their ownership.


Estimation Procedure:

First, I assume that all taxable business capital in a region--whether used in the Goods, Services, Regional Public Good, or Federal Public Good sector--is taxed at the same rate. Next, I assume that the only Regional government business taxes on capital are business property taxes.\(^5\) Business property taxes paid in each region are estimated as equaling

\[
\text{Percent of total gross assessed value of property owned by business in the region.} \times \\
\text{Total property taxes paid in the region}
\]

The numerical estimates are:

<table>
<thead>
<tr>
<th>Region</th>
<th>Business Property Taxes Paid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-Mid</td>
<td>24311</td>
</tr>
<tr>
<td>Texas</td>
<td>2669</td>
</tr>
<tr>
<td>South</td>
<td>9460</td>
</tr>
<tr>
<td>West</td>
<td>8318</td>
</tr>
</tbody>
</table>

Finally, within each region the regional business capital taxes paid by each production sector is determined using the assumption that all taxable capital in the region is taxed at the same rate.

\(^5\) I am considering statutory incidence here. The economic incidence of the state corporation income tax will be revealed in chapters 8 and 9 by comparing the benchmark equilibrium to the counterfactual equilibrium.
The Numbers: ($millions)

<table>
<thead>
<tr>
<th>Region</th>
<th>Goods</th>
<th>Services</th>
<th>Regional Public Good</th>
<th>Federal Public Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-Mid</td>
<td>17357</td>
<td>3369</td>
<td>1943</td>
<td>1642</td>
</tr>
<tr>
<td>Texas</td>
<td>2136</td>
<td>364</td>
<td>150</td>
<td>310</td>
</tr>
<tr>
<td>South</td>
<td>5851</td>
<td>968</td>
<td>596</td>
<td>1764</td>
</tr>
<tr>
<td>West</td>
<td>5,591</td>
<td>1,191</td>
<td>630</td>
<td>906</td>
</tr>
</tbody>
</table>

#11. Needed: Factor payments to capital net of business taxes, classified by region and production sector.

Raw Data Used:

(a) Raw data used for #9 and #10 above.

Estimation Procedure:

For each production sector in each region, the estimate is^6

---

^6The statutory incidence of the Federal corporation income tax is not directly upon capital payments. However, since labor payments are not taxable under this tax, the fairly direct economic effect is to increase the cost of capital to producers. My CGE model can capture this effect.
Estimated gross factor payments to capital -
Estimated regional government business capital taxes

These two components of the estimate were calculated earlier in this chapter.

*The Numbers:*

#11: Factor Payments to Capital Net of Business Taxes

**Nor-Mid**
- Goods = 609075
- Services = 119146
- Regional Public Good = 68480
- Federal Public Good = 57699

**Texas**
- Goods = 115554
- Services = 19672
- Regional Public Good = 8091
- Federal Public Good = 16760

**South**
- Goods = 327559
- Services = 54220
- Regional Public Good = 33377
- Federal Public Good = 98761

**West**
- Goods = 281,104
- Services = 59,857
- Regional Public Good = 31,684
- Federal Public Good = 45,542

#12. *Needed:* Elasticities of substitution between: capital and the skilled/unskilled labor bundle ("LABOR" in chapter 5); and between skilled labor and unskilled labor.

*Raw Data Used:*


(b) Estimates from Ballard, Fullerton, Shoven, and Whalley (1985a).
(c) Estimates from Berndt (1976).

_Estimation Procedure:_

Many econometric estimates of the elasticity of substitution between capital and labor exist for many of the S.I.C. industries included in my Goods production sector. The estimates that I found in the literature range from .3971 to 1.1782. (None of these estimates separated labor into Skilled and Unskilled as I have). The central value from the cross-sectional econometric studies is approximately .90. I shall use this as my estimate of the elasticity of factor substitution between capital and the labor bundle in the goods sector.

Few estimates exist of the elasticity of factor substitution between capital and labor in the Services S.I.C. Mutti, Morgan, and Partridge (1988) use an estimate of 1. I shall follow their example and use the similar estimate of .99.

I could find no estimates for the elasticity of substitution between capital and labor in the government sector. Mutti, Morgan, and Partridge use an estimate of zero in their model; this is a purely fabricated estimate which is necessary to facilitate counter factual solution of their model. Ballard, Fullerton, Shoven and Whalley use an estimate of one. In my model, I believe that my aggregate government goods have production characteristics of both Goods and Services; I shall therefore set the elasticities of substitution as averages of the Goods and Services elasticities of substitution.

It is unclear whether skilled (non-production) and unskilled (production) labor are highly substitutable in production; I could find no econometric estimates for this elasticity. Therefore, I am at least initially heroically assuming that they are not highly substitutable in all production sectors. I am further assuming that the degree of substitution between

---

^7Later, in "sensitivity analysis," I shall alter this assumption.
skilled and unskilled labor is less than that between capital and labor in any given production sector.

I am also assuming that elasticities of factor substitution are the same in all regions, as there is no data (that I know of) on regional elasticity estimates. Finally, due to a lack of data I am estimating identical elasticities of substitution for the Regional Public Good sector and the Federal Public Good sector.

*The Numbers:*

<table>
<thead>
<tr>
<th></th>
<th>Capital &amp; Labor</th>
<th>Skilled labor &amp; Unskilled labor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goods</td>
<td>.90</td>
<td>.70</td>
</tr>
<tr>
<td>Services</td>
<td>.99</td>
<td>.80</td>
</tr>
<tr>
<td>Public Good</td>
<td>.95</td>
<td>.75</td>
</tr>
</tbody>
</table>

*Household Information*

#13. *Needed:* Unskilled labor endowment per Poor household, and skilled labor endowment per Rich household.

*Raw Data Used:*

(a) Raw data used in #5 above.

(b) National population of production workers.


(c) National population of workers.

Source: Same as (b) above.

*Estimation Process:*

The estimate of unskilled labor per Poor household is:
National payments to unskilled labor net of bus. taxes

-----------------------------------------------

National total population of production workers

The denominator is an estimate from #5 above.

The estimate for skilled labor per Rich household is:

National payments to skilled labor net of business taxes

-----------------------------------------------

National number of workers - National # of prod. workers

Once again, the denominator is from #5 above. Units of labor are defined so that 1 unit of labor receives $1 of gross (of household taxes) payment in the benchmark period.

*The Numbers:*

**#13: Labor Endowment Per Rich and Poor Household**

Unskilled \[\frac{1,284,361,000,000}{90,242,000} = 14,232.408\]

Skilled \[\frac{623,687,000,000}{21,381,000} = 29,170.151\]

**#14. Needed:** Capital endowment per Rich household, and capital endowment per Poor household.

*Raw Data Used:*

(a) Raw data used in #11 above.

(b) Raw data used in #13 above.

(c) Interest received, dividends, pensions and annuities,

and net gain in property sales, as part of I.R.S.-defined Adjusted Gross Income.

Estimation Procedure:
29% percent of the national total of interest received plus dividends plus pensions and annuities plus net gain in property sales accrued in 1988 to persons whose adjusted gross incomes were less than $30,000. I am using this percent as a proxy, and allocating 29% of capital income to Poor households; the remaining 71% goes to Rich households.

This allocation procedure is indeed crude; however, I believe it superior to the procedure used by Mutti, Morgan, and Partridge, who allocate capital income among their regions solely on the basis of where dividends were paid.

Having allocated total capital income to Poor and Rich households, I then divide the allocations by the national populations of Poor and Rich households, finally arriving at capital endowments per Poor household and Rich household (where 1 unit of capital is defined so as to pay $1 gross of household taxes.)

The Numbers

#14: Capital Endowment Per Poor and Rich Household

<table>
<thead>
<tr>
<th></th>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>0.29(1,946,590,000,000)/90,242,000</td>
<td>6,252.458</td>
</tr>
<tr>
<td>Rich</td>
<td>0.71(1,946,590,000,000)/21,381,000</td>
<td>64,640.517</td>
</tr>
</tbody>
</table>

#15. Needed: Factor incomes of each Rich and Poor household, gross of household-type taxes.

Raw Data Used:
(a) Raw data used in #13 and #14 above.

Estimation Process:
The estimate of the gross factor income of each Poor household is:

Unskilled labor endowment + capital endowment

= 14,232.408 + 6,255.5251 = 20,487.933
The estimate of the gross factor income of each Rich household is:

\[
\text{Skilled labor endowment + capital endowment} = 29,170.151 + 64,640.517 = 93,810.668
\]

Components of these two estimates are from #14 and #13 above.


**Raw Data Used:**

(a) Raw data used in #5 and #13 above.

**Estimation Procedure:**

In each region, the population of Poor households is estimated as

\[
\frac{\text{Factor payments to unskilled workers in the region net of business taxes, gross of household taxes.}}{\text{Unskilled labor endowment per household, gross of household taxes}}
\]

The numerator is from #5, the denominator is from #13.

For the Rich, the estimate is

\[
\frac{\text{Factor payments to skilled workers in the region net of business taxes, gross of household taxes.}}{\text{Skilled labor endowment per household, gross of household taxes}}
\]

Again, the numerator is from #5, the denominator from #13.

*The Numbers:*
### #16: Regional Population of Rich and Poor Households

**Nor-Mid**

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$144,359,000,000 / 29,170.151$</td>
<td>$300,083,000,000 / 14,232.408$</td>
</tr>
<tr>
<td></td>
<td>= 10196759</td>
<td>= 43000524</td>
</tr>
</tbody>
</table>

**Texas**

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$153,082,000,000 / 29,170.151$</td>
<td>$311,918,000,000 / 14,232.408$</td>
</tr>
<tr>
<td></td>
<td>= 1281858</td>
<td>= 5371263</td>
</tr>
</tbody>
</table>

**South**

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$193,414,000,000 / 29,170.151$</td>
<td>$396,600,000,000 / 14,232.408$</td>
</tr>
<tr>
<td></td>
<td>= 5348676</td>
<td>= 22494739</td>
</tr>
</tbody>
</table>

**West**

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$132,832,000,000 / 29,170.151$</td>
<td>$275,760,000,000 / 14,232.408$</td>
</tr>
<tr>
<td></td>
<td>= 4553696</td>
<td>= 19419764</td>
</tr>
</tbody>
</table>

### #17. Needed: Capital payments to Rich and Poor households, gross of household taxes, classified by region.

**Raw Data Used:**

(a) Raw data used in #14 and #16 above.

**Estimation Procedure:**

Total capital income gross of household taxes received by households in a region does not necessarily equal capital payments by producers within the region, since households may supply all or part of their capital endowments in other regions. Thus regions may be 'exporting' capital if total household endowments in the region exceed capital used by producers in the region. Using similar logic, regions may also be capital 'importers'. But I digress.

Within a region the estimate for total capital income of Rich households gross of household capital taxes is:

\[ \text{Rich population in the region} \times \text{Capital endowment per Rich household} \]
For Poor households, the estimate is:

\[
\text{Poor population in the region} \times \text{Capital endowment per Poor household}
\]

Components of these estimates are from #13 and #15 above.

*The Numbers:*

<table>
<thead>
<tr>
<th>Region</th>
<th>Rich Product (x)</th>
<th>Poor Product (x)</th>
<th>Rich Total ($ millions)</th>
<th>Poor Total ($ millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nor-Mid</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rich</td>
<td>(64,640.517 \times 4,948,860.2)</td>
<td>(6,255.5251 \times 21,804,485)</td>
<td>(659124)</td>
<td>(268859)</td>
</tr>
<tr>
<td>Poor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Texas</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rich</td>
<td>(64,640.517 \times 5,247,898.8)</td>
<td>(6,255.5251 \times 21,916,038)</td>
<td>(82860)</td>
<td>(33584)</td>
</tr>
<tr>
<td>Poor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>South</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rich</td>
<td>(64,640.517 \times 6,630,545)</td>
<td>(6,255.5251 \times 27,865,980)</td>
<td>(345741)</td>
<td>(140647)</td>
</tr>
<tr>
<td>Poor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>West</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rich</td>
<td>(64,640.517 \times 4,553,696)</td>
<td>(6,255.5251 \times 19,375,499)</td>
<td>(294,353.2644)</td>
<td>(121,421.2574)</td>
</tr>
<tr>
<td>Poor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**#18. Needed:** Regional governments' taxes received from skilled labor income, unskilled labor income, and capital income paid by Rich and Poor households.

*Raw Data Used:*

(a) Raw data used in #15, #16 and #17 above.

(b) State and local individual income taxes paid in each region.

(c) State and local property taxes paid in each region.

Source: Same as (b) above.

*Estimation Procedure:*

Within each region the total of state and local income taxes are allocated among skilled labor, unskilled labor, and capital so that Rich households' average tax rate on earned income is exactly double the average tax rate of Poor households. This heroic assumption attempts to capture the progressive nature of most state and local governments' income tax levies; however, within the confines of my model it is indeed difficult to mirror with any precision the multitude of income tax policies of the many real world U.S. sub-national governments.

I also assume that capital income and labor income are taxed at the same rate by the state and local income tax system; this assumption combined with the above assumption provides a two-tiered income tax rate structure for each regional government.

Mathematically, for each region the average regional income tax rate for Poor households is calculated as follows:

Poor household's average regional income tax rate =

\[
\frac{\text{Total state and local income taxes collected in the region}}{\text{Poor Earned Income} + (2 \times \text{Rich Earned Income})}
\]

Where "earned income" is income received from capital and labor.

In each region the Rich household's average regional income tax rate is calculated by doubling the Poor household's average regional income tax rate.

---

*In Texas, there was no personal income tax in 1988 (nor is there one in 1996).*
The above mathematical procedure yields the following average regional income
tax rates:

Nor-Mid

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>=</td>
<td>.0171801</td>
</tr>
<tr>
<td>Rich</td>
<td>=</td>
<td>.0343602</td>
</tr>
</tbody>
</table>

Texas

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>=</td>
<td>0</td>
</tr>
<tr>
<td>Rich</td>
<td>=</td>
<td>0</td>
</tr>
</tbody>
</table>

South

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>=</td>
<td>.0123173</td>
</tr>
<tr>
<td>Rich</td>
<td>=</td>
<td>.0246346</td>
</tr>
</tbody>
</table>

West

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>=</td>
<td>.0174062</td>
</tr>
<tr>
<td>Rich</td>
<td>=</td>
<td>.0348124</td>
</tr>
</tbody>
</table>

These tax rates can now be used to calculate total regional income taxes paid by
Rich and Poor households in each region.

Nor-Mid ($millions)

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>=</td>
<td>15145</td>
</tr>
<tr>
<td>Rich</td>
<td>=</td>
<td>32855</td>
</tr>
</tbody>
</table>

Texas

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>=</td>
<td>0</td>
</tr>
<tr>
<td>Rich</td>
<td>=</td>
<td>0</td>
</tr>
</tbody>
</table>

South

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>=</td>
<td>5,673.4811</td>
</tr>
<tr>
<td>Rich</td>
<td>=</td>
<td>12,362.503</td>
</tr>
</tbody>
</table>

West

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>=</td>
<td>6,909.6334</td>
</tr>
<tr>
<td>Rich</td>
<td>=</td>
<td>14,871.344</td>
</tr>
</tbody>
</table>
In addition to the state and local income tax, a portion of property tax receipts in
the region are paid for by Rich and Poor households. In each region the household
portion of property taxes paid equals

Total property tax receipts - estimated property taxes paid by business

where the estimate of property taxes paid by business is from #15 above. This equation
yields the following estimates of total household property taxes paid in each region:

Nor-Mid: = 46,972
Texas: = 4718
South: = 16721
West: = 19,069

These property tax payments must be allocated between Rich and Poor
households' capital income. I am bravely assuming that the average property tax rate
befalling Rich households is exactly double that faced by Poor households, reasoning that
many Poor households may rent their housing rather than own it.

Mathematically, for each region the average regional household property tax rate
for Poor households equals:

\[
\frac{\text{Total household property taxes paid in the region}}{\text{Poor capital income} + (2 \times \text{Rich capital income})}
\]

In each region the Rich household's average property tax rate is double the Poor
household's rate.

The above mathematical procedure yields the following average household
property tax rates on capital income:
Nor-Mid
Poor = .029596
Rich = .059192

Texas
Poor = .0236724
Rich = .0473448

South
Poor = .0200942
Rich = .0401885

West
Poor = .0268611
Rich = .0537223

These property tax rates can now be used to calculate total regional property taxes paid by Rich and Poor households in each region: ($millions)

Nor-Mid
Poor = 7957
Rich = 39015

Texas
Poor = 795
Rich = 3923

South
Poor = 2826
Rich = 13895

West
Poor = 3,255.6
Rich = 15,813.334

Finally, adding state and local income taxes and property taxes paid by Rich and Poor households gives us household-type taxes collected by each Regional government.

The Numbers:
### #18: Regional Government Household-Type Tax Receipts ($millions)

<table>
<thead>
<tr>
<th>Region</th>
<th>Poor</th>
<th>Rich</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-Mid</td>
<td>23102</td>
<td>71870</td>
</tr>
<tr>
<td>Texas</td>
<td>795</td>
<td>3923</td>
</tr>
<tr>
<td>South</td>
<td>8499</td>
<td>26258</td>
</tr>
<tr>
<td>West</td>
<td>10,165.233</td>
<td>30,684.678</td>
</tr>
</tbody>
</table>

### #19. Needed: Federal government household-type taxes received from skilled labor income, unskilled labor income, and capital income.

**Raw Data Used:**


(b) Raw data used in #5 and #12 above.

**Estimation Procedure:**

I first assume that the Federal individual income tax and contributions to social insurance programs are the only federal household-type income taxes.

I next assume that capital income and labor income are taxed at the same average rate. At least statutorily, this assumption accurate in 1988.

I also assume that Rich and Poor households face the same average tax rate on their income. It is far from clear that this assumption is correct, given the proportional-to-regressive statutory average rate structure of the social security tax and the progressive
statutory rate structure of the personal income tax. However, studies by Pechman (1985) show that under certain economic assumptions the combination of the social security and personal income taxes result in a proportional distribution of the tax burden over a significant income range.

Finally, I assume that regional household-type taxes are not deductible from taxable Federal income. Given the small average tax rates calculated in #18 above, this assumption is acceptable.

The (identical) average Federal tax rate faced by households is calculated as follows:

\[
\frac{\text{Total Federal income taxes} + \text{Federal social insurance taxes}}{\text{National total of labor income and capital income, gross of household-type taxes, net of business-type taxes}}
\]

\[
\frac{632,900}{3,584,638} = .1641918
\]

Finally, multiplying the total earned income of Rich and Poor households in each region gives us Federal household income taxes paid by each type of household in each region.

*The Numbers:*

**#19: Federal Government Household-Type Tax Receipts ($millions)**

*Nor-Mid*

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>144296</td>
</tr>
<tr>
<td>Rich</td>
<td>157110</td>
</tr>
</tbody>
</table>

*Texas*

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>18066</td>
</tr>
<tr>
<td>Rich</td>
<td>19744</td>
</tr>
<tr>
<td>Region</td>
<td>Category</td>
</tr>
<tr>
<td>--------</td>
<td>----------</td>
</tr>
<tr>
<td>South</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td>Rich</td>
</tr>
<tr>
<td>West</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td>Rich</td>
</tr>
</tbody>
</table>

#20. **Needed**: Elasticities of substitution between: regional public goods and federal public goods; goods and services; regional/federal public goods ("PUBL_H") and goods/services ("PRIV_H"); and goods from the four different regions.

**Data Used:**


**Estimation Procedure:**

These elasticity of substitution estimates are necessary to calibrate household utility functions. Ballard, Fullerton, Shoven and Whalley (1985) and Jones and Whalley (1988) impose a Cobb-Douglas utility function, so that all substitution elasticities in their models equal one. I shall impose an elasticity of substitution between goods and services equal to .99, as well as an elasticity of substitution between regional and federal public goods equal to .99. However, I believe that public goods and private goods are less substitutable than goods and services; Mutti, Morgan and Partridge seem to agree, since they assign an elasticity of substitution of zero between private and public goods. This assignment is purely for mathematical reasons and is obviously incorrect (surely, for example, public and private schools are substitutable); I am imposing an estimate of .8 rather than zero.

Finally, I shall use an estimate of 3 for the elasticity of substitution between goods produced in different regions, following Mutti, Morgan, and Partridge.

**The Numbers:**
#20: Elasticities of Substitution

<table>
<thead>
<tr>
<th>Category</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goods and Services</td>
<td>.99</td>
</tr>
<tr>
<td>Regional and Federal Public Goods</td>
<td>.99</td>
</tr>
<tr>
<td>Private Goods bundle and Public Goods Bundle</td>
<td>.80</td>
</tr>
<tr>
<td>Goods produced in different regions</td>
<td>3.00</td>
</tr>
</tbody>
</table>

**Government Information**


*Raw Data Used:*

(a) Raw data used in #1

*Estimation Procedure:*

In order for my constructed 1988 economy to be in equilibrium, the Federal government's budget must be balanced; that is, Federal government expenditures on public goods and transfer payments must equal Federal tax collections. Since in this chapter I have already estimated values for Federal public goods and Federal tax receipts, Federal transfer payments are left as a residual:

\[
\text{Federal transfer payments} = \text{Total Federal taxes} - \text{Federal public goods expenditures} = 828,539 - 321,220 = 507,319
\]

Casual empiricism suggests that this estimate is too low. This unfortunate circumstance results from the "residual" nature of the calculation of the transfer payment; it is 'leftover' after taxes and public goods are calculated. However, since a limitation of my model is that the Federal government's budget deficit (174 billion dollars in 1988) must be ignored, the 'leftover' is too small by the amount of the budget deficit. Regrettably, I see no correction to this problem.
The total transfer payment must be divided among Rich and Poor households. I assume that each type of household receives the same amount of federal transfer payment regardless of the region in which it resides. I also make the valiant assumption that a Poor household's transfer payment is exactly double that of a Rich household.\(^9\)

Mathematically, the federal transfer payment per Rich household equals:

\[
\text{Total Federal Transfer Payment} = \text{Rich National Population} + (2 \times \text{Poor National Population})
\]

\[
= 2517 \quad \text{per Rich household.}
\]

The federal transfer payment per Poor household is double the Rich transfer payment, or 5034

Total federal transfer payments to Rich and Poor households can now be calculated. For example, the total federal transfer payments received by the Rich population equals the transfer payment per household multiplied by the national Rich household population.

\textit{The Numbers:}

\begin{align*}
\#21: \text{Total Federal Transfer Payments to Rich and Poor ($millions$)} \\
\text{Rich} & \quad 21,381,000 \times 2517 = 53,239 \\
\text{Poor} & \quad 90,241,997 \times 5034 = 454,080
\end{align*}

\#22. \textit{Needed}: Transfer payments paid to Rich and Poor households by the four regional governments.

\textit{Raw Data Used:}

(a) Raw data used in #1 and #16 above.

\(^9\)Dr. Robert Stein has graciously provided me with statistics that will allow me to refine this crude delineation between Rich and Poor households' transfer payments received in my later research.
Estimation Procedure:

As with the Federal government above, each Regional government's total transfer payments are residuals left after subtracting regional expenditures on public goods from regional taxes collected. These numbers were estimated for #1 above.

Regional government's total transfer payments =

Regional tax receipts - value of regional public goods

<table>
<thead>
<tr>
<th>Region</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-Mid</td>
<td>29905</td>
</tr>
<tr>
<td>Texas</td>
<td>2323</td>
</tr>
<tr>
<td>South</td>
<td>8621</td>
</tr>
<tr>
<td>West</td>
<td>10513</td>
</tr>
</tbody>
</table>

These estimates need to be allocated to Rich and Poor households. Once again, I magnanimously assume that each Poor household receives a regional transfer payment double the size of a Rich household. The transfer payment per Rich household in each region equals

\[
\text{Total Regional Transfer Payment} = \frac{\text{Region's Rich Population} + (2 \times \text{Region's Poor Population})}{\text{Region's Rich Population}}
\]

The Numbers:

#22: Regional Government Transfer Payments Per Household

<table>
<thead>
<tr>
<th>Region</th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-Mid</td>
<td>311</td>
<td>622</td>
</tr>
<tr>
<td>Texas</td>
<td>193</td>
<td>386</td>
</tr>
</tbody>
</table>
### South

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rich</td>
<td>171</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>342</td>
<td></td>
</tr>
</tbody>
</table>

### West

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rich</td>
<td>243</td>
</tr>
<tr>
<td>Poor</td>
<td>486</td>
</tr>
</tbody>
</table>

**Congestion of Government Provided Goods**

Recall from chapter 5 that the numerical variables of "j" and "k" determine the degree of congestion of the Regional Public Good and the Federal Public Good, respectively. I am grandly assuming that the regional public good is completely rivalrous and excludable, while the federal public good is a pure public good; this assumption means that "j" and "k" are estimated as equaling 1 and 0, respectively.

**#23: Estimates of "j" and "k"**

\[ j = 1 \quad k = 0 \]

All of the data has now been gathered to "calibrate" the mathematical model in chapter 5 to represent the modern U.S. economy. This calibration will be displayed in chapter 7.
7. Model Calibration

This chapter integrates the economic data presented in chapter 6 into the general mathematical form of my CGE model presented in chapter 5. The "calibration" technique transforms the mathematical model to represent the modern day United States economy in equilibrium. This new operational model is then ready to be manipulated with computer techniques to simulate changes in government policy. Two such computer simulations will be undertaken in chapters 8 and 9.

The data from chapter 6 are used to determine specific numerical values for production function and utility function parameters generally expressed as variables in chapter 5. These specific values allow the model to be "solved" for various counterfactual equilibria (representing policy changes from the benchmark equilibrium) using an iterative computer solution algorithm. These counter-factual solutions can give numerical values concerning how the policy change affects important economic measures such as incomes, utility, and regional value-added, as will be seen in chapters 8 and 9.

This chapter will proceed as follows: first, production function parameters will be specified. Second, household utility function parameters will be specified. Lastly, government tax revenues and expenditures will be displayed.

Production Function Parameters

Consider for example the production function from chapter 5 representing Goods production in the Nor-Mid region, repeated below:

\[ G_N = A_G[b_G \text{LABOR}_{G\text{N}}(eG-1)/eG+(1-b_G)\text{CAP}_{G\text{N}}(eG-1)/eG]eG/(eG-1) \]

1Many of the calibration methods employed in this chapter were developed by John Shoven and John Whalley.
2 See appendix C for a complete list of variables.
where "LABOR\_GN"=
[c\_G\_SKIL\_GN\_GN\_GL^{-1}\_GL + (1-c\_G)UNSKIL\_GN\_GN\_GL^{-1}\_GL]eGL/(1-eGL)

Benchmark numeric values for G\_N, CAP\_GN, SKIL\_GN, UNSKIL\_GN, c\_G, and eGL are obtained from chapter 6. Here I shall calculate A\_G, b\_G, and c\_G.

First, I shall determine c\_G. Using the assumption of cost minimization, the Nor-Mid Goods producer will minimize:

P\_SKIL\_GN\_SKIL\_GN + P\_UNSKIL\_GN\_UNSKIL\_GN + L\_LABOR\_GN

where "L" is a Lagrange multiplier. This minimization leads to the following first order conditions:
P\_UNSKIL\_GN + L\_\((1/eGL-1)(1-c\_G)UNSKIL\_GN^{-1}/eGL = 0
P\_SKIL\_GN + L\_\((1/eGL-1)c\_GUNSKIL\_GN^{-1}/eGL = 0

where \((\_\) = c\_GSKIL\_GN\_GN\_GL^{-1}/eGL + (1-c\_G)UNSKIL\_GN\_GN\_GL^{-1}/eGL

These first order conditions can be used to determine c\_G:

c\_G = \frac{(P\_SKIL\_GN\_SKIL\_GN^{1/eGL}) / (P\_UNSKIL\_GN\_UNSKIL\_GN^{1/eGL})}{1 + (P\_SKIL\_GN\_SKIL\_GN^{1/eGL}) / (P\_UNSKIL\_GN\_UNSKIL\_GN^{1/eGL})}

To facilitate computer solution, I assume that in the benchmark equilibrium the prices of skilled labor and unskilled labor net of business taxes both equal 1, so that:
\[ P_{SKILGN} = 1 + T_{SKILGN} + T_{SKILGF} \]
\[ P_{UNSKILGN} = 1 + T_{UNSKILGN} + T_{UNSKILGNF} \]

I can now insert numeric values from chapter 6 in order to calculate the numeric values for \( c_G \). For ease of exposition, these numeric values are listed below:

\[ P_{UNSKILGN} = P_{UNSKILGN} = 1.076 \]
\[ SKIL_{GN} = 215059 \]
\[ e_{GL} = .70 \]
\[ UNSKIL_{GN} = 397487 \]

Using these values,

\[
\frac{(1.076 \times 215059^{1/7})}{(1.076 \times 397487^{1/7})} + \frac{(1.076 \times 215059^{1/7})}{(1.076 \times 187,471^{1/7})}
\]

\[ = .29369 \]

Now that the value of \( c_G \) is known, I can calculate numeric values for \( A_G \) and \( b_G \). First, using the assumption of cost minimization, the Nor-Mid producer of Goods will minimize:

\[ P_{LABOR_{GN}} \text{LABOR}_{GN} + P_{CAPGN} \text{CAP}_{GN} + \\
T_{CORPGN}[(P_{LABOR_{GN}} \text{LABOR}_{GN} + P_{CAPGN} \text{CAP}_{GN})/3 \text{NNP} \\
+ (P_{LABOR_{GN}} \text{LABOR}_{GN})/(3 \text{LABOR}_{GUS}) \\
+ (P_{CAPGN} \text{CAP}_{GN})/(3 \text{CAP}_{GUS}) ] \\
+ T_{CORPGNF}(P_{CAPGN} \text{CAP}_{GN}) + L(G_N) \]
where "L" is a Lagrange multiplier.

This minimization leads to the following first order conditions:

\[
[1 + (T_{\text{CORPGN}}/(3\text{LABORGUS}G)) + (T_{\text{CORPGN}}/3\text{NNPUS}G)] \, P_{\text{LABORGN}} \\
+ L \times A_G(\cdot)^{1/eG-1}b_G\text{LABORG}_{-1/eG} = 0
\]

\[
[1 + ((T_{\text{CORPGN}}/3\text{CAPUS}G)) + (T_{\text{CORPGN}}/3\text{NNPUS}G) + T_{\text{CORPGN}}] \, P_{\text{CAPGN}} \\
+ L \times A_G(\cdot)^{1/eG-1}(1-b_G)\text{CAPG}_{-1/eG} = 0
\]

where 

\[
(\cdot)^{1-eG-1} = b_G\text{LABORG}_{(eG-1)/eG} + (1-b_G)\text{CAPG}_{(eG-1)/eG}
\]

To facilitate computer solution, I assume that in the benchmark equilibrium the price of capital net of business taxes equals 1, so that:

\[
P_{\text{CAPGN}} = 1 + T_{\text{CAPGN}} + T_{\text{CAPGF}}
\]

"P_{\text{LABORGN}}" is a weighted price index of the gross prices of skilled and unskilled labor:

\[
P_{\text{LABORGN}} = c_G P_{\text{SKILGN}}(1-c_G) + (1-c_G) P_{\text{UNSKILGN}}(1-c_G)
\]

These first order conditions can be used to determine b_G:

I now have sufficient information to calculate a numeric value for b_G. First, using information from chapter 6, and the numeric value of "c_G" calculated earlier in this chapter, I can calculate T_{\text{CAPGN}}, T_{\text{CAPGF}}, 3\text{NNPUS}G, 3\text{LABORGUS}, 3\text{CAPUS}G, T_{\text{CORPGN}}, T_{\text{CORPGN}}, P_{\text{CAPGN}}, P_{\text{LABORGN}}, and LABORG. These values are all necessary to calculate b_G using the first order conditions above. First, here are T_{\text{CAPGN}} and T_{\text{CAPGF}}:
Capital Tax Paid by Goods Sector to Reg. Govt

\[ T_{\text{CAPGN}} = \text{Net Payments to Capital by Goods Sector} \]

\[ = 0.02849 \]

Capital Tax Paid by Goods Sector to Fed. Govt\(^1\)

\[ T_{\text{CAPGF}} = \text{Net Payments to Capital by Goods Sector} \]

\[ = 0.00 \]

These numeric values for \( T_{\text{CAPGN}} \) and \( T_{\text{CAPGF}} \) can now be used to calculate a numeric value for \( P_{\text{CAPGN}} \):

\[ P_{\text{CAPGN}} = 1 + 0.02849 + 0.00 = 1.02849 \]

Next, I shall calculate \( P_{\text{LABORGN}} \):

\[ P_{\text{LABORGN}} = 0.29369 \times 1.076(1^{-0.7}) + (1-0.29369) \times 1.076(1^{-0.7}) \]

\[ = 1.0222 \]

Next, I shall calculate \( \text{LABOR}_{\text{GN}} \). It equals:

\[ [0.29369 \times 215059(0.7-1)/.7 + (1-0.29369) \times 397487(0.7-1)/.7] / 7/.7-1 \]

\[ = 326166.3 \]

\(^1\) Recall from ch. 6 that the federal corporation income tax is not considered statutorily a direct capital tax.
3LABOR\textsubscript{GUS} equals triple the sum of LABOR\textsubscript{Gi} for the four regions, 
\[ i = N,TX,W,S. \]
\[ = 671400.37 \times 3 = 2014201.1 \]

3CAP\textsubscript{GUS} equals triple the sum of CAP\textsubscript{Gi} for the four regions, 
\[ i = N,S,TX,W. \]
\[ = 1333305 \times 3 = 3999915 \]

3NNP\textsubscript{GUS} equals triple the sum of national Goods output, net of sales and corporation income taxes. 
\[ = 2,718,946 \times 3 = 8156838 \]

Next, I shall calculate T\textsubscript{CORPGNF}. 
\[
T_{\text{CORPGNF}} = \frac{\text{Federal Corporation Income Taxes Paid By "Nor-Mid" Goods Sector}}{\text{"Nor-Mid" Goods Net Sales - "Nor-Mid" Goods Labor Payments}}
\]
\[ = .036606 \]

Next, I shall calculate T\textsubscript{CORPGN}: 
\[
T_{\text{CORPGN}} = \frac{\text{State and Local Corporation Income Taxes Paid by NE Goods Sector}}{(*)}
\]
\[ = 21180.05455 \]

where "**" equals \[ (P_{LABORGN} LABOR_{GN} + P_{CAPGN} CAP_{GN})/3NNP \]
\[ + (P_{LABORGN} LABOR_{GN})/(3PLABOR\textsubscript{GUS} LABOR\textsubscript{GUS}) \]
\[ + (P_{CAPGN} CAP_{GN})/(3PCAP\textsubscript{GUS} CAP\textsubscript{GUS}) ] \]

Finally, we have the numbers necessary to give b\textsubscript{G} a numeric value. Here it is:
\[ b_G = .50419258 \]

Now I can calculate \( A_G \), using information from above, and using the Goods production function.

\[ A_G = 2.24489 \]

Thus the Goods-producing technology in the Nor-Mid region has been calibrated to represent the modern United States. It is as follows:

\[ G_N = 2.24489 \times \text{LABOR}_{GN}^{(0.9-1)/9} + (1-.50419) \times \text{CAP}_{GN}^{(0.9-1)/9} \times 0.9/(9-1) \]

where

\[ \text{LABOR}_{GN} = [\cdot29369 \times \text{SKIL}_{GN}^{(7-1)/7} + (1-.29369) \times \text{UNSKIL}_{GN}^{(7-1)/7}] \times 0.7/(1-7) \]

Using similar calibration techniques, the production technologies for the Services sector, the Regional Public Goods sector, the Federal Public Goods sector, and the remaining Goods sectors can be numerically specified. In order to eliminate redundancy, I shall not undertake to display each of these calibrations here in their entirety. Rather, I shall list the important numeric calculations required, along with the calibrated production technology.

**Goods-Producing Sector in Texas:**

\[ P_{\text{UNSKILGM}} = 1 + .07671 = 1.07671 \]

\[ P_{\text{SKILGM}} = 1.07671 \]

\[ \text{SKIL}_{GM} = 27073 \]

\[ \text{UNSKIL}_{GM} = 50038 \]
\[ c_G = \frac{(1.07671 \times 27073^{1/7})}{(1.07671 \times 50038^{1/7})} \]

\[ 1 + (1.07671 \times 27073^{1/7}) / (1.07671 \times 50038^{1/7}) \]

\[ = 0.29370 \]

\[ T_{CAPGM} = 0.01848 \]

\[ T_{CAPGF} = 0 / 318524 = 0 \]

\[ P_{CAPGM} = 1 + 0.01848 = 1.01848 \]

\[ P_{LABORGM} = 0.29370 \times 1.07671(1-7) + (1-0.29370) \times 1.07671(1-7) \]

\[ = 1.02242 \]

\[ LABOR_{GM} = [0.29370 \times 113629(7-1)^{1/7} + (1-0.29370) \times 210016(7-1)^{1/7}]^{0.7/7-1} \]

\[ = 41060 \]

\[ T_{CORPQM} = 0 \]

\[ T_{CORPQMF} = 0.00^2 \]

\[ b_G = 0.39603 \]

\[ A_G = 2.17952 \]

---

So here is the calibrated production function for Texas Goods:

\[ G_M = 2.17952[0.39603 \times LABOR_{GM}^{(9-1)/9} + (1-0.39603) \times CAP_{GM}^{(9-1)/9}]^{9/(9-1)} \]

where

\[ LABOR_{GM} = [0.29370 \times SKIL_{GM}^{(7-1)/7} + (1-0.29370) \times UNSKL_{GM}^{(7-1)/7}]^{7/(1-7)} \]

---

Goods-Producing Sector in the South:

\[ P_{UNSKILGS} = 1 + 0.07479 = 1.07479 \]

---

2Recall that Texas does not have a corporation income tax in the benchmark period.
\[ P_{SKILGS} = 1.07479 \]
\[ SKIL_{GS} = 109636 \]
\[ UNSKL_{GS} = 202637 \]

\[
\begin{align*}
  c_G &= \frac{(1.07479 \times 136709^{1/7}) / (1.07479 \times 252676^{1/7})}{1 + (1.07479 \times 136709^{1/7}) / (1.07479 \times 252676^{1/7})} \\
  &= .29370
\end{align*}
\]

\[ T_{CAPGS} = .01786 \]
\[ T_{CAPGF} = .0 \]
\[ P_{CAPGS} = 1 + .01786 = 1.01786 \]
\[ P_{LABORGS} = .29370 \times 1.07479^{(1-.7)} + (1-.29370) \times 1.07479^{(1-.7)} \\
  = 1.02187 \]
\[ LABOR_{GS} = [.29370 \times 109636^{(.7-1)/.7} + (1-.29370) \times 202637^{(.7-1)/.7}]^{7/7.7-1} \\
  = 166279 \]
\[ T_{CORP GS} = 12449.34646 \]
\[ T_{CORP GF} = .03667 \]
\[ b_G = .49127 \]
\[ A_G = 2.24032 \]

So here is the calibrated production function for South Goods:

\[ G_S = 2.24032 \times [.49127 \times LABOR_{GS}^{(9-1)/.9} + (1-.49127) \times CAP_{GS}^{(9-1)/.9}]^{9/(9-1)} \]

where

\[ LABOR_{GN} = [.29370 \times SKIL_{GS}^{(.7-1)/.7} + (1-.29370) \times UNSKL_{GS}^{(.7-1)/.7}]^{7/(1-.7)} \]
**Goods-Producing Sector in the West:**

\[ P_{UNSKILGW} = 1 + .07688 = 1.07688 \]
\[ P_{SKILGW} = 1.07688 \]
\[ SKIL_{GW} = 90262 \]
\[ UNSKIL_{GW} = 166830 \]

\[ c_G = \frac{(1.07688 \times 90262^{1/7}) \div (1.07688 \times 166830^{1/7})}{1 + (1.07688 \times 90262^{1/7}) \div (1.07688 \times 166830^{1/7})} \]

\[ = .29369 \]

\[ T_{CAPGW} = .01989 \]
\[ T_{CAPGF} = .0 \]
\[ P_{CAPGW} = 1 + .0989 = 1.01989 \]
\[ P_{LABORGW} = .29369 \times 1.01989^{(1\div7)} + (1-.29369) \times 1.01989^{(1\div7)} \]

\[ = 1.02247 \]
\[ LABOR_{GW} = [.29369 \times 90262^{(1\div7)} + (1-.29369) \times 166830^{(1\div7)}]^{7/1} \]

\[ = 136895 \]
\[ T_{CORPGW} = 20424 \]
\[ T_{CORPGF} = .03475 \]
\[ b_G = .48022 \]
\[ A_G = 2.2442 \]

*So here is the calibrated production function for West Goods:*

\[ G_W = 2.2442\times .48022 \times \text{LABOR}_{GW}^{(9\div1)/.9} + (1-.48022) \times \text{CAP}_{GW}^{(9\div1)/.9} \]

where

\[ \text{LABOR}_{GN} = [.29369 \times \text{SKIL}_{GW}^{(1\div7)} + (1-.29369) \times \text{UNSKIL}_{GW}^{(1\div7)}]^{7/(1\div7)} \]
Services-Producing Sector in the Nor-Mid Region:

\[ P_{\text{UNSKILVN}} = 1 + .07637 = 1.07637 \]
\[ P_{\text{SKILVN}} = 1.07637 \]
\[ \text{SKILVN} = 42878 \]
\[ \text{UNSKILVN} = 133059 \]

\[ CV = \frac{(1.07637 \times 42878^{1/8}) / (1.07637 \times 133059^{1/8})}{1 + (1.07637 \times 42878^{1/8}) / (1.07637 \times 133059^{1/8})} \]
\[ = .19536 \]

\[ T_{\text{CAPVN}} = .0283 \]
\[ T_{\text{CAPVF}} = 0 \]
\[ P_{\text{CAPVN}} = 1.0283 \]
\[ P_{\text{LABORVN}} = .19536 \times 1.07636^{(1-8)} + (1-.19536) \times 1.07636^{(1-8)} \]
\[ = 1.01483 \]
\[ \text{LABORVN} = [.19536 \times 42878^{(8-1)/8} + (1-.19536) \times 133059^{(8-1)/8}]^{8/8-1} \]
\[ = 103846 \]
\[ T_{\text{CORPVN}} = 5287.6125 \]
\[ T_{\text{CORPVF}} = .04542 \]
\[ bV = .59736 \]
\[ AV = 2.2124 \]

So here is the calibrated production function for Nor-Mid Services:

\[ V_N=2.2124[.59735x\text{LABORVN}^{(99-1)/99}+(1-.59735)x\text{CAPVN}^{(991)/99}]^{99/(99-1)} \]

3 Instead of using "1" as the elasticity of substitution estimate between capital and skilled/unskilled labor in the Services production sectors, I am using "99." This eases computation and writing time. And I'm tired. So there.
where

$$\text{LABOR}_V = [1.19536 \times \text{SKIL}_V^{(8-1)/8} + (1 - 1.19536) \times \text{UNSKIL}_V^{(8-1)/8}] \cdot 8/(1-8)$$

**Services-Producing Sector in Texas:**

$$P_{\text{UNSKILVM}} = 1 + .07670 = 1.07670$$

$$P_{\text{SKILVM}} = 1.07670$$

$$\text{SKIL}_{VM} = 4927$$

$$\text{UNSKIL}_{VM} = 15290$$

$$c_V = \frac{(1.07670 \times 4927^{1/8}) / (1.07670 \times 15290^{1/8})}{1 + (1.07670 \times 4927^{1/8}) / (1.07670 \times 15290^{1/8})}$$

$$= .19537$$

$$T_{\text{CAPVM}} = .01848$$

$$T_{\text{CAPVF}} = .0$$

$$P_{\text{CAPVM}} = 1 + .01848 = 1.01848$$

$$P_{\text{LABORVM}} = .19537 \times 1.07670^{(1-8)} + (1 - .19537) \times 1.07670^{(1-8)}$$

$$= 1.01489$$

$$\text{LABOR}_{VM} = [.19537 \times 4927^{(8-1)/8} + (1 - .19537) \times 15290^{(8-1)/8}] \cdot .8/8-1$$

$$= 11933$$

$$T_{\text{CORPVM}} = 0$$

$$T_{\text{CORPVF}} = .03495$$

$$b_V = .51173$$

$$A_V = 2.23818$$

*So here is the calibrated production function for Texas Services:*
\[ V_M = 2.23818 \cdot 0.51173 \cdot \text{LABOR}_{VM}^{(99-1)/99} + (1 - 0.51173) \cdot \text{CAP}_{VM}^{(99-1)/99} \cdot 0.99^{(99-1)/99} \]

where

\[ \text{LABOR}_{VM} = [0.19537 \cdot \text{SKIL}_{VM}^{(8-1)/8} + (1 - 0.19537) \cdot \text{UNSKIL}_{VM}^{(8-1)/8}]^{0.8/(1-8)} \]

**Services-Producing Sector in the South:**

\[ P_{\text{UNSKILVS}} = 1 + 0.07481 = 1.07481 \]
\[ P_{\text{SKILVS}} = 1.07481 \]
\[ \text{SKILVS} = 21005 \]
\[ \text{UNSKILVS} = 65184 \]

\[ c_V = \frac{(1.07481 \cdot 21005^{1/8}) / (1.07481 \cdot 65184^{1/8})}{1 + (1.07481 \cdot 21005^{1/8}) / (1.07481 \cdot 65184^{1/8})} = 0.19536 \]

\[ T_{\text{CAPVS}} = 0.01786 \]
\[ T_{\text{CAPVF}} = 0 \]
\[ P_{\text{CAPVS}} = 1 + 0.01786 = 1.01786 \]
\[ P_{\text{LABORVS}} = 0.19536 \cdot 1.07481^{(1-8)} + (1 - 0.19536) \cdot 1.07481^{(1-8)} = 1.01453 \]
\[ \text{LABOR}_{VS} = [0.19536 \cdot 21005^{(8-1)/8} + (1 - 0.19536) \cdot 65184^{(8-1)/8}]^{0.8/(8-1)} = 50873 \]
\[ T_{\text{CORPVS}} = 2279.7245 \]
\[ T_{\text{CORPVF}} = 0.0477 \]
\[ b_V = 0.61661 \]
\[ A_{V} = 2.19438 \]

So here is the calibrated production function for South Services:

\[ V_{S} = 2.19438 \times 0.61661 \times \text{LABOR}_{VS}^{0.99-1/0.99} + (1-0.61661) \times \text{CAP}_{VS}^{0.99-1/0.99} \times 0.99/(0.99-1) \]

where

\[ \text{LABOR}_{VS} = [0.19536 \times \text{SKIL}_{VS}^{(8-1)/8} + (1-0.19536) \times \text{UNSKIL}_{VS}^{(8-1)/8}]^{0.8/(1-8)} \]

Services-Producing Sector in the West:

\[ P_{\text{UNSKIL}_{VW}} = 1 + 0.07686 = 1.07686 \]

\[ P_{\text{SKIL}_{VW}} = 1.07686 \]

\[ \text{SKIL}_{VW} = 20921 \]

\[ \text{UNSKIL}_{VW} = 64922 \]

\[ c_{V} = \frac{(1.07686 \times 20921^{1/8}) / (1.07686 \times 64922^{1/8})}{1 + (1.07686 \times 20921^{1/8}) / (1.07686 \times 64922^{1/8})} \]

\[ = 0.19536 \]

\[ T_{\text{CAP}_{VW}} = 0.01990 \]

\[ T_{\text{CAP}_{VF}} = 0 \]

\[ P_{\text{CAP}_{VW}} = 1 + 0.01990 = 1.01990 \]

\[ P_{\text{LABOR}_{VW}} = 0.19536 \times 1.07686^{(1-8)} + (1-0.19536) \times 1.07686^{(1-8)} \]

\[ = 1.01492 \]

\[ \text{LABOR}_{VW} = [0.19536 \times 20921^{(8-1)/8} + (1-0.19536) \times 64922^{(8-1)/8}]^{0.8/(8-1)} \]

\[ = 50668.43746 \]

\[ T_{\text{CORP}_{VW}} = 4918.8937 \]
\[ T_{CORPVF} = 0.04446 \]

\[ b_V = 0.59256 \]

\[ A_V = 2.22118 \]

So here is the calibrated production function for West Services:

\[ V_W = 2.22118 \times 0.59256 \times \text{LABOR}_W^{(0.99-1)/0.99 + (1-0.59256) \times \text{CAP}_W^{(0.99-1)/0.99 - (0.99-1)}} \]

where

\[ \text{LABOR}_W = (0.19536 \times \text{SKIL}_W^{(0.8-1)/0.8 + (1-0.19536) \times \text{UNSKIL}_W^{(0.8-1)/0.8}})^{0.8/(1.8)} \]

Regional Public Goods-Producing Sector in the "Nor-Mid" region:

\[ P_{\text{UNSKILRN}} = 1 + 0.0910553 = 1.0910553 \]

\[ P_{\text{SKILRN}} = 1.0910553 \]

\[ \text{SKIL}_{RN} = 31072 \]

\[ \text{UNSKIL}_{RN} = 64067 \]

\[ c_R = \frac{(1.0910553 \times 31072^{1/0.75})}{(1.0910553 \times 64067^{1/0.75})} \]

\[ = 0.27591 \]

\[ T_{\text{CAPRN}} = 0.0283 \]

\[ T_{\text{CAPRF}} = 0 \]

\[ P_{\text{CAPRN}} = 1 + 0.0283 = 1.0283 \]

\[ P_{\text{LABORRN}} = 0.27591 \times 1.0910553^{(1.75)} + (1-0.27591) \times 1.0910553^{(1.75)} \]

\[ = 1.02202 \]
\[
\text{LABOR}_\text{RN} = [0.27591 \times 31072^{(0.75-1)/0.75} + (1-0.27591) \times 31072^{(0.75-1)/0.75}]^{0.75/(1-0.75)} = 51533
\]

\[T_{\text{CORPRN}} = 692.37121\]

\[T_{\text{CORPRF}} = 0.0108\]

\[b_R = 0.59731\]

\[A_R = 2.1051\]

So here is the calibrated production function for Nor-Mid Regional Public Goods:

\[R_N = 2.1051 \times 0.59731 \times \text{LABOR}_\text{RN}^{(0.95-1)/0.95} + (1-0.59731) \times \text{CAP}_{\text{RN}}^{(0.95-1)/0.95} \times \text{CAP}_{\text{RN}}^{(0.95)/(0.95-1)}\]

where

\[\text{LABOR}_\text{RN} = [0.27591 \times \text{SKIL}_{\text{RN}}^{(0.75-1)/0.75} + (1-0.27591) \times \text{UNSKIL}_{\text{RN}}^{(0.75-1)/0.75}]^{0.75/(1-0.75)}\]

Regional Public Goods-Producing Sector in Texas:

\[P_{\text{UNSKILRM}} = 1 + 0.09143 = 1.09143\]

\[P_{\text{SKILRM}} = 1.09143\]

\[\text{SKIL}_{\text{RM}} = 3133\]

\[\text{UNSKIL}_{\text{RM}} = 6461\]

\[c_R = \frac{(1.09143 \times 3133^{1/0.75}) / (1.09143 \times 6461^{1/0.75})}{1 + (1.09143 \times 3133^{1/0.75}) / (1.09143 \times 6461^{1/0.75})} = 0.27592\]

\[T_{\text{CAPRM}} = 0.01848\]

\[T_{\text{CAPRF}} = 0\]

\[P_{\text{CAPRM}} = 1 + 0.01848 = 1.01848\]
\[ P_{LABORRM} = 0.27592 \times 1.09143^{(1-0.75)} + (1-0.27592) \times 1.09143^{(1-0.75)} \]
\[ = 1.02211 \]
\[ LABOR_{RM} = [0.27592 \times 3133^{(0.75-1)/0.75} + (1-0.27592) \times 6460^{(0.75-1)/0.75}]^{0.75/(0.75-1)} \]
\[ = 5197 \]
\[ T_{CORPRM} = 0 \]
\[ T_{CORPRF} = 0.00948 \]
\[ b_R = 0.55915 \]
\[ A_R = 2.10974 \]

So here is the calibrated production function for Texas Regional Public Goods:

\[ R_{M} = 2.10974 \times 0.55915 \times LABOR_{RM}^{(0.95-1)/0.95} + (1-0.55915) \times CAP_{RM}^{(0.95-1)/0.95} \times 0.95/(0.95-1) \]

where

\[ LABOR_{RM} = [0.27592 \times SKIL_{RM}^{(0.75-1)/0.75} + (1-0.27592) \times UNSKIL_{RM}^{(0.75-1)/0.75}]^{0.75/(0.75-1)} \]

Regional Public Goods-Producing Sector in the South:

\[ P_{UNSKILRS} = 1 + 0.08950 = 1.08950 \]
\[ P_{SKILRS} = 1.08950 \]
\[ SKIL_{RS} = 14273 \]
\[ UNSKIL_{RS} = 29431 \]

\[ c_R = \frac{(1.08950 \times 14273^{1/0.75}) / (1.08950 \times 29431^{1/0.75})}{1 + (1.08950 \times 14273^{1/0.75}) / (1.08950 \times 29431^{1/0.75})} \]
\[ = 0.27591 \]
\[ T_{\text{CAPRS}} = 0.01786 \]
\[ T_{\text{CAPRF}} = 0 \]
\[ P_{\text{CAPRS}} = 1 + 0.01786 = 1.01786 \]
\[ P_{\text{LABORRS}} = 0.27591 \times 1.08950^{(1-0.75)} + (1-0.27591) \times 1.08950^{(1-0.75)} \]
\[ = 1.02166 \]
\[ \text{LABOR}_{RS} = [0.27591 \times 14273^{(0.75-1)/0.75} + (1-0.27591) \times 29431^{(0.75-1)/0.75}]^{0.75/(0.75-1)} \]
\[ = 23673 \]
\[ T_{\text{CORPRS}} = 377.1401 \]
\[ T_{\text{CORPRF}} = 0.01047 \]
\[ b_R = 0.58448 \]
\[ A_R = 2.10021 \]

So here is the calibrated production function for South Regional Public Goods:

\[ R_S = 2.10021 \times 0.58448 \times \text{LABOR}_{RS}^{(0.95-1)/0.95} \times (1-0.58448) \times \text{CAP}_{RS}^{(0.95-1)/0.95} \]

where

\[ \text{LABOR}_{RS} = [0.27591 \times \text{SKIL}_{RS}^{(0.75-1)/0.75} + (1-0.27591) \times \text{UNSKIL}_{RS}^{(0.75-1)/0.75}]^{0.75/(0.75-1)} \]

Regional Public Goods-Producing Sector in the West:

\[ P_{\text{UNSKILRW}} = 1 + 0.09156 = 1.09156 \]
\[ P_{\text{SKILRW}} = 1.09156 \]
\[ \text{SKIL}_{RW} = 14625 \]
\[ \text{UNSKIL}_{RW} = 30156 \]

\[ \epsilon_R = \frac{(1.09156 \times 14625^{1/0.75}) / (1.09156 \times 30156^{1/0.75})}{1 + (1.09156 \times 14625^{1/0.75}) / (1.09156 \times 30156^{1/0.75})} \]
\[ T_{\text{CAPRW}} = 0.01988 \]
\[ T_{\text{CAPRF}} = 0 \]
\[ P_{\text{CAPRW}} = 1 + 0.01988 = 1.01988 \]
\[ P_{\text{LABORRW}} = 0.27590 \times 1.09156^{(1-0.75)} + (1-0.27590) \times 1.09156^{(1-0.75)} = 1.02214 \]
\[ \text{LABOR}_{\text{RW}} = [0.27590 \times 14625^{(0.75-1)/0.75} + (1-0.27590) \times 30156^{(0.75-1)/0.75}]^{0.75/0.75-1} = 24256.45800 \]
\[ T_{\text{CORPRW}} = 658.0615 \]
\[ T_{\text{CORPRF}} = 0.0081 \]
\[ b_R = 0.6038 \]
\[ A_R = 2.09384 \]

So here is the calibrated production function for West Regional Public Goods:

\[ R_W = 2.09384 \times 0.6038 \times \text{LABOR}_{\text{RW}}^{(0.95-1)/0.95} + (1-0.6038) \times \text{CAP}_{\text{RW}}^{(0.95-1)/0.95} \times 0.95/(0.95-1) \]

where

\[ \text{LABOR}_{\text{RW}} = [0.27590 \times \text{SKIL}_{\text{RW}}^{(0.75-1)/0.75} + (1-0.27590) \times \text{UNSKIL}_{\text{RW}}^{(0.75-1)/0.75}]^{0.75/(1-0.75)} \]

Federal Public Goods-Producing Sector in the Nor-Mid:

\[ P_{\text{UNSKILFN}} = 1 + 0.08881 = 1.08881 \]
\[ P_{\text{SKILFN}} = 1.08881 \]
\[ \text{SKIL}_{\text{FN}} = 8432 \]
\[ \text{UNSKIL}_{\text{FN}} = 17388 \]
\[ c_F = \frac{(1.08881 \times 8432^{1/75}) / (1.08881 \times 17388^{1/75})}{1 + (1.08881 \times 8432^{1/75}) / (1.08881 \times 17388^{1/75})} \]

\[ = 0.27586 \]

\[ T_{\text{CAPFN}} = 0.0283 \]

\[ T_{\text{CAPFF}} = 0.0 \]

\[ P_{\text{CAPFN}} = 1 + 0.0283 = 1.0283 \]

\[ P_{\text{LABORFN}} = 0.27586 \times 1.08881^{(1-75)} + (1-0.27586) \times 1.08881^{(1-75)} \]

\[ = 1.02150 \]

\[ \text{LABOR}_{\text{FN}} = [0.27586 \times 8432^{(75-1)/75} + (1-0.27586) \times 17388^{(75-1)/75}]^{75/75-1} \]

\[ = 13986 \]

\[ T_{\text{CORPFN}} = 608.4187 \]

\[ T_{\text{CORPFF}} = 0.00644 \]

\[ b_F = 0.31124 \]

\[ A_F = 1.96604 \]

So here is the calibrated production function for Nor-Mid Federal Public Goods:

\[ F_N = 1.96604 \times 0.31124 \times \text{LABOR}_{\text{FN}}^{(0.95-1)/0.95} + (1-0.31124) \times \text{CAP}_{\text{FN}}^{(0.95-1)/0.95} x^{0.95/(0.95-1)} \]

where

\[ \text{LABOR}_{\text{FN}} = [0.27586 \times \text{SKIL}_{\text{FN}}^{(75-1)/75} + (1-0.27586) \times \text{UNSKIL}_{\text{FN}}^{(75-1)/75}]^{75/(1-75)} \]

Federal Public Goods-Producing Sector in Texas:

\[ P_{\text{UNSKILFM}} = 1 + 0.0893 = 1.0893 \]

\[ P_{\text{SKILFM}} = 1.0893 \]

\[ \text{SKIL}_{\text{FM}} = 2259 \]
UNSKIL\textsubscript{FM} = 4657

\[
\cF = \frac{(1.08930 \times 2259^{1/75}) / (1.08930 \times 4657^{1/75})}{1 + (1.08930 \times 2259^{1/75}) / (1.08930 \times 4657^{1/75})}
\]

= .27589

\[T\text{CAPFM} = .01848\]

\[T\text{CAPFF} = .0\]

\[P\text{CAPFM} = 1 + .01848 = 1.01848\]

\[P\text{LABORFM} = .27589 \times 1.08930^{(1-.75)} + (1-.27589) \times 1.08930^{(1-.75)} = 1.02161\]

\[LABOR\text{FM} = [.27589 \times 2259^{(.75-1)/.75} + (1-.27589) \times 4657^{(.75-1)/.75}]^{.75/(.75-1)} = 3746\]

\[T\text{CORPFM} = .00\]

\[T\text{CORPFF} = .00432\]

\[b\text{F} = .29516\]

\[A\text{F} = 1.91921\]

So here is the calibrated production function for Texas Federal Public Goods:

\[F\text{M}=1.91921[.29516 \times LABOR\text{FM}^{(95-1)/95} + (1-.29516) \times CAP\text{FM}^{(95-1)/95}]^{.95/(95-1)}\]

where

\[LABOR\text{FM} = [.27589 \times SKIL\text{FM}^{(.75-1)/.75} + (1-.27589) \times UNSKIL\text{FM}^{(.75-1)/.75}]^{.75/(1-.75)}\]

Federal Public Goods-Producing Sector in the South:

\[P\text{UNSKILFS} = 1 + .08724 = 1.08724\]

\[P\text{SKILFS} = 1.08724\]

\[SKIL\text{FS} = 11107\]
UNSKIL\(FS\) = 22902

\[c_F = \frac{(1.08724 \times 11107^{1/75}) / (1.08724 \times 22902^{1/75})}{1 + (1.08724 \times 11107^{1/75}) / (1.08724 \times 22902^{1/75})}\]

= .27591

\(T_{CAPFS} = .01786\)
\(T_{CAPFF} = .0\)
\(P_{CAPFS} = 1 + .01786 = 1.01786\)
\(P_{LABORFS} = .27591 \times 1.08724^{(1-.75)} + (1-.27591) \times 1.08724^{(1-.75)}\)

= 1.02113

\(LABOR_{FS} = [.27591 \times 11107^{(.75-1)/75} + (1-.27591) \times 22902^{(.75-1)/75}]^{.75/75-1}\)

= 18422

\(T_{CORPFS} = 333.2548\)
\(T_{CORPFF} = .00624\)
\(b_F = .25697\)
\(A_F = 1.85174\)

So here is the calibrated production function for South Federal Public Goods:
\(F_S = 1.85174[.25697 \times LABOR_{FS}^{(.95-1)/.95} + (1-.25697) \times CAP_{FS}^{(.95-1)/.95}]^{.95/(.95-1)}\)

where
\(LABOR_{FS} = [.27591 \times SKIL_{FS}^{(.75-1)/.75} + (1-.27591) \times UNSKIL_{FS}^{(.75-1)/.75}]^{.75/(1-.75)}\)

Federal Public Goods-Producing Sector in the West:
\(P_{UNSKILFW} = 1 + .08941 = 1.08941\)
\(P_{SKILFW} = 1.08941\)
SKIL\textsubscript{FW} = 7024
UNSKIL\textsubscript{FW} = 14482

\[
c_F = \frac{(1.08941 \times 7024^{1/75}) / (1.08941 \times 14482^{1/75})}{1 + (1.08941 \times 7024^{1/75}) / (1.08941 \times 14482^{1/75})}
\]

\[= .27593\]

\[T_{\text{CAPFW}} = .01989\]
\[T_{\text{CAPFF}} = .0\]
\[P_{\text{CAPFW}} = 1 + .01989 = 1.01989\]
\[P_{\text{LABORFW}} = .27593 \times 1.08941^{(1-.75)} + (1-.27593) \times 1.08941^{(1-.75)}\]
\[= 1.02164\]
\[\text{LABORFW} = [.27593 \times 7024^{(.75-1)/.75} + (.1-.27593) \times 14482^{(.75-1)/.75}]^{.75/1.75}\]
\[= 11648.85968\]
\[T_{\text{CORPFW}} = 577.37927\]
\[T_{\text{CORPFF}} = .00652\]
\[b_F = .32524\]
\[A_F = 1.9767\]

So here is the calibrated production function for West Federal Public Goods:
\[F_W = 1.9767[.32524 \times \text{LABORFW}^{(.95-1)/.95} + (.1-.32524) \times \text{CAPFW}^{(.95-1)/.95}]^{.95/(.95-1)}\]

where
\[\text{LABORFW} = [.27593 \times \text{SKILFW}^{(.75-1)/.75} + (.1-.27593) \times \text{UNSKILFW}^{(.75-1)/.75}]^{.75/(1-.75)}\]
Utility Function Parameters:

Recall that each household has identical preferences regardless of region of residence or factor endowments. I shall therefore estimate utility function parameters using national data, and assign the correspondingly calibrated utility function to each household in each region.

Since the functional form of household utility is homogeneous of degree one, we can theoretically use 1 large "national consumer" to estimate the necessary utility function parameters. Consider the instance where this fictional consumer has the following utility function, repeated here from chapter 5:

\[ U_H = (d_1 \text{PRIV}_H^{(i1-1)/i1} + (1-d_1) \text{PUBL}_H^{(i1-1)/i1})^{i1/(i1-1)} \]

where

\[ \text{PRIV}_H = (\text{GOOD}_H^{d2} \times V^{(1-d2)}) \]

\[ \text{PUBL}_H = (R^{d3} \times F^{(1-d3)}) \]

\[ \text{GOOD}_H = (d_4 G_N^{(i4-1)/i4} + d_5 G_M^{(i4-1)/i4} + d_6 G_S^{(i4-1)/i4} + d_7 G_W^{(i4-1)/i4})^{i4/(i4-1)} \]

and \( d_4 + d_5 + d_6 + d_7 = 1 \)

Benchmark data quantifying \( i_1 \), \( V \), \( R \), \( F \), \( i_4 \), \( G_N \), \( G_M \), \( G_S \), and \( G_W \) are in chapter 5. Our mission is to use this data to gather numerical estimates for \( \text{PRIV}_H \), \( \text{PUBL}_H \), \( \text{GOOD}_H \), \( d_1 \), \( d_2 \), \( d_3 \), \( d_4 \), \( d_5 \), \( d_6 \), and \( d_7 \), so that the utility function will be completely specified.

First, since the consumer tries to maximize utility garnered from \( \text{GOOD}_H \), the following LaGrangean can be used to specify \( d_4 \), \( d_5 \), \( d_6 \), and \( d_7 \):

\[ P_G N G_N + P_G M G_M + P_G S G_S + P_G W G_W + L((d_4 G_N^{(i4-1)/i4} + d_5 G_M^{(i4-1)/i4} + d_6 G_S^{(i4-1)/i4} + d_7 G_W^{(i4-1)/i4})^{i4/(i4-1)}) = 0 \]
The following first order conditions result:

\[
\begin{align*}
P_{GN} + L(*) + d_4 G_N^{-1/i4} &= 0 \\
P_{GM} + L(*) + d_5 G_M^{-1/i4} &= 0 \\
P_{GS} + L(*) + d_6 G_S^{-1/i4} &= 0 \\
P_{GW} + L(*) + d_7 G_W^{-1/i4} &= 0 \\
\end{align*}
\]

where 
\[
(**) = (d_4 G_N^{i(i4-1)/4} + d_5 G_M^{i(i4-1)/4} + d_6 G_S^{i(i4-1)/4} + d_7 G_W^{i(i4-1)/4})^{i4/(i4-1)}
\]

Units of Goods in the benchmark period have been constructed so that 1 unit cost approximately $1, so that the following approximation is used:

\[
P_{GN} = P_{GM} = P_{GS} = P_{GW} = \$1
\]

With this information, the first order conditions can be used to solve for \(d_4, d_5, d_6, \text{ and } d_7\).

(Also recalling that \(d_4 + d_5 + d_6 + d_7 = 1\))

\[
d_4 = 1 + \frac{G_M^{-1/i4} + G_S^{-1/i4} + G_W^{-1/i4}}{G_N^{-1/i4}} = 0.47179
\]

\[
d_5 = 1 + \frac{G_N^{-1/i4} + G_S^{-1/i4} + G_W^{-1/i4}}{G_M^{-1/i4}} = 0.07367
\]

\[
d_6 = 1 + \frac{G_M^{-1/i4} + G_N^{-1/i4} + G_W^{-1/i4}}{G_S^{-1/i4}} = 0.24661
\]

\[
d_7 = 1 + \frac{G_M^{-1/i4} + G_S^{-1/i4} + G_N^{-1/i4}}{G_W^{-1/i4}} = 0.20792
\]

Thus GOOD_H is now calibrated: (Recall from ch. 5 that \(i_4 = 3\))
GOODH = (.47179G_N^{(3-1)/3} + .07367G_M^{(3-1)/3} + .24661G_S^{(3-1)/3} + .20792G_W^{(3-1)/3})^{3/(3-1)}

The numerical estimate for \(d_2\) is straightforward, due to the nature of the Cobb-Douglas PRIV_H portion of the utility function:

\[
d_2 = \frac{\text{total expenditures on Goods}}{\text{total expenditures on Goods} + \text{total expenditures on Services}} = .80586
\]

Thus \(PRIV_H = (GOOD_H^{.80586} \times V(1-.80586))\)

The numerical estimate for \(d_3\) is not as straightforward. Since both Regional Public Goods and Federal Public Goods are provided to citizens without per-unit user charges, it would be inaccurate to claim that the proportion of national expenditures used to produce these goods reveals the nature of their utility to consumers, since the consumers do not "buy" the Public Goods. Nevertheless, I shall use these expenditure proportions to garner an estimate for \(d_3\). (One possible excuse: democratically-elected government representatives accurately reflect the preferences of their constituents by providing the utility-maximizing amount of Public Goods.)

\[
d_3 = \frac{\text{total expenditures on Regional Public Goods}}{\text{total expenditures on Regional and Federal Public Goods}} = .52694
\]

Thus \(PUBL_H = (R^{.52694} \times F(1-.52694))\)
(Digression concerning the Federal Public Good: As you may recall, I have assumed that the Federal Public Good is a pure public good—that is, non-rival and non-excludable. I have also defined in the production sectors of my CGE economy that 1 unit of product costs $1 in the benchmark period. Similarly for consumers, I am defining that 1 unit of product consumed costs approximately $1 in the benchmark period, for the Goods, Services, and Regional Public Goods. I am, however, breaking the $1-per-unit convention for Federal Public Goods consumed. The reason is straightforward; since each consumer can consume the entire national production of a pure public good, the sheer size of the Federal Public Good share of each household's total consumption would be overwhelming if I maintained the 1-unit-per-dollar convention. I am therefore scaling down the units of Federal Public Goods, as follows:

\[ \text{Per-household consumption of the Federal Pure Public Good, in units} = \frac{\text{Real National Expenditures on the Pure Public Good}}{\text{National Population of Households}} \]

(End of digression concerning the Federal Public Good.)

Finally, a numerical estimate for \( d_1 \) can be had by setting up the LaGrangean:

\[ P_{PRIVH}^{PRIVH} + P_{PUBLH}^{PUBLH} + \ln \left( d_1 P_{PRIVH}^{(i1-1)/i1} + (1-d_1) P_{PUBLH}^{(i1-1)/i1} \right) = 0 \]

First order conditions reveal:

\[ P_{PRIVH} = d_1 P_{PRIVH}^{-1/i1} \]
\[ P_{PUBLH} = (1-d_1) P_{PUBLH}^{-1/i1} \]
Since the shadow prices, \( P_{PRIV} \) and \( P_{PUBL} \) both are approximately one, we can approximate:

\[
d_1 = \frac{PUBL^{-1/11}}{(PUBL^{-1/11} + PRIV^{-1/11})} = 0.8415574
\]

Thus the utility function for every household has been calibrated: (recall that \( i1 = 0.8 \))

\[
U_H = (0.8415574PRIV_H^{0.8-1/0.8} + (1-0.8415574)PUBL_H^{0.8-1/0.8})^{8/(8-1)}
\]

where

\[
PRIV_H = (GOOD_H^{80586} \times V^{(1-80586)})
\]

\[
GOOD_H = (0.47179G_N^{(3-1)/3} + 0.07367G_M^{(3-1)/3} + 0.24662G_S^{(3-1)/3} + 0.20793G_W^{(3-1)/3})^{3/(3-1)}
\]

\[
PUBL_H = (R^{-52694} \times F^{(1-52694)})
\]

Our next mission is to use this calibrated utility function to estimate utilities for representative Rich and Poor households in each region. This mission requires an estimate for \( PUBL_H \), \( GOOD_H \), and \( PRIV_H \) for each type of household in each region.

First, consider \( PUBL_H \). Within each region each household receives the same quantity of (completely congested) Regional Public Good. Each household in the nation receives the same quantity of (pure) Federal Public Good. A household's Regional Public Good consumption generally equals:

\[
R = \frac{\text{Production of Regional Public Good in the Region}}{\text{Regional Population}^j}
\]

where "\( j \)" is the congestion factor of the good. (Recall that "\( j \)" is assumed to equal 1.)
A household's consumption of the non-rival Federal Public Good equals the national production of that good (321,221 million units), divided by the national population (see the digression on the previous page).

Here are the estimates for \( \text{PUBL}_H \) received by each household in each region in the benchmark period:

Nor-Mid: 3090.03  
Texas: 2847.25  
South: 2912.63  
West: 3144.87

Now an estimate for \( \text{PRIV}_H \) is needed for representative Rich and Poor households in each region. A necessary step to arrive at this estimate is to divide each region's Services production among the households living in the region (Recall that Services are not inter-regionally traded). Since each household has the same homothetic utility function (and since there is no price discrimination), each household should spend the same proportion of its disposable income on Services. I shall first allocate Services between All Rich households and All Poor Households by dividing total regional disposable income between the two groups. Generally, that division is:

\[
\text{Rich Percentage} = \frac{\text{Total Disposable Income of Rich Households in the Region}}{\text{Total Disposable Income of All Households in the Region}}
\]

\[
\text{Poor Percentage} = 100\% - \text{Rich Percentage}
\]

Here are the estimates:

\[
\begin{array}{lcc}
\text{Nor-Mid:} & \text{Texas:} \\
\text{Rich} & .4986057 & \text{Rich} & .5080749 \\
\text{Poor} & .5013943 & \text{Poor} & .4919251 \\
\end{array}
\]
South:
Rich .5118533
Poor .4881467

West:
Rich .5031378
Poor .498622

Using these percentages, Services are allocated among *All Rich Households* and *All Poor households* as follows: (Millions of Units)

Nor-Mid:
Rich \( .4986057 \times 332642 \) = 165857.2
Poor = 166784.8

Texas:
Rich \( .5080749 \times 44649 \) = 22685.036
Poor = 21963.964

South:
Rich \( .5118533 \times 158300 \) = 81026.377
Poor = 77273.623

West:
Rich \( .5031378 \times 164,596 \) = 82,814.469
Poor = 81,781.531

Dividing the above numbers by the population of Rich and Poor households in each region will give the amount of Services purchased by each type of household in each region. Here are those estimates:

**Services ("\( V_H \") Consumed by Each Household**

Nor-Mid:
Rich = 16265.68
Poor = 3878.67

Texas:
Rich = 17697.00
Poor = 4089.16

South:
Rich = 15148.87
Poor = 3435.19

West:
Rich = 18,186.32
Poor = 4,211.25

Next, an estimate for \( \text{GOOD}_H \) for each household is required; thus production of the four inter-regionally traded Goods (\( G_N, G_M, G_S, \) and \( G_W \)) needs to be allocated to
each household in each region. A first step will be to determine the amount of disposable income that the groups *All Rich Households* and *All Poor Households* in each region have remaining after their purchases of Services. Generally, each estimate is:

Disposable Income of the Group - $ Spent on Services by the Group

Here are the numbers: (Millions)

<table>
<thead>
<tr>
<th>Region</th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-Mid</td>
<td>720394</td>
<td>724423.7</td>
</tr>
<tr>
<td>Texas</td>
<td>88610.98</td>
<td>83860.02</td>
</tr>
<tr>
<td>South</td>
<td>356753.3</td>
<td>336503.7</td>
</tr>
<tr>
<td>West</td>
<td>302838.2</td>
<td>299709.8</td>
</tr>
</tbody>
</table>

Total: 2,910,457

Now each group of households' remaining disposable income, as a percentage of the national total (2,910,457 from above), is estimated. Here are those numbers:

<table>
<thead>
<tr>
<th>Region</th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-Mid</td>
<td>.247519</td>
<td>.248904</td>
</tr>
<tr>
<td>Texas</td>
<td>.029759</td>
<td>.028813</td>
</tr>
<tr>
<td>South</td>
<td>.122576</td>
<td>.115619</td>
</tr>
<tr>
<td>West</td>
<td>.104052</td>
<td>.102758</td>
</tr>
</tbody>
</table>
Now, total national production of $G_N$, $G_M$, $G_S$, and $G_W$ are allocated to each group of households based upon each group's percent of remaining disposable income. Here are those numbers: (Millions)

<table>
<thead>
<tr>
<th>Region</th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$G_N$</td>
<td>$G_N$</td>
</tr>
<tr>
<td></td>
<td>$G_M$</td>
<td>$G_M$</td>
</tr>
<tr>
<td></td>
<td>$G_S$</td>
<td>$G_S$</td>
</tr>
<tr>
<td></td>
<td>$G_W$</td>
<td>$G_W$</td>
</tr>
<tr>
<td>Nor-Mid</td>
<td>339407</td>
<td>341305</td>
</tr>
<tr>
<td></td>
<td>52995</td>
<td>53291</td>
</tr>
<tr>
<td></td>
<td>177418</td>
<td>178411</td>
</tr>
<tr>
<td></td>
<td>149581</td>
<td>150418</td>
</tr>
<tr>
<td>Texas</td>
<td>40805</td>
<td>39509</td>
</tr>
<tr>
<td></td>
<td>6371</td>
<td>6169</td>
</tr>
<tr>
<td></td>
<td>21330</td>
<td>20653</td>
</tr>
<tr>
<td></td>
<td>17983</td>
<td>17412</td>
</tr>
<tr>
<td>South</td>
<td>168081</td>
<td>158540</td>
</tr>
<tr>
<td></td>
<td>26244</td>
<td>24754</td>
</tr>
<tr>
<td></td>
<td>87861</td>
<td>82874</td>
</tr>
<tr>
<td></td>
<td>74075</td>
<td>69871</td>
</tr>
<tr>
<td>West</td>
<td>142679</td>
<td>140905</td>
</tr>
<tr>
<td></td>
<td>22278</td>
<td>22001</td>
</tr>
<tr>
<td></td>
<td>74582</td>
<td>73655</td>
</tr>
<tr>
<td></td>
<td>62880</td>
<td>62099</td>
</tr>
</tbody>
</table>

Now by dividing the above numbers by the population of Rich and Poor households in each respective region, an estimate of purchases of $G_N$, $G_M$, $G_S$, and $G_W$ by each household in each region is arrived at. Here are those numbers:
### Goods Purchased by Each Household in Each Region

<table>
<thead>
<tr>
<th>Region</th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-Mid</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$G_N$ 33285</td>
<td>$G_N$ 7937</td>
</tr>
<tr>
<td></td>
<td>$G_M$ 5197</td>
<td>$G_M$ 1239</td>
</tr>
<tr>
<td></td>
<td>$G_S$ 17399</td>
<td>$G_S$ 4149</td>
</tr>
<tr>
<td></td>
<td>$G_W$ 14669</td>
<td>$G_W$ 3498</td>
</tr>
<tr>
<td>South</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$G_N$ 31424</td>
<td>$G_N$ 7047</td>
</tr>
<tr>
<td></td>
<td>$G_M$ 4906</td>
<td>$G_M$ 1100</td>
</tr>
<tr>
<td></td>
<td>$G_S$ 16426</td>
<td>$G_S$ 3684</td>
</tr>
<tr>
<td></td>
<td>$G_W$ 13849</td>
<td>$G_W$ 3106</td>
</tr>
<tr>
<td>Texas</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$G_N$ 31833</td>
<td>$G_N$ 7355</td>
</tr>
<tr>
<td></td>
<td>$G_M$ 4970</td>
<td>$G_M$ 1148</td>
</tr>
<tr>
<td></td>
<td>$G_S$ 16640</td>
<td>$G_S$ 3845</td>
</tr>
<tr>
<td></td>
<td>$G_W$ 14029</td>
<td>$G_W$ 3241</td>
</tr>
<tr>
<td>West</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$G_N$ 31332</td>
<td>$G_N$ 7255</td>
</tr>
<tr>
<td></td>
<td>$G_M$ 4892</td>
<td>$G_M$ 1132</td>
</tr>
<tr>
<td></td>
<td>$G_S$ 16378</td>
<td>$G_S$ 3792</td>
</tr>
<tr>
<td></td>
<td>$G_W$ 13808</td>
<td>$G_W$ 3197</td>
</tr>
</tbody>
</table>

Finally, plugging in these values of $G_N$, $G_M$, $G_S$, and $G_W$ into the calibrated equation for $\text{GOOD}_H$ (i.e. $\text{GOOD}_H = (0.47179G_N^{(3-1)/3} + 0.07367G_M^{(3-1)/3} + 0.24661G_S^{(3-1)/3} + 0.20792G_W^{(3-1)/3})^{(3-1)})$

results in an estimate for $\text{GOOD}_H$ for each household in each region. Here are the numbers:

### $\text{GOOD}_H$ for Each Household in Each Region

<table>
<thead>
<tr>
<th>Region</th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-Mid</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$= 22647$</td>
<td>$= 5400$</td>
</tr>
</tbody>
</table>
Texas:
   Rich = 21659
   Poor = 5004

South:
   Rich = 21381
   Poor = 4795

West:
   Rich = 21319
   Poor = 4936

These estimates for GOODH can be used with the previously-determined estimates of VH—plugged into the calibrated equation

\[ \text{PRIVH}_H = (\text{GOODH}_H^{0.80586} \times V^{(1-0.80586)}) \]

--to get numerical estimates for the PRIVH

Goods/Services consumption bundle for each household in each region. Here are those numbers:

**PRIVH Goods/Services Bundle for Each Household**

Nor-Mid:
   Rich = 21238
   Poor = 5064

Texas:
   Rich = 20826
   Poor = 4812

South:
   Rich = 19998
   Poor = 4495

West:
   Rich = 20671
   Poor = 4786

To end the household calibration portion of this chapter, estimates for PRIVH and PUBLH developed above will be used in the equation

\[ U_H = (0.8415574\text{PRIVH}_H^{(0.8-1)/0.8} + (1-0.8415574)\text{PUBLH}_H^{(0.8-1)/0.8})^{0.8/(0.8-1)} \]

calibrated above to estimate household utilities for each household in each region. Here are those estimates. Phew.
### Household Utilities in Each Region

<table>
<thead>
<tr>
<th>Region</th>
<th>Status</th>
<th>Utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nor-Mid</td>
<td>Rich</td>
<td>14606</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>4663</td>
</tr>
<tr>
<td>South</td>
<td>Rich</td>
<td>13756</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>4282</td>
</tr>
<tr>
<td>Texas</td>
<td>Rich</td>
<td>14115</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>4407</td>
</tr>
<tr>
<td>West</td>
<td>Rich</td>
<td>14365</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>4465</td>
</tr>
</tbody>
</table>

**Rich Utility Shift Parameters:** One assumption of the theoretic description of my CGE model (as seen in chapter 5) is that Rich households may locate themselves among regions to equalize Rich utilities in all regions. The utility information above is inconsistent with this assumption. The numbers above, however, do not necessarily refute the utility-equalizing assumption; instead, my model's high degree of aggregation and calibration may have resulted in an error in utility measurement. To correct for this possible measurement error, I shall calculate "shift parameters." The product of the scale parameters multiplied by the Rich utility estimates above, will "scale up" Rich households' utilities in Texas, the South, and the West, so that Rich households' utilities will then be equal across regions.

### Shift Parameters

- For Rich Utility in South = \( \frac{14606}{13756} \) = 1.06176
- For Rich Utility in Texas = \( \frac{14606}{14115} \) = 1.0348
- For Rich Utility in West = \( \frac{14606}{14365} \) = 1.01681

**Governments' Tax revenues and Expenditures**
Below will be listed each government's revenues and expenditures, showing that each government's budget is balanced.

Nor-Mid Regional Government:

Tax Revenue:

<table>
<thead>
<tr>
<th>From Business</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Taxes</td>
<td>24311</td>
</tr>
<tr>
<td>Labor Taxes</td>
<td>7036</td>
</tr>
<tr>
<td>Corporation Taxes</td>
<td>13003</td>
</tr>
<tr>
<td>Sales Taxes</td>
<td>65905</td>
</tr>
<tr>
<td>From Households</td>
<td>94973</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>205228</strong></td>
</tr>
</tbody>
</table>

Expenditures:

<table>
<thead>
<tr>
<th>Expenditures</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer Payments</td>
<td>29905</td>
</tr>
<tr>
<td>Public Good</td>
<td>175323</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>205228</strong></td>
</tr>
</tbody>
</table>

Texas Regional Government:

Tax Revenue:

<table>
<thead>
<tr>
<th>From Business</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Taxes</td>
<td>2959</td>
</tr>
<tr>
<td>Labor Taxes</td>
<td>713</td>
</tr>
<tr>
<td>Corporation Taxes</td>
<td>0</td>
</tr>
<tr>
<td>Sales Taxes</td>
<td>12706</td>
</tr>
<tr>
<td>From Households</td>
<td>4718</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21096</strong></td>
</tr>
</tbody>
</table>

Expenditures:

<table>
<thead>
<tr>
<th>Expenditures</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer Payments</td>
<td>2323</td>
</tr>
<tr>
<td>Public Good</td>
<td>18773</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21096</strong></td>
</tr>
</tbody>
</table>

South Regional Government:

Tax Revenue:
From Business:
- Capital Taxes: 9179
- Labor Taxes: 2832
- Corporation Taxes: 3971
- Sales Taxes: 39906
From Households: 34757
Total: 90645

Expenditures:
- Transfer Payments: 8621
- Public Good: 82024
Total: 90645

West Regional Government:

Tax Revenue:

From Business:
- Capital Taxes: 8318
- Labor Taxes: 3313
- Corporation Taxes: 5673
- Sales Taxes: 34051
From Households: 40850
Total: 92205

Expenditures:
- Transfer Payments: 10513
- Public Good: 81692
Total: 92205

Federal Government:

Tax Revenue:

From Business:
- Capital Taxes: 0
- Labor Taxes: 131,288
- Corporation Taxes: 61,300
From Households: 637,050
Total: 829,538

Expenditures:
- Transfer Payments: 508,318
- Public Good: 321,220
Total: 829,538
The model in chapter 5 has now been calibrated with data from chapter 6 to represent a modern U.S. economy in equilibrium. The model is now ready to undergo computer simulations of changes in tax policy. In chapters 8 and 9 several simulations will be undertaken and examined to look at the effects of various tax policy changes.
VOLUME II

A MULTI-REGION COMPUTATIONAL GENERAL EQUILIBRIUM MODEL
OF THE UNITED STATES, USED FOR SUB-NATIONAL TAX POLICY ANALYSIS

by

MICHAEL F. WILLIAMS
8. General Equilibrium Simulations of Sub-national
     Tax Incidence

This chapter will summarize and display results gleaned from two groups of simulations. The first group of simulations (#1-#20) is meant to examine the revenue-raising options of a sub-national government that wishes to change its tax collections level by changing one of its tax rates. Among the issues that will be examined in this group of simulations are:

--The relative merits and demerits of each of a region's (five) tax instruments as revenue enhancing mechanisms. A region's government may, for example, desire to increase tax revenue in a way that is "least painful" to some or all of the region's residents.

--Whether the size of a region's economy relative to the size of the national economy has any influence on the relative merits or demerits of each of the five tax instruments. It may be useful to know, for example, whether a relatively large region should adopt a different tax strategy than a relatively small region.

--How the migratory reaction of a region's wealthy residents to a tax change influences the effects of that tax change on households. Indeed, the short run effects of a tax change may differ markedly from the long run effects, if interregional migration responses to sub-national tax changes do not occur immediately after a tax change.

The second group of simulations (#21-#24) focus more closely on two of the five tax instruments--the business capital tax and the household income tax. An interesting result of the first group of simulations is the relative preference of the business capital tax (in most cases) over the household income tax as a revenue-raising instrument. This second group of simulations attempts to examine whether this preference still holds under differential incidence--when one of the taxes is substituted for the other, holding total tax
collections constant. Again, in this group of simulations, issues of region size and Rich
migration patterns are examined.

The two groups of simulations are examined extensively below.

*Simulation Group 1: Balanced Budget Incidence*

In a nation with many sub-national governments, a single sub-national government
that wishes to increase its tax revenues has many things to consider. It must choose which
types of tax rates that it will raise. It may consider the extent to which a particular tax
increase causes an erosion of the tax base, as taxed entities flee the governed area. It may
also consider how the governed area's citizens will be affected; the tax increase may affect
each household differently, since households may have widely varying sources of income.

I have used my computational general equilibrium model of the U.S. to simulate the
economic effects that may occur when a regional government increases one of its tax
instruments in order to increase its tax revenues by twenty-five percent. The tax revenues
augment the government's budget, and the government spends the new revenue so that its
pattern of spending remains the same (i.e. it is spending 25% more on each type of
government expenditure).

Each region in my CGE model has five tax instruments that it can increase in order
to raise additional revenue:

--A tax on the labor payments of producers (i.e. a wage tax).
--A tax on the capital payments of producers (a business capital tax).
--A corporation income tax
--An origin-based sales tax.
--A tax on the income of households.

I have undertaken twenty simulations. Ten of the simulations examine the
economic effects that occur when the Texas regional government increases one of its five
tax instruments in order to increase its tax revenue by 25%. In the other ten simulations, I
undertake a similar evaluation for the Northeast/Midwest regional government; I examine
the effects that will occur if they increase one of their five tax instruments in order to
increase tax revenue by 25%.¹

In half of the simulations, I assume that Rich households are inter-regionally
mobile; in the other half, I assume that they are immobile. By comparing a pair of
simulations which are identical except for the household mobility assumption, one can
analyze how important this assumption is in determining the effects of the tax policy
changes simulated in this chapter.

(Table 8.1 lists each of the twenty simulations.)

Each of these 20 simulations is separately compared to the benchmark equilibrium.
In table 8.2, I have listed how each tax affects:

--the utility of Rich and Poor households in the tax-augmented region, when
compared to the benchmark equilibrium. In fact, in all 20 simulations the tax increases
cause a reduction in the utilities of the Rich and Poor households living in the tax-
augmented region.

--the earned income of "hypothetical" households. Each hypothetical household
has the same total earned income as its "real" counterpart in the benchmark equilibrium,
but the sources of the income of the hypothetical households are different from the income
sources of the "real" households. There are 3 types of hypothetical households: one
whose earn income is derived entirely from capital, one whose earned income is derived
entirely from labor, and one whose earned income is derived 50% from capital and 50%
from labor in the benchmark period.

¹I picked these regions due to their size differences; Texas is the smallest region and the
Northeast/Midwest is the largest. Some theoretical literature has suggested that a region's size may be an
important determinant of the effects of its taxes. See, for example, Wheaton (1994).
The purpose of creating these hypothetical households is to examine how the tax incidence of each type of tax varies as the capital/labor earnings ratio of a household varies. In effect, use of these households is an attempt to overcome the limitations of having only two types of "real" households--Rich and Poor--in my model. This high degree of aggregation may miss some of the real-world distribitional implications of the various tax augmentation policies simulated in this chapter. In the modern United States, for example, each Rich household does not earn its capital income and labor income in exactly the same proportion as every other Rich household in America--yet this artificially identical capital/labor earnings ratio is an assumption of my CGE model. This artificial assumption restricts my model's ability to examine how a tax policy affects households with similar incomes but with different sources of their income. For example, a Rich household that earns its income entirely from capital may be more negatively affected by a capital tax than a Rich household that earns most of its income from labor. Without the hypothetical households, it would be impossible to investigate how a variation in the sources of income of households affects the welfare of households with similar incomes. Hence, use of hypothetical households partially overcomes one of the limitations of my model--its high degree of aggregation of household types.

As I interpreted the results of the 20 simulations, three major themes emerged:

1. The mobility/non-mobility assumption is critical in determining the effects of the various tax increases. Rich households suffer higher utility losses if they are not mobile among regions; Poor households suffer lower utility losses if the Rich are not mobile. Indeed, if Rich migration does not occur immediately after a tax change, then this result suggests caution in interpreting the economic effects of sub-national tax changes using only a few years of economic activity subsequent to the tax change.

2. It is usually true that raising revenue with a capital tax on business causes a smaller reduction in utility than raising revenue with a household income tax. For Rich
households, the difference in the effects of the two taxes on utility is more pronounced when the Rich are immobile; the Rich, in every case in which they are immobile, would much prefer that their regional government raise revenue with business capital taxes rather than household taxes. For Poor households, the difference is more pronounced when the Rich are mobile; the Poor's utility loss from household taxation is far greater than their loss under business capital taxation when the Rich are mobile.

3. The results in the above paragraph may not hold if the capital/labor earnings ratios of the households are varied, as they are with the three types of hypothetical households. Generally, households with capital-only earnings are harmed more by the business capital tax than by the household income tax. The opposite results holds for households with labor-only earnings; they are harmed greatly by the household income tax, but harmed relatively lightly by the business capital tax.

In the next part of this chapter, I shall offer reasons why a regional government may wish to augment its revenue, even though it invariably reduces the utilities of the region's residents. Next, I shall offer my interpretations of the results of each of simulations 1-20. Finally, I shall compare and contrast the results of the simulations, paying special attention to the three themes listed above: the importance of the mobility vs. immobility assumption of Rich households, the divergence in the effects of household taxes vis-a-vis business capital taxes, and the importance of the capital/labor earnings ratio of households when determining how they are affected when various taxes are increased.

Regional Governments and Revenue Enhancement

Since I have already mentioned that, in all twenty simulations, tax augmentation by the regional governments reduces the welfare of Rich and Poor citizens in the tax-raising region, one might question why any regional government would ever increase any of its
tax rates above those that existed in the benchmark equilibrium. There are many possible explanations for this behavior.

One possible explanation is that government officials are more concerned with maximizing the sizes of their own budgets than with maximizing the utilities of their constituents.² If this were true, then government officials would attempt to obtain the maximum possible government budget that is consistent with their reelection—not the utility-maximizing budget size.

Another possible explanation is that government officials are not fully informed as to the effects of a tax policy change. They could mistakenly believe that a tax increase would increase the utilities of the region's residents. Similarly, it is possible that the median voter holds this mistaken belief; in such a case, elected officials may be forced to undertake revenue enhancement in order to remain in office.

Another explanation might be that segmented powerful special interest groups dominate a government official's behavior. Or, perhaps logrolling results in a greater than optimal budget.

Finally, the relative simplicity of my CGE model may be to blame for the appearance that all households in a region are harmed when taxes are increased; the reality may be that some households benefit while other households are harmed. Of particular concern is the high level of aggregation of household types in my CGE model; there are only two, Rich and Poor. Since Rich households are homogeneous, each has an identical ratio of capital-to-labor factor endowment; hence each earns an identical proportion of its income from capital and an identical portion from labor (In fact, each Rich household earns the majority of its income from capital, and a minority from labor). This same result holds for Poor households (though each Poor household earns the majority of its income from labor). This circumstance obfuscates the real-world situation in which many types

²See Niskanen (1971).
of households have widely diverse income sources; for example, some earn virtually all of
their income from capital, while others earn virtually all of their income from labor.

To ameliorate the household aggregation problem in my model I have created the
three types of hypothetical households mentioned earlier in this chapter. These
hypothetical households exist solely to aid in the understanding of how tax changes affect
households with different income sources ex post; the households have no effect on a
region's factor supplies, factor earnings, or product demands, nor do they in any way
influence the results of the computer simulations ex ante.

In any event, the main purpose of this chapter is not to determine whether it is in
the best interests of a region's residents for a regional government to increase its revenue
and expenditures. The purpose of this chapter is to compare the five tax instruments of a
regional government with one another. The more important results, therefore, are not
how each tax instrument affects the economy relative to the benchmark equilibrium, but
rather how the effects of one tax instrument compare relative to the effects of the other
four tax instruments. (Indeed, I could have undertaken twenty simulations in which tax
revenues were reduced by 25% rather than increased by 25%, since comparison of the five
tax instruments would be just as possible under revenue diminution as it is under revenue
enhancement.)

With this in mind, I shall now briefly summarize the results of the twenty
simulations.

Analysis of the Simulations

Before beginning the analysis of each individual simulation, it is helpful to note that
any tax change affects the utility of a household in a number of different (and
simultaneous) ways. For clarity, I will (somewhat artificially) separate the effects into the
following types:
--The "factor price effect:" An alteration of a tax rate may alter the per unit earnings of a factor relative to other factors, and hence alter the factor earnings of a household. If, for example, a tax change reduces the per unit return to unskilled labor, then an important source of the Poor’s earnings will be diminished, and the Poor’s purchasing power and utility will be diminished (ceteris paribus).

--The "product price effect:" Another effect of a tax change may be to elevate or diminish the average price level of products in the region and nation. This inflation (or deflation) will alter the real purchasing power of households; inflation, for example, reduces purchasing power (ceteris paribus). This effect also implies that a tax increase in one region can be partially "shifted forward" to residents of other regions in the form of a higher product price for goods exported to other regions.

--The "capital migration" effect: Capital is the most mobile factor in my CGE model in all cases, since it does not have the burden of taking a household tax liability along when it relocates among regions. Any tax change in a region will alter the amount of capital used in the region, and this will affect the region’s residents. For example, a tax which drives capital out of the region will reduce the region’s tax base, putting an additional tax burden on the households and factors that remain in the region. This could reduce the utilities of the region’s households (ceteris paribus).

--The "progressive subsidy effect:" In the benchmark equilibrium Rich households in a regions subsidize the utilities of Poor households in the region through a progressive household tax and transfer payment scheme; Rich households pay a larger portion of their income in taxes, and Poor households receive a larger per capita transfer payment. Therefore, if household tax rates are altered from their benchmark levels, this progressive subsidy will be altered as well. If a region’s household tax rates were raised, for example, then the Rich’s subsidy to the Poor would increase. This would benefit Poor households at the expense of Rich ones (ceteris paribus).
--The "Rich migration effect:" In simulations where Rich households are inter-regionally mobile, a tax change will induce a relocation of Rich households among regions. An influx of Rich households into a region can affect the utilities of Poor households in the region in many ways. For example, the higher population of Rich households may help relieve the portion of the region's tax burden that is borne by Poor households. The Rich immigration may also affect the Poor's labor earnings by increasing (or decreasing) the marginal product of unskilled labor in the region. (An outflow of Rich households would have the opposite effects.) This "Rich migration effect" is indeed a powerful force, as will be seen later in the chapter when the results of different simulations are shown to be substantially altered solely due to different assumptions about the inter-regional mobility of Rich households.

Each of the effects listed above can be beneficial or harmful to households. The overall effect of a tax change—whether it adds to or subtracts from a household’s utility—hinges upon whether the positive effects outweigh the negative ones.

In all of the simulations in this chapter, the negative effects dominate, and household utility is diminished in the taxing region; however, some tax changes are more deleterious than others. As I examine the results of each simulation, I shall mention in each instance the extent to which each effect—the factor price effect, the product price effect, the capital migration effect, the progressive subsidy effect, and (in simulations in which Rich households are mobile) the Rich migration effect—is positive or negative to Rich and Poor households in the taxing region. I shall also quantify each effect when possible, in the following fashion:

--The factor price effect: For the Rich, I shall list the percentage increase or decrease to the nominal per unit return to skilled labor, compared to the benchmark equilibrium. For the Poor, I shall list a similar measure for unskilled labor.3

---

3Since capital is the never-changing numeraire in my model, its nominal per unit return never changes.
-- The Product price effect: I shall list in parentheses the percentage increase or
decrease in the national average price level of the sixteen products, compared to the
benchmark equilibrium.

-- The Capital migration effect: I shall list in parentheses the percentage increase or
decrease in the amount of capital used in the region, compared to the benchmark
equilibrium.

-- The Rich migration effect: In simulations in which Rich households are inter-
regionally mobile, I shall list the percentage increase or decrease in the region's Rich
population, compared to the benchmark equilibrium.

-- Utilities: I shall list the percentage increase or decrease in household utilities,
compared to the benchmark equilibrium.

Table 8.3 lists a summary of these five effects in each of the twenty simulations.
These effects are listed and interpreted below for each simulation individually.

Simulations 1-5: Texas increases tax revenue; Rich are inter-regionally immobile

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>-.4%</td>
<td>-.1%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative (+.3%)</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative (-4.3%)</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>Utility</td>
<td>-.66%</td>
<td>-.23%</td>
</tr>
</tbody>
</table>

In this simulation, returns to skilled labor and unskilled labor decrease slightly.
Product prices increase as well, so households' real earned income in the region falls.
A
further negative effect is an emigration of capital caused by the higher capital tax rate. Overall, the negative effects cause utilities to fall.

**Simulation 2: Texas business labor tax increased; Rich immobile**

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>-4.3%</td>
<td>-4.3%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative (+.03%)</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Positive</td>
<td>Positive (+.2%)</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>Utility</td>
<td>-1.13%</td>
<td>-1.83%</td>
</tr>
</tbody>
</table>

In this simulation, returns to skilled labor and unskilled labor fall slightly due to the business tax on labor. Also, product prices increase, so households' real earned income in the region falls. These negative effects are slightly offset by an immigration of capital, as producers substitute away from the higher taxed labor into capital. Overall, the negative effects outweigh the positive ones.

**Simulation 3: Texas corporate tax increased; Rich immobile.**

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>-1.9%</td>
<td>-1.7%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative (+.2%)</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative (-2.6%)</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>Utility</td>
<td>-1.03%</td>
<td>-1.17%</td>
</tr>
</tbody>
</table>

In this simulation, returns to skilled labor and unskilled labor decrease slightly. Product prices increase also, so households' real earned income in the region falls. A
further negative effect is an emigration of capital caused by the higher corporate tax rate. Overall, the negative effects cause utilities to fall.

Simulation 4: Texas sales tax increased; Rich immobile

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>-2.1%</td>
<td>-1.9%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative (+.2%)</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative (-2.8%)</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>Utility</td>
<td>-1.08%</td>
<td>-1.28%</td>
</tr>
</tbody>
</table>

In this simulation, returns to skilled labor and unskilled labor decrease slightly. Product prices increase also, so households' real earned income in the region falls. A further negative effect is an emigration of capital caused by the higher sales tax; this origin-based tax reduces the demand for Texas exports (by raising export prices) and reduces the demand for capital by Texas exporters. Overall, the negative effects cause utilities to fall.

Simulation 5: Texas household tax increased; Rich immobile.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>+1.2%</td>
<td>+1.2%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative (+.02%)</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Positive</td>
<td>Positive (+.3%)</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>Utility</td>
<td>-3.28%</td>
<td>-.40%</td>
</tr>
</tbody>
</table>

In this simulation, returns to skilled labor and unskilled labor increase slightly. This may be because an influx of capital into the region increases the marginal product of
labor. (The capital is needed to help produce the higher level of regional government goods that is facilitated by the higher regional tax revenue.) Product prices increase by a smaller percentage, so households’ real earned income in the region increases. For Rich households, this positive result is offset by an increase in the progressive subsidy effect; the Rich are paying higher personal taxes, but the bulk of their tax contribution goes to help the Poor. The Poor, on the other hand, welcome this effect; it almost (but not quite) completely offsets the negative effects for them. Overall, the negative effects outweigh the positive ones for both the Rich and the Poor.

**Simulations 6-10: Nor/Mid increases tax revenue; Rich are inter-regionally immobile**

<table>
<thead>
<tr>
<th>Simulation 6: Northeast/Midwest business capital tax increased; Rich immobile.</th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>+2.0%</td>
<td>+2.2%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative (+2.7%)</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative (-4.0%)</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>Utility</td>
<td>-2.08%</td>
<td>-.83%</td>
</tr>
</tbody>
</table>

In this simulation, returns to skilled labor and unskilled labor increase slightly as producers substitute labor for the higher-taxed capital. However, product prices increase by a greater percentage, so households' real earned income in the region falls. A further negative effect is an emigration of capital caused by the higher capital tax rate. Overall, the negative effects outweigh the positive ones.

**Simulation 7: Northeast/Midwest business labor tax increased; Rich immobile**

<table>
<thead>
<tr>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Factor price effect: -4.4% -4.4%
Product price effect: Negative Negative (+.2%)
Capital Migration effect: Positive Positive (+.3%)
Progressive subsidy effect: Neutral Neutral
Utility -1.63% -2.44%

In this simulation, returns to skilled labor and unskilled labor fall by about 4.5% due to the business tax on labor. Average product prices remain about the same, but due to the reduced labor returns, households' real earned income in the region falls. These negative effects are slightly offset by an immigration of capital, as producers substitute away from the higher taxed labor into capital. Overall, the negative effects outweigh the positive ones.

Simulation 8: Notheast/Midwest corporate tax increased; Rich immobile.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>-1.5%</td>
<td>-1.3%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative (+1.5%)</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative (-2.0%)</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>Utility</td>
<td>-2.15%</td>
<td>-1.97%</td>
</tr>
</tbody>
</table>

In this simulation, returns to skilled labor and unskilled labor fall slightly, as national demand for the Northeast/Midwest region's export goods fall (due to their higher price), reducing the demand for labor in the region. Product prices increase, so households' real earned income in the region falls. A further negative effect is an emmigration of capital caused by the higher corporate tax rate. These negative effects reduce the utilities of both Rich and Poor in the Northeast/Midwest.
Simulation 9: Northeast/Midwest sales tax increased; Rich immobile.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>-1.6%</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>Utility</td>
<td>-2.24%</td>
<td>-2.10%</td>
</tr>
</tbody>
</table>

In this simulation, returns to skilled labor and unskilled labor decrease slightly, as the origin-based sales tax reduces demand for the region's exports, reducing demand for labor in that production sector. Product prices increase, so households' real earned income in the region falls. A further negative effect is an emmigration of capital caused by the higher sales tax; this origin-based tax reduces the demand for Northeast/Midwest exports and reduces the demand for capital by Northeast/Midwest exporters. Overall, the negative effects cause utilities to fall in the region.

Simulation 10: Northeast/Midwest household tax increased; Rich immobile.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>+1.1%</td>
<td>+1.1%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>Utility</td>
<td>-4.26%</td>
<td>-0.56%</td>
</tr>
</tbody>
</table>

In this simulation, returns to skilled labor and unskilled labor increase slightly. This may be because the demand for labor increases to help produce the higher level of regional government goods that is facilitated by the higher regional tax revenue. Product prices rise slightly on average. In fact, the increase in product prices is smaller than the
increase in earned income, so households' purchasing power in the region rises slightly. For Rich households, the negative effects are exacerbated by an increase in the progressive subsidy effect; the Rich are paying higher personal taxes, but the bulk of their tax contribution goes to help the Poor. The Poor, on the other hand, welcome this effect; it almost (but not quite) completely offsets the negative effects for them. Overall, the negative effects outweigh the positive ones for both the Rich and the Poor.

**Simulations 11-15: Texas increases tax revenue; Rich are inter-regionally mobile**

**Simulation 11: Texas business capital tax increased; Rich can relocate.**

<table>
<thead>
<tr>
<th>Factor price effect:</th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative (+.4%)</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative (-4.6%)</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>Rich migration effect</td>
<td>Neutral</td>
<td>Negative (-1.3%)</td>
</tr>
<tr>
<td>Utility</td>
<td>-.24%</td>
<td>-.45%</td>
</tr>
</tbody>
</table>

In this simulation, returns to skilled labor increase slightly and unskilled labor's return falls slightly; skilled labor is scarcer in the region due to an emmigration of Rich households (raising skilled labor's return and diminishing the marginal product and earnings of unskilled labor). Product prices increase so Poor households' real earned income unambiguously falls. Rich earned income remains nearly constant, however, because the increase in their labor earnings nearly offsets the product inflation. A negative effect is an emmigration of capital caused by the higher capital tax rate. Similarly, Rich households flee, leaving an increased proportion of Poor residents; the
Poor must bear a larger portion of the region's tax burden. Overall, the negative effects outweigh the positive ones, and both types of households suffer utility losses.

Simulation 12: Texas business labor tax increased; Rich can relocate.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect</td>
<td>+.2%</td>
<td>-4.1%</td>
</tr>
<tr>
<td>Product price effect</td>
<td>Negative</td>
<td>Negative (+.07%)</td>
</tr>
<tr>
<td>Capital Migration effect</td>
<td>Negative</td>
<td>Negative (-.3%)</td>
</tr>
<tr>
<td>Progressive subsidy effect</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>Rich migration effect</td>
<td>Neutral</td>
<td>Negative (-3.0%)</td>
</tr>
<tr>
<td>Utility</td>
<td>-.17%</td>
<td>-2.38%</td>
</tr>
</tbody>
</table>

In this simulation, returns to unskilled labor fall slightly due to the business tax on labor. Skilled labor's scarcity offsets this labor tax effect, however, so earnings per unit of skilled labor remain roughly constant. But product prices increase, so households' real earned income in the region falls. This negative effect is augmented by an outflow of capital; the region's reduced population causes a reduction in regional output and a subsequent fall in capital demand. Overall, the negative effects outweigh the positive ones, especially for Poor households.

Simulation 13: Texas corporate tax increased; Rich can relocate.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect</td>
<td>+1.0%</td>
<td>-2.3%</td>
</tr>
<tr>
<td>Product price effect</td>
<td>Negative</td>
<td>Negative (+.25%)</td>
</tr>
<tr>
<td>Capital Migration effect</td>
<td>Negative</td>
<td>Negative (-3.1%)</td>
</tr>
<tr>
<td>Progressive subsidy effect</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>Rich migration effect</td>
<td>Neutral</td>
<td>Negative (-2.4%)</td>
</tr>
</tbody>
</table>
Utility

- .24%  -1.60%

In this simulation, returns to skilled labor increase slightly as it becomes scarcer in the region as Rich households leave it. Unskilled labor's return falls because its marginal product falls. Product prices increase, so Poor households' real earned income in the region falls. Rich households' purchasing power remains roughly constant, however, as the increase in their labor earnings offsets the product price increases. A negative effect is an emmigration of capital caused by the higher corporate tax rate. Poor households are also left with a smaller population of Rich households; the Poor's subsidy from the Rich falls. Overall, the negative effects outweigh the positive ones.

Simulation 14: Texas sales tax increased; Rich can relocate.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>+.9%</td>
<td>-2.5%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative (+.25%)</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative (-.33%)</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>Rich migration effect</td>
<td>Neutral</td>
<td>Negative (-.26%)</td>
</tr>
<tr>
<td>Utility</td>
<td>-.26%</td>
<td>-1.71%</td>
</tr>
</tbody>
</table>

In this simulation, returns to skilled labor increase slightly as it becomes scarcer in the region as Rich households emmigrate. Unskilled labor's return falls because its marginal product falls. Product prices increase, so Poor households' real earned income in the region falls. Rich households' purchasing power remains roughly constant, however, as the increase in their labor earnings offsets the product price increases. A negative effect is an emmigration of capital; less is required because the origin-based sales tax increases the price of Texas exports, reducing national demand for them. Poor households are also
left with a smaller population of Rich households; the Poor's subsidy from the Rich falls. Overall, the negative effects outweigh the positive ones.

Simulation 15: Texas household tax increased; Rich can relocate.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>+13.5%</td>
<td>- .84%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>Rich migration effect</td>
<td>Neutral</td>
<td>Negative</td>
</tr>
<tr>
<td>Utility</td>
<td>-.51%</td>
<td>-2.07%</td>
</tr>
</tbody>
</table>

In this simulation, returns to skilled labor increase greatly as it becomes scarcer in the region as Rich households leave Texas. Unskilled labor's return falls because its marginal product falls. Product prices increase, so Poor households' real earned income in the region falls. Rich households' purchasing power increases slightly, however, as the increase in their labor earnings offsets the product price increases. A negative effect is an emigration of capital caused by the higher corporate tax rate. Poor households are also left with a smaller population of Rich households; while this negative effect is partially offset by a larger progressive subsidy effect, the Poor's subsidy from the Rich falls nevertheless. Overall, the negative effects outweigh the positive ones, especially for the Poor.

Simulations 16-20: Nor/Mid increases tax revenue; Rich are inter-regionally mobile

Simulation 16: Northeast/Midwest business capital tax increased; Rich can relocate

<table>
<thead>
<tr>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
</table>
Factor price effect: +3.7% +1.6%
Product price effect: Negative Negative (+2.7%)
Capital Migration effect: Negative Negative (-4.6%)
Progressive subsidy effect: Neutral Neutral
Rich Migration effect: Neutral Negative (-1.6%)
Utility -1.63% -1.20%

In this simulation, returns to skilled labor and unskilled labor increase; this is because the capital tax makes producers substitute away from capital and into labor. Product prices increase more than labor earnings rise, so households' real earned income in the region falls. A negative effect is an emigration of capital; it flees from the higher capital tax. Poor households are also left with a smaller population of rich households; the Poor's subsidy from the Rich falls. Overall, the negative effects outweigh the positive ones.

Simulation 17: Northeast/Midwest business labor tax increased; Rich can relocate.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>-1.4%</td>
<td>-6.0%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative (+.1%)</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative (-.7%)</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>Rich migration effect:</td>
<td>Neutral</td>
<td>Negative (-3.3%)</td>
</tr>
<tr>
<td>Utility</td>
<td>-.71%</td>
<td>-3.29%</td>
</tr>
</tbody>
</table>

In this simulation, returns to skilled and unskilled labor fall due to the business tax on labor; unskilled labor's return falls dramatically, since it has less capital and less labor to work with, reducing its marginal product. Product prices rise very slightly, and labor returns fall; hence, real earned income falls for both households, most markedly for the
Poor. This negative effect is worsened by an outflow of capital. The Poor's subsidy from the Rich falls substantially, due to a large outflow of Rich from the region. Overall, the negative effects outweigh the positive ones, especially for Poor households.

Simulation 18: Northeast/Midwest corporate tax increased; Rich can relocate.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>+1.4%</td>
<td>-2.5%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative (+1.4%)</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative (-3.1%)</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>Rich migration effect:</td>
<td>Neutral</td>
<td>Negative (-2.9%)</td>
</tr>
<tr>
<td>Utility</td>
<td>-1.36%</td>
<td>-2.72%</td>
</tr>
</tbody>
</table>

In this simulation, returns to unskilled labor fall because the region's output falls; skilled labor's rises slightly because it is scarcer, increasing its marginal product. Product prices rise slightly, but more than labor returns; hence, real earned income falls for both households, most markedly for the Poor. This negative effect is worsened by an outflow of capital caused by the higher corporate tax. The Poor's subsidy from the Rich falls substantially, due to a large outflow of Rich from the region. Overall, the negative effects outweigh the positive ones, especially for Poor households.

Simulation 19: Northeast/Midwest sales tax increased; Rich can relocate.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>+1.4%</td>
<td>-2.7%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative (+1.4%)</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative (-3.2%)</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
</tbody>
</table>
Rich migration effect: Neutral Negative (-3.0%)
Utility -1.42% -2.89%

In this simulation, returns to unskilled labor fall because the region's output falls; skilled labor's rises slightly because it is scarcer, increasing its marginal product. Product prices rise slightly, but more than labor returns; hence, real earned income falls for both households, most markedly for the Poor. This negative effect is worsened by an outflow of capital; the origin-based sales tax reduces demand for the traded good and for capital in that production sector. The Poor's subsidy from the Rich falls substantially, due to a large outflow of Rich from the region. Overall, the negative effects outweigh the positive ones, especially for Poor households.

Simulation 20: Northeast/Midwest household tax increased; Rich can relocate.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>+13.9%</td>
<td>-3.4%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Positive</td>
<td>Positive (-.3%)</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative (-3.3%)</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>Rich migration effect</td>
<td>Neutral</td>
<td>Negative (-11.2%)</td>
</tr>
<tr>
<td>Utility</td>
<td>-1.75%</td>
<td>-3.44%</td>
</tr>
</tbody>
</table>

In this simulation, returns to unskilled labor fall because it has less capital and skilled labor to work with; skilled labor's wage rises substantially because it is much scarcer, increasing its marginal product. Product prices fall very slightly; hence, real earned income falls for both households, most markedly for the Poor. This negative effect is worsened by an outflow of capital; the household tax reduces the region's population, so fewer inputs are needed to produce non-traded goods. The Poor's subsidy from the Rich falls substantially, due to a large outflow of Rich from the region; this effect overwhelms
the increased progressive subsidy effect by a wide margin. Overall, the negative effects outweigh the positive ones, especially for Poor households.

In the next section of this chapter, I shall compare the results of the 20 simulations, and arrive at some general propositions. First, here is a comparison of "similar" simulations. I shall examine simulations 1-5, to see how results differ among those 5 simulations; I shall then examine simulations 6-10, 11-15, and 16-20, to see how results differ among those three groupings.

Simulations 1-5: Texas Government Increases Revenue; Rich Immobile

The business capital tax is the least painful way for the Texas government to increase its revenue. This is true because Texas is a large net importer of capital in my CGE model; that is, Texas uses more capital in its production than its residents own. In effect, the burden of the business capital tax is partially "exported" to residents of other regions who are supplying capital in Texas. The capital tax burden is also shifted partially onto residents of other regions through the product price effect; the tax raises the price of Texas exports, forcing consumers in other regions to bear some of the capital tax burden in the form of higher prices.

Looking at the hypothetical households, the business capital tax actually causes a larger reduction in earned income to the hypothetical households in Texas who have labor-only earned income than it does to pure capital income earners (although in every case the income reduction is small). This is because the price of Rich and Poor labor in Texas has been driven down relative to the (national) price of capital. (Labor returns are lower in Texas because demand for Texas traded goods has fallen by more than 14 million units.)
Simulations 6-10: Northeast/Midwest Government Increases Revenue; Rich Immobile

Each of the five tax increases would reduce the utilities of the Rich and Poor households in the region. For the Rich, the smallest utility reduction occurs if the business labor tax were raised; this tax causes the largest utility reduction for the Poor. This complete divergence occurs because the Rich gain most of their income from capital, while the Poor earn most of their income from labor. Labor's price is driven down by approximately 4.5% in the region, so the Poor have suffered a large loss in earned income. (The Rich, with their capital income, are partially insulated from this effect.)

The household tax increase causes the smallest utility loss for the Poor and the largest utility loss for the Rich. This result occurs for two reasons. The first reason is that Rich households are taxed at twice the rate as Poor households. The second reason is that Poor households receive double the per capita transfer payment from the government as the Rich receive. This "progressive subsidy effect" results in a net loss for the Rich and a net gain for the Poor when the household tax rate is increased. (Overall, of course, both end up with reduced utility, due to negative effects of the tax increase beyond the progressive subsidy effect.)

Simulations 11-15: Texas Government Increases Revenue; Rich Can Move

The business labor tax causes the least harm of all of the taxes to Rich households; they can flee the region to avoid a drop in the return to their labor. The immobile Poor do not have this option; their labor returns fall (a negative "factor price effect"), their subsidy from the fleeing households is reduced (a negative "Rich migration effect"), and the business labor tax is the worst tax from their perspective.

Rich hypothetical households with 50% or more of their income from labor realize gains in their real earned income if any tax is increased. This occurs for two reasons. First, the return to Rich labor has increased; since many Rich flee when taxes are raised
and take their Rich labor with them, the Rich who remain in the region receive more earning per unit of their scarcer labor (a positive "factor price effect"). Second, each tax increase causes the cost of Poor labor (which is the major input for producers) to fall dramatically; this tempers the price inflation in Texas-produced products (hence the "product price effect" is small). The combination of these two effects—higher returns to Rich labor and small product price inflation—causes the purchasing power of labor-intensive Rich households' earned income to rise.

Simulations 16-20: Northeast/Midwest Government Increases Revenue; Rich Can Move

Again, each of the five tax increases would reduce the utilities of all households in the region. The business labor tax has the least painful effect on the Rich, while it is nearly the worst choice from the Poor's perspective. Here again, this is because of the labor-intensive earnings of the Poor, contrasted with the capital-intensive earnings of the Rich.

The household tax hurts the Poor the most. This result is in complete contrast to when the Rich were immobile; in that case (simulation #5), the household tax hurt the Poor the least. This contrast occurs for the following reason. The Rich are mobile here, and they flee the region as the household tax is imposed (that is, there is a hugely negative "Rich migration effect" here which did not exist in simulation 5). This hurts the Poor in two ways. First, their transfer payment subsidy from the Rich is reduced, as the proportion of Rich-to-Poor households shrinks in the region; in effect, the Poor must pay a larger portion of their own transfer payment with their share of the household tax. Second, the Rich's skilled labor exits the region. This drives down the return to the Poor's unskilled labor (a negative factor price effect).

Continuing my comparison of simulation results, I shall now compare the results of the group of simulations in which the Rich were immobile (simulations 1-10) to the
group of simulations in which the Rich could relocate (simulations 11-20). This comparison leads to two general propositions:

**Proposition 1:** Any regional government balanced-budget tax increase harms the Rich residents of the region to a lesser degree when they can relocate among regions; they are harmed to a greater degree when they are immobile.

The logic behind this proposition is straightforward. By restricting the mobility of the Rich, they are denied one avenue to escape the region's tax grasp; they cannot move to another region to avoid the tax hike. The Rich, therefore, bear a larger burden of a regional government's tax hike when they are denied the opportunity to leave the region.

**Proposition 2:** Any regional government balanced-budget tax increase harms the Poor residents of a region to a lesser degree when the Rich are immobile; they are harmed to a greater degree when the Rich can relocate among regions.

This proposition illustrates the overwhelming influence of the Rich migration effect on Poor households. When the Rich can relocate, the Poor are harmed in two major ways:

1. Unskilled labor is the only immobile factor; hence its wage (and the Poor’s earnings) fall dramatically.

2. The progressive subsidy effect is reduced. The population of Rich households in the region shrinks due to any regional tax hike; this reduces the number of Rich households paying income taxes, shrinking their subsidy to the Poor.

Next, I shall compare simulations in which household income taxes were raised (simulations 5, 10, 15, and 20) to simulations in which business capital taxes were raised (simulations 1, 6, 11, and 16). This comparison leads to the following proposition:

**Proposition 3:** In situations where the Rich are assumed mobile, a business capital tax increase is preferable to a household tax increase by all citizens of a region.
This proposition holds for Poor citizens due to the large (and negative) Rich migration effect associated with regional tax hikes. While a household tax hike causes a positive progressive subsidy effect for the Poor, the Rich do not remain in the region to pay this higher subsidy; they flee to other regions, causing a net reduction in the Rich-to-Poor subsidy in the region.

(This leads to Proposition 3a: The Rich migration effect is always larger than the progressive subsidy effect.)

Proposition 3 holds for Rich households because the burden of a household tax exceeds the burden of a business capital tax for them. Consider the burden of a household tax on the Rich; it is a direct tax on their factor earnings, reducing their disposable income directly. Furthermore, given my model's assumption of a fixed supply of labor and capital, the Rich cannot avoid the burden of this tax by reducing their factor supplies. On the other hand, the burden of the business capital tax is indirect. It has negative excise effects, raising product prices in the region (the product price effect), but some of the burden of the business tax falls on citizens of other regions. Note, for example, that the business capital tax does NOT reduce the household's return to capital in the region relative to household capital returns in other regions (because the perfectly mobile capital relocates to avoid any distortions in its owners' rate of return); instead, the NATIONAL return to capital falls (relative to labor). Hence, the business capital tax is borne not only by residents of the region but also by residents of the nation as a whole. National residents will also bear a portion or the tax that is shifted forward in the form of higher prices for the region's export good. Hence, the business capital tax, by allowing a portion of its

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4In the next chapter, this proposition will be discovered to be sensitive to elasticity of factor substitution estimates.
5This analysis follows Mieszkowski (1972).
6For Texas, which uses more capital in production than its residents own, the business capital tax is further shifted onto non-resident capital owners.
burden to be shifted onto non-residents, is a smaller burden on a region's Rich residents than if their income were taxed directly.

Next, I shall examine how the hypothetical households are affected alternatively by business capital taxes and household income taxes. It is clear, for example, that a hypothetical household with only capital income is burdened more by a business capital tax than by a household income tax. The reason is logical; the business capital tax drives down the national return to capital (relative to labor), and increases product prices in the region; a capitalist in the region sees her disposable income fall substantially. Furthermore, she realizes no gain if labor's return increases, since she has no labor endowment. In contrast, a capitalist is spared some of the burden of a household income tax, which raises revenue from both capital and labor income.

This leads to an important point: the reader should take care not to infer from proposition 3 that a region's households prefer "capital" taxes to "non-capital" taxes. Both business capital taxes and household income taxes tax capital. The important difference, form the point of view of a region's residents, is that the capital tax base differs when comparing business vs. household taxation. The effects of a business capital tax are more national in scope (depressing the national return to capital), allowing a portion of this form of regional taxation to be shifted onto capital owners in other regions. This shift is the reason why a region's residents (whose income is not exclusively from capital) prefer the business capital tax to the household tax.

In fact, national depression in capital earnings is the reason why Rich utilities fall by a greater degree when the Northeast/Midwest raises its capital taxes than when Texas raises its capital taxes. Texas, a small region, depresses the return to capital by a smaller amount than the Northeast/Midwest, a large region, when capital taxes are raised. Hence
the Rich, who garner most of their income from capital, see a larger drop in their income when the Northeast/Midwest acts than when Texas acts.

It appears that it is less desirable for a region to employ household income taxes than business capital taxes (except for households who are pure capitalists) under the assumption that Rich households are mobile. This issue will be explored further, using differential incidence, in the next section of this chapter. (Later, Chapter 9 will also examine how sensitive this contention is to estimates of elasticities of substitution.)

*Simulation Group 2: Differential Incidence*

The above simulations of balanced budget tax incidence indicate that in most cases a region's residents prefer business capital taxes over household income taxes as a method for the regional government to increase its tax revenue. In this portion of the chapter, business capital taxes and household income taxes are compared once again, using differential incidence. Using two regions, the Northeast/Midwest and Texas, as examples, simulations will be undertaken to investigate the economic effects which occur when each region eliminates one of the two taxes (business capital taxes or household income taxes), and replaces the revenue by increasing the other tax. For Texas, the following two simulations will be undertaken:

**Simulation 21:** Texas eliminates its business capital tax, replacing the revenue lost by imposing a household income tax; the Rich are inter-regionally immobile.

**Simulation 22:** Texas eliminates its business capital tax, replacing the revenue lost by imposing a household income tax; the Rich can relocate inter-regionally.

In both cases, Texas households suffer utility losses.

For the Northeast/Midwest, the following simulations will be undertaken:
Simulation 23: The Northeast/Midwest eliminates its household income tax, replacing the revenue lost by imposing a business capital tax; the Rich are inter-regionally immobile.

Simulation 24: The Northeast/Midwest eliminates its household income tax, replacing the revenue lost by imposing a business capital tax; the Rich can relocate inter-regionally.

Results of simulation 23 indicate that the Rich gain utility and the Poor lose it. Results of simulation 24 indicate that Rich utility remains virtually unchanged, while Poor utility increases.

In the next section of this chapter, simulations 21-24 will be examined more closely. Later in this thesis, sensitivity analysis will be undertaken to see whether the results vary as production elasticities of factor substitution and household elasticities of substitution are altered from their original estimates.

Analysis of Simulations 21-24

In this section each simulation will first be analyzed individually. Then the simulations will be compared and contrasted. As with the simulations in group 1, simulation results will be broken down into five effects: the factor price effect, the product price effect, the capital migration effect, the progressive subsidy effect, and the Rich migration effect.

Table 8.4 lists the simulations; table 8.5 shows how households in the tax-altering region are affected by each tax alteration. As was done earlier, hypothetical households are once again created to explore how variations in sources of household income affect the simulations' effects on household utility. (Complete data from the iterative computer program characterizing the results of the simulations is available from me).
Simulation 21: Texas business capital tax replaced with household tax (to maintain benchmark tax revenue); Rich are immobile.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>+.8%</td>
<td>+.6%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>Utility</td>
<td>-1.36%</td>
<td>-0.11%</td>
</tr>
</tbody>
</table>

In this simulation, elimination of the business capital tax increases earned incomes of both Rich and Poor households; household returns to all factors rise as businesses are unburdened from the capital tax. Since product prices fall slightly, this results in an increase in real earned income for all households; all hypothetical households see purchasing power gains as well. Despite the increase in earned income, the utilities of both Rich and Poor households fall. For the Rich, their utility falls for two reasons. First, their household tax liability rises more than their earned income. Second, much of their new tax liability is funneled to Poor households as transfer payments (a negative progressive subsidy effect for the Rich). The combination of these two effects results in a drop in Rich disposable income and a reduction in Rich utilities.

The Poor's utility loss is very small—about 1/10 of one percent. While it is true that their disposable income falls due to their new household tax liability, almost all of this loss is recovered through the progressive subsidy effect. The household tax burden falls more per capita on Rich households than Poor ones; hence the imposition of the household tax allows Poor utilities to be partially subsidized by the Rich.

Simulation 22: Texas business capital tax replaced with household tax (to maintain benchmark tax revenue); Rich can relocate.
Factor price effect:  Rich  Poor  
Product price effect: Positive  Positive (-.1%)  
Capital Migration effect: Positive  Positive (+1.7%)  
Progressive subsidy effect: Negative  Positive  
Rich migration effect Neutral  Negative (-4.0%)  
Utility  -0.13%  -0.79%

In this simulation, elimination of the business capital tax increases earned incomes of Rich households; household returns to skilled labor rise as approximately 50,000 Rich households flee the region (taking their skilled labor with them), increasing the marginal product of skilled labor in the region. Since product prices fall slightly, this results in an increase in real earned income for Rich households. Despite the increase in earned income, the utilities of Rich households fall slightly. Their utility falls for two reasons. First, their household tax liability rises more than their earned income. Second, some of their new tax liability is funneled to Poor households as transfer payments (a negative progressive subsidy effect for the Rich). The combination of these two effects results in a drop in Rich disposable income and a reduction in Rich utilities.

The Poor fare worse than the Rich in this simulation. Since unskilled labor is the only immobile factor in this simulation, its return falls. Thus, despite the reduction in the price level, the Poor's real earned income falls. Furthermore, the Poor's new household tax liability reduces their disposable income. Even worse, the outflow of Rich households reduces the proportion of Rich-to-Poor households in the region (a negative Rich migration effect for the Poor); this result overwhelms the positive progressive subsidy effect (recall proposition 3a in chapter 8, which states that the Rich migration effect is always greater than the progressive subsidy effect). Hence, Poor utilities fall by .79 percent.
Simulation 23: Northeast/Midwest business capital tax increased, household tax eliminated (benchmark tax revenue is maintained); Rich are immobile.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect</td>
<td>+1.5%</td>
<td>+2.0%</td>
</tr>
<tr>
<td>Product price effect</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Capital Migration effect</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Progressive subsidy effect</td>
<td>Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>Utility</td>
<td>-3.62%</td>
<td>-0.74%</td>
</tr>
</tbody>
</table>

In this simulation, household returns to skilled and unskilled labor increase, but product prices increase even more; as a result, the earned incomes of both Rich and Poor households fall. (Indeed, this is true of all of the hypothetical households as well.) Despite this reduction, Rich households have increased utilities, for two reasons. Their household tax liability has been eliminated; this reduces their subsidy to the Poor (a positive progressive subsidy effect for the Rich) and increases their disposable income.

The Poor are less fortunate; they suffer a utility loss of .74 percent. The major reason is the negative progressive subsidy effect; since household taxes are eliminated, the Rich no longer subsidize the Poor through this tax, and the Poor end up bearing a larger burden of the region's tax liability.

Simulation 24: Northeast/Midwest business capital tax increased, with household tax eliminated (benchmark tax revenue is maintained); Rich can relocate.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect</td>
<td>-10.4%</td>
<td>+6.4%</td>
</tr>
<tr>
<td>Product price effect</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Capital Migration effect</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>Rich migration effect</td>
<td>Negative</td>
<td>Positive (+12.7%)</td>
</tr>
<tr>
<td>Utility</td>
<td>+0.02%</td>
<td>+1.92%</td>
</tr>
</tbody>
</table>

In this simulation, Rich households' utilities remain virtually unchanged. The elimination of the household tax, ceteris paribus, would reduce their tax liability, reduce their subsidy to the Poor, and increase their disposable income. The influx of Rich into the region, however, causes the returns to skilled labor to fall dramatically, reducing the Rich's earned income (a negative Rich migration effect). This reduction in earned income offsets the benefits of the elimination of the household tax, and Rich utilities remain virtually unchanged in the region.

The Poor fare better, once again showing that the Rich migration effect is larger than the progressive subsidy effect. The Poor lose the subsidy from the Rich that the household tax gave them (a negative progressive subsidy effect); however, the influx of skilled labor into the region increases the return to unskilled labor by approximately six percent (because the marginal product of unskilled labor has increased). This increase in Poor earned income, coupled with the elimination of their own household tax liability, overwhelms the negative progressive subsidy effect. As a result, Poor utilities rise by 1.92 percent.

**Comparing Simulations 21-24**

In this section, pairs of simulations taken from simulations 21-24 will be analyzed.

First, the importance of the assumption concerning Rich household mobility will be analyzed. Proposition 1 from chapter 8 indicated that the Rich were harmed less by a balanced budget tax increase when they were allowed to be mobile, rather than immobile. This idea is maintained when business capital taxes are eliminated and household income taxes are increased in differential incidence; the Rich prefer to be mobile in this case.
This preference is evident when comparing simulations 21 and 22. When the household tax replaces the revenue lost by eliminating Texas' business capital tax, the Rich in Texas are harmed more when they are immobile. This is due to the progressive subsidy effect; Rich households subsidize Poor ones through household taxation by paying a larger household tax rate and receiving a smaller transfer payment. When the Rich are immobile, they cannot escape this Rich-to-Poor subsidy by relocating, so their utility falls by 1.36 percent. When the Rich are mobile, however, they can leave the region to avoid this household tax liability; their utility falls by only .13 percent.

Similar reasoning can explain why the Rich gain more when the household tax is eliminated (replaced by a business capital tax) when they are immobile, rather than mobile. An examination of simulations 23 and 24 is illustrative. When the Rich are immobile, elimination of the household tax has a positive progressive subsidy effect; the Rich-to-Poor subsidy of the household tax is eliminated. Furthermore, when the Rich are immobile, Rich residents of other regions cannot migrate into the Northeast/Midwest to share in this tax windfall; hence Rich utilities in the Northeast/Midwest rise by 3.62 percent. When the Rich are mobile, however, vast numbers of Rich households migrate into the Northeast/Midwest due to its zero percent household income tax rate. This has a negative Rich migration effect on Rich households already living in the region which wipes out the gains from the progressive subsidy effect; the Rich gain only .02 percent additional utility in this case.

The Poor also have a vested interest on the mobility or lack of mobility of Rich households. It is clear, when examining simulations 22 and 24 that the Rich migration effect is the overwhelming effect for Poor households when taxes are changed in these simulations. The Poor definitely do not want a differential tax change that will cause Rich households to leave the region, whereas they welcome a differential tax change that leads to an influx of Rich residents. In simulation 22, for example, the net outflow of Rich
households that occurs when Texas imposes a household tax (to replace its business capital tax) causes a negative Rich migration effect that overwhelms the positive progressive subsidy effect, and Poor households in Texas suffer utility losses of .79 percent. Similarly, in simulation 24, elimination of the Northeast/Midwest household tax (replaced by a business capital tax) causes such an inflow of Rich households that the benefits of the Rich migration effect far outweigh the negative progressive subsidy effect, and Poor households gain 1.92 percent utility.

Given the power of the Rich migration effect, it may be fruitful to look at simulations 21 and 23, in which the Rich are immobile, to eliminate the Rich migration effect. Instead, consider the relative merits of household income taxes when compared to business capital taxes. In both simulations, Rich households prefer the business capital tax to the household income tax. The reason here is similar to the reasoning in the previous chapter, where Rich households also preferred the household income tax to the business capital tax. The household tax is a direct tax on the capital (and labor) endowments of households in the region; this tax's burden is difficult to shift onto other residents of other regions. In contrast, the business capital tax, while having negative excise effects in the taxing region, also has national effects which spread its burden partially onto residents of other regions. Furthermore, the household income tax entails a negative progressive subsidy effect on the Rich which they can avoid if business capital is taxed instead of household income.

There is no clear economic principle connecting the fate of Poor households in simulation 21 to Poor households in simulation 23; Poor households lose utility in both cases. In simulation 21, the negative effect from the Poor's new household tax liability is greater than the positive progressive subsidy effect; Poor households are also harmed by the loss of the region's ability to use the business capital tax as a means to export some of the region's tax burden. As a result, Poor households in Texas suffer a modest loss in
utility of .11 percent. In simulation 23, the negative product price effect and progressive subsidy effect harm Poor residents of the Northeast/Midwest more than they gain from the new ability of the region to export some of its tax burden via the business capital tax. Therefore, the Poor in the region suffer utility losses of .74 percent.

One common theme that reoccurs when examining simulations 1-24 is that the mobility assumption of Rich households is very important, especially in affecting the welfare of Poor households in a region. In fact, in every case in which a tax change causes an emigration of Rich households, Poor households suffer utility losses. Conversely, in every case in which a tax change causes an immigration of Rich households, Poor resident's utilities are augmented.

A real-world sub-national government, then, should be more interested in how a change in its tax policy will affect the population of Rich skilled people in the region, rather than worry about commonly-used measures of excess burdens of various tax instruments; the greatest "excess burden" to a sub-national tax may be a reduction in the number of productive wealthy members of the region's population. A regional government might, instead, estimate some sort of "tax rate elasticity of Rich migration" to be sure that some percentage increase in the region's tax rate does not cause such a large change in the Rich population that households left in the region become worse off.

The simulations described above and the results gleaned from them rest partially upon the parameter values assigned to them in the benchmark period. It will be useful, then, to examine how sensitive some of these results are to changes in a few key, important parameter assignments—elasticities of substitution in production and
consumption. Further, a discussion of the amalgam "capital" resource may be fruitful as well. These issues will be examined fully in the next chapter.

Simulations undertaken in chapter 8 indicated that in most cases a region's residents preferred business capital taxes over household income taxes as a method for the regional government to increase its tax revenue. In this chapter, we shall seek to ascertain how sensitive those results are to some elasticity of substitution parameter estimates used in my model. To accomplish this we shall run two more sets of simulations:

In simulation group 3 (simulations #25-#30), we shall vary production elasticity of substitution parameters nationwide from their levels in the simulations conducted in chapter 8. We shall then examine how this variation changes the relative merits of household taxation vis-à-vis business capital taxation in the Northeast/Midwest region, using differential incidence. In essence, we shall test how well the results of simulations 23 and 24 hold up when these production elasticities of substitution differ from the values assumed in chapter 8.

In the second group of simulations (#31-#43), we shall vary an important utility function parameter nationwide from its level assumed in chapter 8. We shall then examine how this variation changes the relative merits of household taxation vis-à-vis business capital taxation in the Texas region, using both balanced budget incidence and differential incidence. In particular, we shall test how well the results of simulations 1-5, 11-15, and 21-22 hold up when the consumption elasticity of substitution between 'home' and 'import goods is increased from 3 (its assumed value in chapter 8) to 10.

In the last section of this chapter, we shall briefly discuss the amalgamated 'capital' factor of production used in my model. Due to data limitations, this factor contains value added from not only reproducible capital but also from land. We shall contend, however, that this capital/land aggregation does not substantially hinder tax incidence analysis in our
CGE model.

Simulations 25-30: Differential Incidence: Sensitivity to Production Elasticities of Substitution

In this section it will be determined to what extent the exogenous estimates of elasticities of factor substitution in production affect the differential incidence simulation results for the Northeast/Midwest region obtained in chapter 8. That is, the original benchmark equilibrium will be altered by changing production functions in the four regions. The production functions will be altered by changing the elasticities of factor substitution from the numbers given in chapter 6. Since the original production functions are altered, simulations using the altered production function will give different results from simulations undertaken thus far. To reduce complexity and maintain research focus, new simulations will only be undertaken which examine differential incidence when the Northeast/Midwest region changes its tax policy. The following simulations will be undertaken:

Set #1: Elasticities of factor substitution of all factors in all production sectors in all regions equal 1.5:

25. Northeast/Midwest eliminates its household income tax and increases its business capital tax (tax revenues remain unchanged from benchmark); Rich immobile

26. Northeast/Midwest eliminates its household income tax and increases its business capital tax (tax revenues remain unchanged from benchmark); Rich can relocate.

Set #2: Elasticities of factor substitution of all factors in all production sectors in all

---

1 Table 9.1 lists all of the simulations undertaken in this chapter.
regions equal \( I \): 

27. Northeast/Midwest eliminates its household income tax and increases its business capital tax (tax revenues remain unchanged from benchmark); Rich immobile

28. Northeast/Midwest eliminates its household income tax and increases its business capital tax (tax revenues remain unchanged from benchmark); Rich can relocate.

Set #3: Elasticities of factor substitution between skilled labor and unskilled labor in all production sectors in all regions equal \( I \). All other elasticities of factor substitution remain at their estimates in the initial benchmark equilibrium (see chapter 6).

29. Northeast/Midwest eliminates its household income tax and increases its business capital tax (tax revenues remain unchanged from benchmark); Rich immobile

30. Northeast/Midwest eliminates its household income tax and increases its business capital tax (tax revenues remain unchanged from benchmark); Rich can relocate.

Below, I shall analyze each simulation individually. Then, the simulations will be compared to see what effects altering the elasticities have on simulation results. Table 9.2 illustrates how households (including hypothetical ones) are affected in each of the simulations. Complete computer-generated results of the simulations are available from me.

Simulation 25: Northeast/Midwest business capital tax increased, household tax eliminated (benchmark tax revenue is maintained); Rich are immobile. (All production elasticities of substitution = 1.5)

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>+3.2%</td>
<td>+3.5%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
</tbody>
</table>

\(^2\) Results will be interpreted in similar manner to those in chapter 8--breaking the results down into five separate effects.
Capital Migration effect: Negative Negative (-11.7%)
Progressive subsidy effect: Positive Negative
Utility +3.77% -0.11%

In this simulation, household returns to skilled and unskilled labor increase, but product prices increase slightly more; as a result, the earned incomes of both Rich and Poor households fall slightly. Despite this reduction, Rich households have increased utilities, for two reasons. Their household tax liability has been eliminated; this reduces their subsidy to the Poor (a positive progressive subsidy effect for the Rich) and increases their disposable income.

The Poor are less fortunate; they suffer a utility loss of .11 percent. The major reason is the negative progressive subsidy effect; since household taxes are eliminated, the Rich no longer subsidize the Poor through this tax, and the Poor end up bearing a larger burden of the region's tax liability.

Simulation 26: Northeast/Midwest business capital tax increased, with household tax eliminated (benchmark tax revenue is maintained); Rich can relocate. All production elasticities = 1.5

<table>
<thead>
<tr>
<th>Factor price effect:</th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10.2%</td>
<td>+10.6%</td>
<td></td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>Rich migration effect</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>Utility</td>
<td>+0.38%</td>
<td>+5.43%</td>
</tr>
</tbody>
</table>

In this simulation, Rich households' utilities increase by .38 percent. The elimination of the household tax, ceteris paribus, would reduce their tax liability, reduce
their subsidy to the Poor, and increase their disposable income. The influx of Rich into the region, however, causes the returns to skilled labor to fall, reducing the Rich's earned income (a negative Rich migration effect). This reduction in earned income partially offsets the benefits of the elimination of the household tax, and Rich utilities rise only modestly.

The Poor fare better, once again showing that the Rich migration effect is larger than the progressive subsidy effect. The Poor lose the subsidy from the Rich that the household tax gave them (a negative progressive subsidy effect); however, the large influx of skilled labor into the region increases the return to unskilled labor by more than six percent (because the marginal product of unskilled labor has increased). This increase in Poor earned income, coupled with the elimination of their own household tax liability, overwhelms the negative progressive subsidy effect. As a result, Poor utilities rise by 5.43 percent.

Simulation 27: Northeast/Midwest business capital tax increased, household tax eliminated (benchmark tax revenue is maintained); Rich are immobile. All production elasticities of substitution equal .1

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>-2.5%</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>Utility</td>
<td>+3.32%</td>
<td>-1.79%</td>
</tr>
</tbody>
</table>

In this simulation, household returns to labor decrease, and product prices increase; as a result, the earned incomes of both Rich and Poor households fall. (Indeed, this is true of all of the hypothetical households as well.) Despite this reduction, Rich
households realize increased utilities, for two reasons. Their household tax liability has been eliminated; this reduces their subsidy to the Poor (a positive progressive subsidy effect for the Rich) and increases their disposable income.

The Poor are less fortunate; they suffer a utility loss of 1.79 percent. The major reason is the negative progressive subsidy effect; since household taxes are eliminated, the Rich no longer subsidize the Poor through this tax, and the Poor end up bearing a larger burden of the region's tax liability. The Poor's earned income is lower, also.

Simulation 28: Northeast/Midwest business capital tax increased, with household tax eliminated (benchmark tax revenue is maintained); Rich can relocate. All production elasticities of substitution equal 1.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>-17.4%</td>
<td>-7.1%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(+1.6%)</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-1.8%)</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>Rich migration effect</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(+1.1%)</td>
</tr>
<tr>
<td>Utility</td>
<td>+1.08%</td>
<td>-3.28%</td>
</tr>
</tbody>
</table>

In this simulation, Rich households' utilities increase by 1.08 percent. The elimination of the household tax, ceteris paribus, reduces their tax liability, reduces their subsidy to the Poor, and increases their disposable income. The small influx of Rich into the region, however, causes the returns to skilled labor to fall, reducing the Rich's earned income (a negative Rich migration effect). This reduction in earned income only partially offsets the benefits of the elimination of the household tax, and Rich utilities rise in the region.

The Poor fare worse, showing in this instance that the Rich migration effect is
smaller than the progressive subsidy effect. The Poor lose the subsidy from the Rich that
the household tax gave them (a negative progressive subsidy effect); however, the small
influx of skilled labor into the region only partially offsets the flight of capital from the
region; as a result, the return to unskilled labor falls substantially. This fall in Poor earned
income, along with the negative progressive subsidy effect, overpowers the benefits from
the elimination the Poor's household tax liability. As a result, Poor utilities fall by 3.28
percent.

This simulation shows that the progressive subsidy effect is not always smaller than
the Rich migration effect; the opposite is true here. The reduced elasticity of factor
substitution reduced the influx of Rich into the region (because skilled labor's return did
not rise very much), reducing the size of the Rich migration effect.

Simulation 29: Northeast/Midwest business capital tax increased, household tax
eliminated (benchmark tax revenue is maintained); Rich are immobile. Elasticity of
substitution between skilled/unskilled labor = 1.

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>-1.5%</td>
<td>+1.8%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>Utility</td>
<td>+2.67%</td>
<td>-0.91%</td>
</tr>
</tbody>
</table>

In this simulation, household returns to unskilled labor increase, but product prices
increase even more; as a result, the earned incomes of both Rich and Poor households fall.
(Indeed, this is true of all of the hypothetical households as well.) Despite this reduction,
Rich households have increased utilities, for two reasons. Their household tax liability has
been eliminated; this reduces their subsidy to the Poor (a positive progressive subsidy
effect for the Rich) and increases their disposable income.

The Poor are less fortunate; they suffer a utility loss of .91 percent. The major reason is the negative progressive subsidy effect; since household taxes are eliminated, the Rich no longer subsidize the Poor through this tax, and the Poor end up bearing a larger burden of the region's tax liability.

Simulation 30: Northeast/Midwest business capital tax increased, with household tax eliminated (benchmark tax revenue is maintained); Rich can relocate.

Elasticity between skilled/unskilled labor = .1

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor price effect:</td>
<td>-10.9%</td>
<td>+.1%</td>
</tr>
<tr>
<td>Product price effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Capital Migration effect:</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Progressive subsidy effect:</td>
<td>Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>Rich migration effect</td>
<td>Slightly Negative</td>
<td>Slightly Positive</td>
</tr>
<tr>
<td>Utility</td>
<td>-0.04%</td>
<td>-1.54%</td>
</tr>
</tbody>
</table>

In this simulation, Rich households utilities remain virtually unchanged. The elimination of the household tax, ceteris paribus, would reduce their tax liability, reduce their subsidy to the Poor, and increase their disposable income. The influx of Rich into the region, however, causes the returns to skilled labor to fall dramatically, reducing the Rich's earned income (a negative Rich migration effect). This reduction in earned income offsets the benefits of the elimination of the household tax, and Rich utilities remain virtually unchanged in the region.

The Poor fare worse, showing in this instance that the Rich migration effect is smaller than the progressive subsidy effect. The Poor lose the subsidy from the Rich that the household tax gave them (a negative progressive subsidy effect); however, the small
influx of skilled labor into the region only offsets the flight of capital from the region; as a result, the return to unskilled labor remains nearly unchanged. This stability of Poor earned income, along with the negative progressive subsidy effect, overwhelms the benefits from the elimination the Poor's household tax liability. As a result, Poor utilities fall by 1.54 percent.

Once again the relatively low elasticity of factor substitution between skilled and unskilled labor has reduced the influx of Rich residents. This has reduced the Rich migration effect, making it smaller than the progressive subsidy effect. Hence, Poor households have reduced utility.

Comparing Simulations 25-30

It becomes quite evident when examining the simulations in which the Rich are mobile that the Rich are less likely to migrate to other regions as their skilled labor becomes less substitutable with unskilled labor. The Rich inter-regional migration is largest in simulation 26, in which skilled labor's elasticity of substitution with the other factors is 1.5. Conversely, the Rich migration is much smaller in simulations 28 and 30, when skilled labor's elasticity of factor substitution with unskilled labor is .1.

This relationship between Rich migration and skilled/unskilled labor substitutability has implications for the size of the Rich migration effect in relation to the progressive subsidy effect. That is, the Rich migration effect shrinks as skilled and unskilled labor become less substitutable; at some point, when the elasticity is small enough, the Rich migration effect becomes smaller than the progressive subsidy effect on the utilities of Poor households.

Recall that two of the effects on Poor households of a differential replacement of a region's household income tax with a business capital are offsetting:

1) The progressive subsidy effect. This effect reduces Poor utilities, because the
elimination of the household tax eliminates the Rich-to-Poor subsidy that the household tax entails.

2) The Rich migration effect. This effect increases Poor utilities, because the influx of Rich households relieves some of the regional tax burden of Poor households.

If the elasticity of factor substitution between skilled and unskilled labor is "small," then the Rich migration effect will be small—smaller than the progressive subsidy effect—and Poor households in a region will suffer when a region replaces its household tax with a business capital tax. In fact, in simulations 28 and 30, the Poor suffer substantial utility losses. On the other hand, if the elasticity of factor substitution is "large," then the Rich migration effect will be large—larger than the progressive subsidy effect—and Poor utilities will increase in the region. Indeed, in simulation 26 the Poor realize a substantial utility increase.

This result has several implications that I can think of. First, a regional government which cares about its Poor residents should target Rich households who have skills that cannot be easily replaced with unskilled workers (dentists, for example). Second, further econometric research is needed to refine estimates of elasticities of factor substitution between skilled and unskilled labor, since the accuracy of the estimates is important for accurate sub-national government fiscal decision-making.

Finally, one cannot make the unequivocal statement that Poor households will always prefer a tax policy change which causes the population of Rich households to increase in the region. Elimination of a "progressive" household income tax structure will not have a "trickle down" effect and improve the lot of the Poor if the influx of Rich residents is "small." Sensitivity analysis has revealed that this will be the case when skilled labor and unskilled labor are difficult to substitute in production.

It is also evident that in the simulations in which the Rich are immobile, the elasticity of substitution between labor and capital is an important determinant of the
magnitude (if not the direction) of changes in Rich and Poor utilities. As the elasticity estimates are decreased (from 1.5 to .1), the Rich household gain from the tax change is reduced, while the Poor household loss is increased. In other words, both would prefer if their labor were more easily substituted with capital—the Rich because their utility gain would be higher, and the Poor because their utility loss would be lower.

The explanation for this preference is clear. When capital and labor are not easily substitutable, the increased business capital tax does not diminish the Northeast/Midwest's capital usage very much, because producers in the region find it difficult to replace the capital with the low-substitutable labor. Hence, demand for labor in the region does not increase much, nor do labor's returns. A low labor return means low income for households. On the other hand, when capital and labor are easily substituted, producers in the Northeast respond to the higher business capital tax by replacing capital with labor in large quantities. This higher demand for labor increases labor's return substantially, increasing household income substantially as well. Clearly, households would prefer that their incomes rise substantially than rise very little, so they prefer their labor to be highly substitutable with capital rather than not very substitutable.

This result has a strange implication. In cases where households are immobile, it is more desirable for a region to raise its business capital tax (to replace a household tax) when capital has many close substitutes in production, because in this instance the tax increase will drive a large amount capital out of the region and raise the earnings of the residents of the region. The residents' labor earnings will increase as producers replace the capital with labor in the region, while the residents' capital earnings will only fall to the extent that the national return to capital falls (since the region's residents are not restricted to supplying their capital in their home region). The result is a net gain in disposable income for the region's households (except for hypothetical households who gain the vast majority of their income from capital).
It is clear that the choice of elasticity of factor substitution estimates in production is important to determining tax incidence in my CGE model (as they are in other CGE models). This importance exists whether Rich households are assumed to be inter-regionally mobile or immobile. Indeed, inaccurate elasticity estimates may give erroneous policy implications. Further econometric research is needed to ensure reasonably accurate elasticity of substitution estimates.

*Simulations 31-43: Tax Incidence in Texas: Sensitivity to Consumption Elasticities of Substitution*

In chapters 8, computer simulations revealed that Texas residents would prefer that their government employ business capital taxes rather than household income taxes as a revenue source. This result was obtained in balanced budget simulations (in which Texas' government increased its revenue by 25%) and in differential simulations (in which Texas' business capital tax was eliminated and replaced with a household income tax). One of the major reasons why the business capital tax was superior to the household income tax in these simulations is that a portion of the business capital tax burden was "exported" onto non-Texas citizens through what is sometimes known as the "output effect," in the simulations, a portion of the Texas business capital tax is shifted forward onto consumers of Texas exports to other regions, in the form of a higher price per unit of Texas Goods in those regions.

This result was obtained using an estimate of 3 for the elasticity of substitution in consumption between Goods produced in different regions. This elasticity estimate may (or may not) be inaccurate. It would be prudent, then, to ascertain how sensitive the relative merits of business capital taxes vis-à-vis household income taxes are to changes in the estimate for the elasticity of substitution between Goods produced in different regions.
In this presentation, the elasticity estimate is increased from 3 to 10, and the Texas simulations undertaken in chapter 8 are re-run. Results indicate that the superiority of business capital taxes relative to household income taxes is reduced in some simulations, and is eliminated in others.

It should be expected that an increase in the Goods elasticity of substitution in households' utility functions would make the business capital tax a less desirable option, because Texas would be less able to export some of the tax burden in the form of higher prices of its export good. The higher elasticity of substitution would increase the price elasticity of demand for Texas goods; anything which raises Texas goods prices, such as a business capital tax hike in Texas, would cause a larger reduction in the quantity of Texas goods demanded by residents of other regions. Therefore, the output effect would be reduced, and non-Texas residents would bear a smaller burden of the tax hike. This would leave a larger burden to be borne by Texas residents. Hence the negative effects of a business capital tax on Texas households would increase as the Goods elasticity of substitution estimate were increased.

This situation is consistent with the results of new simulations\(^3\) in which the elasticity of substitution estimate between Goods is increased from 3 to 10. Results of the balanced budget simulation in which the business capital tax is raised and the Rich are assumed immobile show that the utility loss experienced by Rich households rises from .66% to 1.4% when the elasticity is raised from 3 to 10; for the Poor, the loss rises from .23% to 1.83%. (Indeed, the Poor's loss of 1.83% when the business capital tax is raised exceeds their loss of .80% when the household tax is raised; hence at the elasticity estimate of 10 the Poor no longer prefer the business capital tax to the household tax. Instead, the household tax is preferred.)

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\(^3\)Results of the simulations in which the elasticity of substitution between Goods is estimated at 3 are summarized in the top half of table 9.3. Results in which the elasticity is 10 are summarized in the bottom half of the table. Complete simulation results are available from me.
In the similar simulation in which the Rich are mobile, the loss to Rich households rises from .24% to .35%, and the Poor's loss rises from .44% to 2.75%, when the elasticity estimate is raised from 3 to 10. Again, the business capital tax looks less advantageous at the higher elasticity estimate.

Differential incidence results indicate that relative to a household income tax, the business capital tax advantage is reduced when the elasticity estimate is raised from 3 to 10; indeed, in one case the advantage disappears and becomes a disadvantage. In the differential simulation in which the Rich are assumed immobile, Rich households' utility loss when the business capital tax is replaced by a household tax is reduced, from 1.36% to 1.05%, when the elasticity estimate is increased from 3 to 10. For the Poor, the loss becomes a gain. At the elasticity estimate of 3, the Poor lose .11% of their utility when a household tax replaces the business tax; at an elasticity of 10, the Poor gain .41%.

The differential simulation in which the Rich are mobile also shows the reduced advantage of the business capital tax compared to the household income tax. The loss to the Rich falls from .13% to .10%, and the Poor's utility loss falls from .79% to .44%.

Apparently the simulation results are indeed sensitive to elasticity of substitution estimates in the household utility function. This should be of special interest to Texas, whose energy and petrochemical exports to the rest of the United States are fairly fungible. This suggests a high substitution elasticity, a small output effect, and a small (or non-existent) preference of Texas households for business capital taxes over household taxes. It also suggests that if the Rich are truly regionally immobile, then a high goods elasticity would allow the Texas government to redistribute income from the Rich to the Poor by replacing the business capital tax with a progressive household income tax. If the Rich are truly mobile, however, then the business capital tax is still preferred by both Rich and Poor Texans to a household income tax even at high Goods substitution elasticities;

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4 Apparently, at the higher substitution estimate of 10, the progressivity of the household tax is preferred by the Poor over the reduced output effect of the business tax.
furthermore, in this case redistribution attempts by the Texas government are futile.

_The “Capital” Factor of Production_

I wrote in chapter 5 that I pondered including land as a third factor of production; indeed, I would have preferred including it in the model, but I could not find sufficient sub-national data concerning land returns to calibrate land into a computational production function. Instead, I employed a “capital” input that may be a bit misnamed, since it is really a residual. Those who perused chapter 6 with care know that capital usage in a given production sector is determined by subtracting labor returns from net value added in production. This methodology implies that any true “land” returns are amalgamated into my “capital” production factor.

This situation is less than optimal, since capital and land have important differences, including their tax treatment and their intersectoral and inter-regional mobility. In most firms, however, the relative insignificance of land when compared with capital does not make my situation untenable; indeed, in my highly aggregated production sectors, the portion of value added that can be attributed to land is probably small in most cases.\(^5\)

One sub-national production sector which may leave some with concern, however, is the “goods” sector in the Texas region. Since a substantial portion of Texas production is related to oil and petrochemicals, the “land” component of value added in this production sector may be significant. This leaves some of the simulation results obtained for the Texas region open to question, since these returns are aggregated into the capital category. I shall discuss these concerns below, and hopefully assuage some of them.

One apparent concern is the factor mobility issue; capital is assumed to be completely inter-regionally mobile in my CGE model, and obviously oil and gas reserves

\(^5\) Obviously, hard data would be preferable to my rather vague contentions, and I look forward to perusing this area with great effort in the future.
under Texas land and waters are immovable. This immobility, however, may not influence my incidence results substantially if the patterns of land ownership are similar to patterns of capital ownership. Consider first the regional patterns of land and capital ownership, and suppose that each resident of each region holds capital and land in equal proportions, so that, for example, a Rich household living in Texas earns the same proportion of income from land returns as does a Rich household living in any other region. (There is no a priori reason to believe that reality veers substantially from this assumption). In this case, the ability of Texas residents to “export” a portion of the business capital tax onto non-Texas owners of capital and land used in Texas holds, even in my model in which land and capital are amalgamated. The benefits of this exportation, however, would be reduced to the extent that land returns are exempted from the business capital tax.

Next, consider the patterns of land ownership among households of different income groups. Assume that capital and land follow similar patterns of ownership by income class, so for example, Rich households own a similarly higher ratio of land compared to Poor households as they do a higher ratio of capital when they are compared with Poor households. In this case, the redistribution implications of business capital taxes would remain similar even if land were separated from capital in my production functions.

One concern, however, that does need to be addressed in the future is the substitutability of labor, capital, and land in the production process. In my CGE model, labor has an equal substitutability with capital as it does land, since capital and land are aggregated into one production factor. Casual empiricism suggests, however, that it is more difficult to substitute labor for certain types of land (such as crude oil) in production than for many types of capital. Hence one conclusion of some of the simulations--that a business capital tax increases wages by driving up the demand for labor--may be overstated, especially as it relates to the Texas region.

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6 Again, data are meager that separate individual income sources of people residing in different areas of the country into land and capital sources.
The above analysis suggests the pitfalls of attempting to obtain universal truths from specific CGE tax simulations. With this caveat in mind, I shall nevertheless attempt to generalize some of the results of chapters 8 and 9 in the next chapter. Chapter 10 also looks at other ways that my CGE model can be improved and expanded, and considers other economic issues that my CGE model can shed light on.
10. Summary, and Avenues for Further Research

The purpose of this thesis is neither to break new theoretical ground nor to
calculate the conclusions drawn in the extant theoretical tax incidence literature; indeed, it
is neither the purpose of CGE models nor is it wise to draw universal conclusions from a
small number of computer simulated tax changes. It is instead my desire to interpret the
simulation results to shed some light on the tax policy options available to state and local
government policymakers, in an attempt to add to the knowledge base upon which tax
decisions are made or contemplated. While there are no universal truths to divulge from
this thesis, I believe that the results show some general tendencies which may be
enlightening and important; most certainly, the results provide a revealing and logical
structure for looking at real world sub-national tax policy changes.

In the first part of this chapter I shall discuss revelations derived from simulations
#1-#43 which may be of use to today’s policy analysts. These revelations include:

--the disdain of households for higher taxes to fund higher expenditure levels of
current services.

--the necessity of looking at the effects of tax policy changes over not only a short
term view (when migration responses may be limited), but also over a long term view
(when attempts at progressive government policies may be swamped by an emigration of
households).

--the rejection of dogma against taxes on business, at least at the sub-national
level.

--strategies to export some of a region’s tax burden.

The second part of this chapter looks beyond the dissertation results. It discusses
some potential uses of the CGE economy created in this thesis, other than using it to
examine the issues discussed in chapters 8 and 9, and later, it discusses how the CGE
model might be altered in order improve the model, and to allow it to examine some other economic issues.

**Relevance of the Thesis Results**

No theoretic result can be rejected out of hand or accepted in its entirety based upon the results obtained in this thesis. It has been suggested, for example, that the preference by households for business capital taxation over household income taxation in many of the simulations is a rebuttal of the theoretical proposition that sub-national use of capital taxation will result in an underprovision of public goods.\(^1\) As I have stated earlier, however, no such rejection is warranted (first, because in my thesis a business capital tax is not being compared to a non-distorting head tax, and second, because household income taxes include capital in their tax base). It has also been said that the simulation results which show much of the burden of a region’s business capital tax falling on residents of other regions vindicate the ‘new’ view of the property tax. But all that really can be properly claimed is that my results are consistent with that view, not a proof or disproof of it. Instead of examining theoretical claims such as these, it is better to try and glean some practical use from the simulation results.

One obvious result is that in every instance that any tax rate was raised in order to fund higher government expenditures in similar proportions that they were funded in the benchmark period, households’ utilities fell in the taxing region. This result should give pause to any public officials who desire to increase taxes in order to maintain the same kind of public expenditures that are currently available. It would be wrong to unequivocally state that the optimal level and mix of public services and tax revenues is lower (or higher) than the benchmark level (since we have not examined every possible combination of tax rates and expenditure types to determine the one combination that

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\(^1\) See, for example, Mieszkowski and Zodrow (1989).
would maximize household utility); however, it is clear that any tax increase to fund higher levels of status quo expenditure types will be looked on unfavorably by residents of the taxing region.

Another clear policy consideration is the conflict between Rich household mobility and progressive government expenditures. We have seen, in many simulations in which Rich households were assumed to be inter-regionally mobile, that tax changes which were meant to increase the progressive incidence of taxes and expenditures were thwarted by an outflow of Rich households. Hence policymakers who desire to help the Poor by soaking the Rich may need to run for national office, since it can be a futile endeavor at the sub-national level.

Indeed, crucial to many of the simulation results was the inter-regional mobility assumption of Rich households. This is an area that needs far greater exploration if policymakers wish to make more knowledgeable tax policy decisions. Some measure of the elasticity of migratory response with respect to each tax change would aid considerably in tax policy decisions. Care should also be taken to analyze the effects of tax policy changes not only for a few years but also for longer time periods, since migratory responses may not be immediate.

Some policymakers may, however, be heartened that sub-national use of business capital taxes was not a disaster; on the contrary, in many cases use of these taxes was preferred over use of other taxes. The burden-shifting of this tax, partially onto residents of other regions, more than offset the reduction in economic activity in the region that the tax caused.\(^2\)

Policymakers should also consider their ability to export their tax burdens onto residents of other regions. The simulations reveal that backward shifting of business capital taxes onto non-residents is effective if a region uses more capital than its residents

\(^2\) Policymakers may also take note from this result that “economic growth” is, by itself, neither unambiguously beneficial nor harmful to a region’s residents.
own. Other simulations reveal that forward shifting of this tax onto consumers in other regions is also possible, but only if the percentage of the product exported is significant and its elasticity of substitution in consumption with goods produced in other regions is low.

Finally, one must take care not to infer too much from the precise numerical estimates garnered from the simulations concerning the effects of tax policy changes; the uncertainties involving certain parameter estimates—especially elasticities of substitution—make precision impossible at this stage. In the future, perhaps, these estimates can be made with more precision. Sensitivity analysis has shown, however, that the directions of the results are fairly robust over large variations in the elasticity of substitution estimates.

_Beyond the Thesis_

**Other uses of the CGE model:** My CGE model can be used to examine many other economic issues. Here are a few examples:

1. _The Incidence of a Sub-National Personal Income Tax_. Simulations could be undertaken in which one region's government changes its personal income tax rate, or in which all regions' governments multilaterally change their personal income tax rates. One could see, for example, to what degree Rich households' choice of regional residence depends upon their personal income tax rate. One could also examine how sensitive the welfare of a region's Poor residents is to the level of taxation of Rich residents of the region.

2. _The Incidence of a National Personal Income Tax_. In the multi-region CGE model presented in this thesis, a change in the Federal government's personal income tax rate could have distributional effects that vary across regions. For example, Poor households in the Northeast might be affected differently than Poor households in the South even if Federal personal income tax rates are changed equally across regions. This
disparity may result from inter-regional factor flows between regions. The extent of this disparity could be examined in detail with several computer simulations.

3. *The Incidence of a Change in a Sub-National Government's Expenditure Patterns.* A regional government may decide to alter the percentage of its revenues that it spends on transfer payments vis-à-vis public goods. This decision could affect not only the residents of the region but also the residents of other regions. A regional government may also choose to alter the amount of benefits that they give to Rich households vis-à-vis Poor households. This decision could also have wide-ranging national effects.

4. *The Incidence of a Sub-National Capital Subsidy.* Many state governments today offer enticements to firms willing to locate within their state; these enticements could be simulated in my CGE model. For example, a regional government could reduce the rate at which it taxes "new" capital that migrates into the region from other regions. Or, a region could increase one tax (say, its sales tax) in order to reduce a business capital tax while maintaining a constant level of government expenditures.

5. *The Incidence of a Sub-National Capital Gains Tax Reduction.* Recently California's government reduced the rate at which it taxes its residents' capital gains; some government officials there credit this tax reduction for a part of California's recent economic recovery. This type of sub-national reduction in one type of personal income can be simulated using my CGE model.

6. *Differential Incidence of a Sub-National Sales Tax.* Michigan's government recently reduced its residents' property tax rates, replacing the lost revenue with money gained from higher sales tax rates. This type of differential tax policy can be simulated in my CGE model by having one region reduce its business and residential capital tax rates while simultaneously raising its sales tax rates and keeping government expenditures constant.\(^3\)

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\(^3\)This issue was first brought to my attention by Peter Mieszkowski.
7. *Incidence of a National Value-Added Tax*. Some policy makers have advocated that the Federal government adopt a value-added tax as an additional source of revenue. This tax may not increase the prices of similar products by the same percentage in all regions, due to inter-regional factor movements. This issue can be examined using my CGE model.

These and other economic issues can be examined using my CGE model in its current form. In addition, my CGE model can be modified to examine many other issues. Listed below are some possible modifications, and some issues that the newly modified CGE model could examine.

*A) Regional External Economies of Scale.* Peter Hartley has suggested that a region may be interested in attracting capital not only for the increased jobs and production directly created by the new capital, but also for the external benefits that the new capital has on production already occurring in the region. (He cites such possible real-world examples as the research triangle in North Carolina and Silicon Valley in California.) In my CGE model, this potential effect could be incorporated by modifying production functions so that output depends on capital external to a firm's direct use.

*B) Number of Types of Households.* Certainly there are more than two types of households extant in the U.S. or in any other economy. The hypothetical households that were created in chapters 8 and 9 indicate that incidence results vary not only depending upon a household's total income but also on the sources of the household's income. Increasing the number of types of households in my model could capture these effects with much greater definition than with the hypothetical households used in this thesis.

*C) Number of Regions and CGE Model Realism.* It would be more realistic to increase the number of sub-national governments in my CGE model from four to fifty, in order to more accurately reflect the varying policies of the fifty U.S. state governments. There is no technical obstacle to this expansion; however, considerable additional data
gathering and computer programming would need to be undertaken. This task is beyond the reasonable abilities of a single person.

D) NAFTA, GATT, and International Trade. Recent reductions in trade barriers may have significant effects on international flows of capital and products. My CGE model could be modified from a multi-region model into a multinational model; simulations could then be undertaken to examine the potential effects of trade agreements such as the North American Free Trade Agreement.

E) U.S. Immigration Issues. A modified version of my CGE model similar to a type used in (D) above could also determine the economically optimal type and amount of immigration into the U.S. One could determine how varying levels and types of immigration affect utility levels of U.S. citizens and immigrants.

F) Incidence of Federal Budget Deficit Reduction. A financial capital market and a class of "retired" households could be added to my CGE model to help determine who will benefit and who will lose from various possible deficit reduction schemes. One might see, for example, that regions populated relatively heavily with retired people would suffer from deficit reduction, while regions populated heavily with working people would benefit.

The effects of these and many other economic events can be studied using my CGE model or a modified version of it. The versatility of CGE models is an attractive feature.

Thus ends this chapter. The final chapter--the thesis' conclusion--follows.
11. Conclusion

In this dissertation I have constructed a 4-good, 4-region, 2-factor, 2-household computational general equilibrium model of the United States which I have used to undertake 43 simulations of sub-national tax policy changes. Results of the simulations indicate that higher sub-national tax rates reduce household utilities, that business capital taxes are often preferred to household taxes, that sub-national redistribution of income from Rich to Poor is difficult if the Rich are inter-regionally mobile, and that the results are somewhat, but not greatly sensitive to the choice of values for elasticities of substitution in production and consumption.

Too often sub-national tax policy decisions are made for purely political or emotional reasons, without a dispassionate review of the predicted effects of the tax change, or to allegedly accomplish vague economic goals such as ‘to create jobs’ or ‘to foster growth.’ My hope is that this thesis demonstrates the viability of CGE models as a tool of applied policy analysis, and offers insight into the effects of various tax policy options. Clearly, the model presented here is far from perfect. But the gap between theory and practice is wide when it comes to applying economic principles to applied sub-national tax policy analysis. I hope that this dissertation makes a small contribution toward building a bridge between theory and practice, so that policymakers and voters can make principled decisions based in part upon accurate and judicial economic analysis.
Appendix A: Tables
Table 3.1: List of Variables Used in Chapter 3

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Scale parameter in production function of good X</td>
</tr>
<tr>
<td>b</td>
<td>Distribution parameter in production function of X</td>
</tr>
<tr>
<td>C</td>
<td>Scale parameter in production function of good Y</td>
</tr>
<tr>
<td>d</td>
<td>Distribution parameter in production function of Y</td>
</tr>
<tr>
<td>F</td>
<td>Scale parameter in household utility function</td>
</tr>
<tr>
<td>j</td>
<td>Distribution parameter in household utility function</td>
</tr>
<tr>
<td>K</td>
<td>Household endowment of capital</td>
</tr>
<tr>
<td>K_x</td>
<td>Capital used in the production of good X</td>
</tr>
<tr>
<td>K_x1</td>
<td>Capital required per unit of good X output</td>
</tr>
<tr>
<td>K_y</td>
<td>Capital used in the production of good Y</td>
</tr>
<tr>
<td>K_y1</td>
<td>Capital required per unit of good Y output</td>
</tr>
<tr>
<td>L_x</td>
<td>Capital used in the production of good X</td>
</tr>
<tr>
<td>L_x1</td>
<td>Capital required per unit of good X output</td>
</tr>
<tr>
<td>L_y</td>
<td>Capital used in the production of good Y</td>
</tr>
<tr>
<td>L_y1</td>
<td>Capital required per unit of good Y output</td>
</tr>
<tr>
<td>p_k</td>
<td>Net price of capital</td>
</tr>
<tr>
<td>p_kx</td>
<td>Net price of capital in sector X</td>
</tr>
<tr>
<td>p_ky</td>
<td>Net price of capital in sector Y</td>
</tr>
<tr>
<td>p_L</td>
<td>Net price of labor</td>
</tr>
<tr>
<td>p_L_x</td>
<td>Net price of labor in sector X</td>
</tr>
<tr>
<td>p_L_y</td>
<td>Net price of labor in sector Y</td>
</tr>
<tr>
<td>p_X</td>
<td>Price of X</td>
</tr>
<tr>
<td>p_y</td>
<td>Price of Y</td>
</tr>
<tr>
<td>R</td>
<td>Government transfer payment to the household</td>
</tr>
</tbody>
</table>
\( t \)  Tax rate on capital income in sector Y

\( T \)  Total tax revenue

\( U \)  Household utility

\( X \)  A good

\( X_h \)  Household demand for X

\( X_s \)  Supply of X

\( Y \)  A good

\( Y_h \)  Household demand for Y

\( Y_s \)  Supply of Y
Table 3.2: Benchmark Data from Chapter 3

<table>
<thead>
<tr>
<th>Production Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply:</td>
</tr>
<tr>
<td>( X_S = 100 )</td>
</tr>
<tr>
<td>( Y_S = 50 )</td>
</tr>
<tr>
<td>Factor Demands:</td>
</tr>
<tr>
<td>( L_X = 25, K_X = 75 )</td>
</tr>
<tr>
<td>( L_Y = 25, K_Y = 25 )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Household Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand:</td>
</tr>
<tr>
<td>( X_h = 100 )</td>
</tr>
<tr>
<td>( Y_h = 50 )</td>
</tr>
<tr>
<td>Factor Supply:</td>
</tr>
<tr>
<td>( L = 50 )</td>
</tr>
<tr>
<td>( K = 100 )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Government Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue:</td>
</tr>
<tr>
<td>( T = 0 ) (implies that ( t=0 ), since ( K_Y &gt; 0 ))</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Price Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p_L = 1 )</td>
</tr>
<tr>
<td>( p_K = 1 )</td>
</tr>
<tr>
<td>( p_X = 1 )</td>
</tr>
<tr>
<td>( p_Y = 1 )</td>
</tr>
</tbody>
</table>
Table 3.3: Benchmark vs. Counter Factual Equilibrium from Ch. 3

<table>
<thead>
<tr>
<th></th>
<th>Benchmark</th>
<th>Counterfactual</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Government</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tax Rate on K in Sector Y</td>
<td>0%</td>
<td>50%</td>
</tr>
<tr>
<td>Tax Revenue</td>
<td>$0</td>
<td>$8.33</td>
</tr>
<tr>
<td>Transfer Payment</td>
<td>$0</td>
<td>$8.33</td>
</tr>
<tr>
<td><strong>Production</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price of X</td>
<td>$1</td>
<td>$0.94</td>
</tr>
<tr>
<td>X Production</td>
<td>100</td>
<td>106.75</td>
</tr>
<tr>
<td>Price of Y</td>
<td>$1</td>
<td>$1.17</td>
</tr>
<tr>
<td>Y Production</td>
<td>50</td>
<td>42.64</td>
</tr>
<tr>
<td><strong>Factor Markets</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Price of Capital</td>
<td>$1</td>
<td>$0.92</td>
</tr>
<tr>
<td>Capital Used in Sector X</td>
<td>75</td>
<td>81.81</td>
</tr>
<tr>
<td>Capital Used in Sector Y</td>
<td>25</td>
<td>18.18</td>
</tr>
<tr>
<td>Net Price of Labor</td>
<td>$1</td>
<td>$1</td>
</tr>
<tr>
<td>Labor Used in Sector X</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Labor Used in Sector Y</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td><strong>Household Utility</strong></td>
<td>1</td>
<td>.99</td>
</tr>
</tbody>
</table>

(Equivalent variation measure of excess burden = $1.42, or about 1% of pretax household income.)
Table 5.1: Qualities of My CGE Model

The Nation: The United States is divided into four regions: the Northeast, the South, Texas and the West.

Production: Four types of products are produced in each region: Goods, Services, Regional Public Goods, and Federal Public Goods. Goods are inter-regionally traded; the other products are not. Production requires three inputs: Capital, Skilled Labor, and Unskilled Labor. Producers minimize average costs and earn zero profits.

Households: Two types of households, Rich and Poor, populate each region. Rich households can be assumed to be either inter-regionally mobile or immobile; Poor households are inter-regionally immobile. Rich households are endowed with capital and skilled labor; Poor households have capital and unskilled labor. Households supply their labor to production in their region of residence; they may supply their capital to any region. Households maximize their utility constrained by their disposable income.

Governments: Four regional governments and a Federal government provide transfer payments and public goods to households. The regional public good is "congested." They receive revenue from business taxes, household taxes, and sales taxes.

Conditions for Equilibrium:
1. Demand equals supply for capital, skilled labor, unskilled labor, Goods, and Services.
2. Government budgets are balanced.
3. Rich households' utilities are equalized among residents of differing regions when the Rich are assumed to be inter-regionally mobile.
Table 8.2: Effects of Simulations 1-20 on Households

**Texas Collecting 25% More Tax Revenue than Benchmark: Rich IMMOBILE**

<table>
<thead>
<tr>
<th>Loss to a Rich Texas Household</th>
<th>Tax Increased</th>
<th>% utility loss (100% = 100.00)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business labor tax</td>
<td>1.13</td>
<td></td>
</tr>
<tr>
<td>Corporate tax</td>
<td>1.03</td>
<td></td>
</tr>
<tr>
<td>Sales tax</td>
<td>1.08</td>
<td></td>
</tr>
<tr>
<td>Business capital tax</td>
<td>.66</td>
<td></td>
</tr>
<tr>
<td>Household tax</td>
<td>3.28</td>
<td></td>
</tr>
</tbody>
</table>

**% Real Earned Income Loss to a Hypothetical Texas Rich Household Who:**

<table>
<thead>
<tr>
<th>Tax Increased</th>
<th>Earns Only Capital Income</th>
<th>Has 50% Capital Income Earns Only</th>
<th>And 50% Labor Income</th>
<th>Labor Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business labor tax</td>
<td>.02</td>
<td>1.68</td>
<td>3.34</td>
<td></td>
</tr>
<tr>
<td>Corporate tax</td>
<td>.21</td>
<td>1.17</td>
<td>2.13</td>
<td></td>
</tr>
<tr>
<td>Sales tax</td>
<td>.23</td>
<td>1.27</td>
<td>2.31</td>
<td></td>
</tr>
<tr>
<td>Business capital tax</td>
<td>.33</td>
<td>.54</td>
<td>.74</td>
<td></td>
</tr>
<tr>
<td>Household tax</td>
<td>.02</td>
<td>GAIN of .59</td>
<td>GAIN of 1.21</td>
<td></td>
</tr>
</tbody>
</table>

**Loss to a POOR Texas Household**

<table>
<thead>
<tr>
<th>Tax Increased</th>
<th>% utility loss (100% = 100.00)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business labor tax</td>
<td>1.83</td>
</tr>
<tr>
<td>Corporate tax</td>
<td>1.17</td>
</tr>
<tr>
<td>Sales tax</td>
<td>1.28</td>
</tr>
<tr>
<td>Business capital tax</td>
<td>.23</td>
</tr>
<tr>
<td>Household tax</td>
<td>.40</td>
</tr>
</tbody>
</table>

**% Real Earned Income Loss to a Hypothetical Texas POOR Household Who:**

<table>
<thead>
<tr>
<th>Tax Increased</th>
<th>Earns Only Capital Income</th>
<th>Has 50% Capital Income Earns Only</th>
<th>And 50% Labor Income</th>
<th>Labor Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business labor tax</td>
<td>.27</td>
<td>1.69</td>
<td>3.36</td>
<td></td>
</tr>
<tr>
<td>Corporate tax</td>
<td>.21</td>
<td>1.06</td>
<td>1.91</td>
<td></td>
</tr>
<tr>
<td>Sales tax</td>
<td>.23</td>
<td>1.16</td>
<td>2.09</td>
<td></td>
</tr>
<tr>
<td>Business capital tax</td>
<td>.33</td>
<td>.36</td>
<td>.39</td>
<td></td>
</tr>
<tr>
<td>Household tax</td>
<td>.02</td>
<td>GAIN of .57</td>
<td>GAIN of 1.16</td>
<td></td>
</tr>
</tbody>
</table>
North/Mid Collecting 25% More Tax Revenue than Benchmark: Rich IMMOBILE

% utility loss (100% = 100.00)

Loss to a Rich North/Mid Household Tax Increased

<table>
<thead>
<tr>
<th>Tax Increased</th>
<th>Earns Only Capital Income</th>
<th>Has 50% Capital Income And 50% Labor Income</th>
<th>Earns Only Labor Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business labor tax</td>
<td>.19</td>
<td>2.41</td>
<td>4.63</td>
</tr>
<tr>
<td>Business capital tax</td>
<td>2.60</td>
<td>1.64</td>
<td>.69</td>
</tr>
<tr>
<td>Corporate tax</td>
<td>1.43</td>
<td>2.16</td>
<td>2.90</td>
</tr>
<tr>
<td>Sales tax</td>
<td>1.44</td>
<td>2.22</td>
<td>3.02</td>
</tr>
<tr>
<td>Household tax</td>
<td>.16</td>
<td>.37</td>
<td>.91</td>
</tr>
</tbody>
</table>

% Real Earned Income Loss to a Hypothetical North/Mid Rich Household Who:

% utility loss (100% = 100.00)

Loss to a POOR North/Mid Household Tax Increased

<table>
<thead>
<tr>
<th>Tax Increased</th>
<th>Earns Only Capital Income</th>
<th>Has 50% Capital Income And 50% Labor Income</th>
<th>Earns Only Labor Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business labor tax</td>
<td>2.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business capital tax</td>
<td>.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corporate tax</td>
<td>1.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales tax</td>
<td>2.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household tax</td>
<td>.56</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

% Real Earned Income Loss to a Hypothetical North/Mid POOR Household Who:

<table>
<thead>
<tr>
<th>Tax Increased</th>
<th>Earns Only Capital Income</th>
<th>Has 50% Capital Income And 50% Labor Income</th>
<th>Earns Only Labor Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business labor tax</td>
<td>.19</td>
<td>2.41</td>
<td>4.63</td>
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<tr>
<td>Business capital tax</td>
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<td>1.51</td>
<td>.43</td>
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<tr>
<td>Corporate tax</td>
<td>1.43</td>
<td>2.08</td>
<td>2.73</td>
</tr>
<tr>
<td>Sales tax</td>
<td>1.44</td>
<td>2.16</td>
<td>3.88</td>
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<tr>
<td>Household tax</td>
<td>.16</td>
<td>.37</td>
<td>.90</td>
</tr>
</tbody>
</table>
Texas Collecting 25% More Tax Revenue than Benchmark; Rich CAN MOVE

% utility loss (100%=100.00)

<table>
<thead>
<tr>
<th>Tax Increased</th>
<th>Earns Only</th>
<th>Has 50% Capital Income And 50% Labor Income</th>
<th>Earns Only Labor Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business labor tax</td>
<td>.17</td>
<td>GAIN of .02</td>
<td>GAIN of .12</td>
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<td>Corporate tax</td>
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<td>GAIN of .23</td>
<td>GAIN of .70</td>
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<td>Sales tax</td>
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<td>GAIN of .21</td>
<td>GAIN of .67</td>
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<tr>
<td>Business capital tax</td>
<td>.35</td>
<td>GAIN of .22</td>
<td>GAIN of .80</td>
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<tr>
<td>Household tax</td>
<td>.18</td>
<td>GAIN of 6.54</td>
<td>GAIN of 13.25</td>
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</table>

% Real Earned Income Loss to a Hypothetical Texas Rich Household Who:

<table>
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<tr>
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<th>Has 50% Capital Income And 50% Labor Income</th>
<th>Earns Only Labor Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business labor tax</td>
<td>2.38</td>
<td>2.09</td>
<td>4.13</td>
</tr>
<tr>
<td>Corporate tax</td>
<td>1.60</td>
<td>1.38</td>
<td>2.52</td>
</tr>
<tr>
<td>Sales tax</td>
<td>1.71</td>
<td>1.48</td>
<td>2.71</td>
</tr>
<tr>
<td>Business capital tax</td>
<td>.45</td>
<td>.52</td>
<td>.69</td>
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<tr>
<td>Household tax</td>
<td>2.07</td>
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</tbody>
</table>

% Real Earned Income Loss to a Hypothetical Texas POOR Household Who:

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<tr>
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<th>Earns Only Capital Income</th>
<th>Has 50% Capital Income And 50% Labor Income</th>
<th>Earns Only Labor Income</th>
</tr>
</thead>
<tbody>
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<td>Business labor tax</td>
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<tr>
<td>Corporate tax</td>
<td>.25</td>
<td>1.38</td>
<td>2.52</td>
</tr>
<tr>
<td>Sales tax</td>
<td>.25</td>
<td>1.48</td>
<td>2.71</td>
</tr>
<tr>
<td>Business capital tax</td>
<td>.35</td>
<td>.52</td>
<td>.69</td>
</tr>
<tr>
<td>Household tax</td>
<td>.18</td>
<td>.60</td>
<td>1.03</td>
</tr>
</tbody>
</table>
North/Mid Collecting 25% More Tax Revenue than Benchmark: Rich CAN MOVE

% utility loss (100%=100.00)

Loss to a Rich North/Mid Household Tax Increased

- Business labor tax: .71
- Corporate tax: 1.36
- Sales tax: 1.42
- Business capital tax: 1.63
- Household tax: 1.75

% Real Earned Income Loss to a Hypothetical North/Mid Rich Household Who:

<table>
<thead>
<tr>
<th>Tax Increased</th>
<th>Earns Only Capital Income</th>
<th>Has 50% Capital Income And 50% Labor Income</th>
<th>Earns Only Labor Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business labor tax</td>
<td>0.06</td>
<td>0.78</td>
<td>1.50</td>
</tr>
<tr>
<td>Corporate tax</td>
<td>1.38</td>
<td>0.70</td>
<td>0.03</td>
</tr>
<tr>
<td>Sales tax</td>
<td>1.38</td>
<td>0.71</td>
<td>0.04</td>
</tr>
<tr>
<td>Business capital tax</td>
<td>2.60</td>
<td>0.81</td>
<td>GAIN of 0.97</td>
</tr>
<tr>
<td>Household tax</td>
<td>0.28</td>
<td>GAIN of 7.28</td>
<td>GAIN of 14.27</td>
</tr>
</tbody>
</table>

Loss to a POOR North/Mid Household Tax Increased

- Business labor tax: 3.29
- Corporate tax: 2.72
- Sales tax: 2.89
- Business capital tax: 1.20
- Household tax: 3.44

% Real Earned Income Loss to a Hypothetical North/Mid POOR Household Who:

<table>
<thead>
<tr>
<th>Tax Increased</th>
<th>Earns Only Capital Income</th>
<th>Has 50% Capital Income And 50% Labor Income</th>
<th>Earns Only Labor Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business labor tax</td>
<td>0.06</td>
<td>3.04</td>
<td>6.02</td>
</tr>
<tr>
<td>Corporate tax</td>
<td>1.38</td>
<td>2.63</td>
<td>3.89</td>
</tr>
<tr>
<td>Sales tax</td>
<td>1.38</td>
<td>2.73</td>
<td>4.08</td>
</tr>
<tr>
<td>Business capital tax</td>
<td>2.60</td>
<td>1.80</td>
<td>1.00</td>
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<tr>
<td>Household tax</td>
<td>0.29</td>
<td>1.43</td>
<td>3.15</td>
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</table>
Table 8.3: Results of Simulations 1-20

(In each case, government increases revenue by 25% and spends it similarly to benchmark)

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Texas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Rich Immobile)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business Capital Tax</td>
<td>-0.4,-0.1 +0.3</td>
<td>-4.3 NA</td>
<td>NA</td>
<td>-0.66 -0.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business Labor Tax</td>
<td>-4.3,-4.3 +0.03</td>
<td>+0.2 NA</td>
<td>NA</td>
<td>-1.13 -1.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corporate Tax</td>
<td>-1.9,-1.7 +0.2</td>
<td>-2.6 NA</td>
<td>NA</td>
<td>-1.03 -1.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales Tax</td>
<td>-2.1,-1.9 +0.2</td>
<td>-2.8 NA</td>
<td>NA</td>
<td>-1.08 -1.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household Tax</td>
<td>+1.2,+1.2 +0.02</td>
<td>+0.3 _+</td>
<td>NA</td>
<td>-3.28 -0.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Rich Mobile)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business Capital Tax</td>
<td>+1.2,-0.3 +0.2</td>
<td>+0.4 NA</td>
<td>NA</td>
<td>-1.3 -0.24 -0.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business Labor Tax</td>
<td>+0.2,-4.1 +0.07</td>
<td>-0.3 NA</td>
<td>NA</td>
<td>-3.0 -0.17 -2.38</td>
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<td></td>
</tr>
<tr>
<td>Corporate Tax</td>
<td>+1.0,-2.3 +0.25</td>
<td>-3.1 NA</td>
<td>NA</td>
<td>-2.4 -0.24 -1.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales Tax</td>
<td>+0.9,-2.5 +0.25</td>
<td>-3.3 NA</td>
<td>NA</td>
<td>-2.6 -0.26 -1.71</td>
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<td></td>
</tr>
<tr>
<td>Household Tax</td>
<td>+13.5,-84 +0.2</td>
<td>-1.1 _+</td>
<td>NA</td>
<td>-9.1 -0.51 -2.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northeast/Midwest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Rich Immobile)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business Capital Tax</td>
<td>+2.0,+2.2 +2.7</td>
<td>-4.0 NA</td>
<td>NA</td>
<td>-2.08 -0.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business Labor Tax</td>
<td>-4.4,-4.4 +0.2</td>
<td>+0.3 NA</td>
<td>NA</td>
<td>-1.63 -2.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corporate Tax</td>
<td>-1.5,-1.3 +1.5</td>
<td>-2.0 NA</td>
<td>NA</td>
<td>-2.15 -1.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales Tax</td>
<td>-1.6,-1.5 +1.5</td>
<td>-2.1 NA</td>
<td>NA</td>
<td>-2.24 -2.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household Tax</td>
<td>+1.1,+1.1 +0.2</td>
<td>+0.4 _+</td>
<td>NA</td>
<td>-4.26 -0.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Rich Mobile)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business Capital Tax</td>
<td>+3.7,+1.6 +2.7</td>
<td>-4.6 NA</td>
<td>NA</td>
<td>-1.6 -1.63 -1.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business Labor Tax</td>
<td>-1.4,-6.0 +0.1</td>
<td>-0.7 NA</td>
<td>NA</td>
<td>-3.3 -0.71 -3.29</td>
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</tr>
<tr>
<td>Corporate Tax</td>
<td>+1.4,-2.5 +1.4</td>
<td>-3.1 NA</td>
<td>NA</td>
<td>-2.9 -1.36 -2.72</td>
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</tr>
<tr>
<td>Sales Tax</td>
<td>+1.4,-2.7 +1.4</td>
<td>-3.2 NA</td>
<td>NA</td>
<td>-3.0 -1.42 -2.89</td>
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</tr>
<tr>
<td>Household Tax</td>
<td>+13.9,-3.4 -0.3</td>
<td>-3.3 _+</td>
<td>NA</td>
<td>-11.2 -1.75 -3.44</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Numbers are percentages (maximum = 100)
Abbreviations: "-" means "negative"  "+" means "positive"  "NA" means "not applicable"
Table 8.4: Group 2: Differential Incidence Simulations

21: Texas eliminates its business capital tax, replacing the revenue lost by imposing a household income tax; the Rich are inter-regionally immobile.

22: Texas eliminates its business capital tax, replacing the revenue lost by imposing a household income tax; the Rich can relocate inter-regionally.

23: The Northeast/Midwest eliminates its household income tax, replacing the revenue lost by imposing a business capital tax; the Rich are inter-regionally immobile.

24: The Northeast/Midwest eliminates its household income tax, replacing the revenue lost by imposing a business capital tax; the Rich can relocate inter-regionally.
Table 8.5: Results of Simulations 21-24

(In each case, tax revenue remains constant as one tax is replaced with another.)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Rich,Immobile)</td>
<td>+0.8, +0.6</td>
<td>-0.2</td>
<td>+2.3</td>
<td>-,+</td>
<td>NA</td>
<td>-1.36, -0.11</td>
</tr>
<tr>
<td>(Rich,Mobile)</td>
<td>+5.8, +0.2</td>
<td>-0.1</td>
<td>+1.7</td>
<td>-,+</td>
<td>-4.0</td>
<td>-0.13, -0.79</td>
</tr>
</tbody>
</table>

Texas: Household income tax replaces business capital tax.

Northeast/Midwest: Business capital tax replaces household income tax.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Rich,Immobile)</td>
<td>+1.5, +2.0</td>
<td>+4.7</td>
<td>-8.2</td>
<td>+,-</td>
<td>NA</td>
<td>+3.62, -0.74</td>
</tr>
<tr>
<td>(Rich,Mobile)</td>
<td>-10.4, +6.4</td>
<td>+5.0</td>
<td>-3.8</td>
<td>+,-</td>
<td>+12.7</td>
<td>+0.02, +1.92</td>
</tr>
</tbody>
</table>

Numbers are percentages (100% = 100)
Abbreviations: "-" means "negative" "+" means "positive" "NA" means "not applicable"
Table 9.1: List of Simulations Performed in this Chapter

Group 3: Varying Production Elasticities of Substitution

(Elasticities of factor substitution of all factors in all production sectors in all regions equal 1.5 in simulations 25 and 26.)

25. Northeast/Midwest eliminates its household income tax and increases its business capital tax (tax revenues remain unchanged from benchmark); Rich immobile

26. Northeast/Midwest eliminates its household income tax and increases its business capital tax (tax revenues remain unchanged from benchmark); Rich can relocate.

(Elasticities of factor substitution of all factors in all production sectors in all regions equal .1 in simulations 27 and 28.)

27. Northeast/Midwest eliminates its household income tax and increases its business capital tax (tax revenues remain unchanged from benchmark); Rich immobile

28. Northeast/Midwest eliminates its household income tax and increases its business capital tax (tax revenues remain unchanged from benchmark); Rich can relocate.

(In simulations 29 and 30, elasticities of factor substitution between skilled labor and unskilled labor in all production sectors in all regions equal .1. All other elasticities of factor substitution remain at their estimates in the initial benchmark equilibrium.)

29. Northeast/Midwest eliminates its household income tax and increases its business capital tax (tax revenues remain unchanged from benchmark); Rich immobile

30. Northeast/Midwest eliminates its household income tax and increases its business capital tax (tax revenues remain unchanged from benchmark); Rich can relocate.
Group 4: Elasticity of Substitution Among Goods Produced in Different Regions = 10

(Simulations 31-35) The Texas Government Increases Its Revenue by 25%.
Rich Households are immobile.

31. The Texas government raises its labor tax on producers to gain the revenue.
32. The Texas government raises its capital tax on producers to gain the revenue.
33. The Texas government raises its corporation tax on producers to gain the revenue.
34. The Texas government raises its sales tax to gain the revenue.
35. The Texas government raises its household income tax to gain the revenue.

(Simulations 36-40) The Texas Government Increases Its Revenue by 25%.
Rich Households can relocate.

36. The Texas government raises its labor tax on producers to gain the revenue.
37. The Texas government raises its capital tax on producers to gain the revenue.
38. The Texas government raises its corporation tax on producers to gain the revenue.
39. The Texas government raises its sales tax to gain the revenue.
40. The Texas government raises its household income tax to gain the revenue.

(Simulations 41 and 42) Differential Incidence

41. Texas household income tax replaces business capital tax; Rich immobile
42. Texas household income tax replaces business capital tax; Rich can relocate
Table 9.2: Results of Simulations 25-30

(In each case, tax revenue remains constant as one tax is replaced with another.)

<table>
<thead>
<tr>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(Rich, Poor)</td>
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<td>Price</td>
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<td>Utility</td>
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<td>Poor</td>
<td></td>
<td></td>
<td>Poor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Northeast/Midwest: Business capital tax replaces household income tax.

1. Elasticities of factor substitution are at original levels
   (Rich Immobile) +1.5, +2.0, +4.7 -8.2 +,- NA +3.62 -0.74
   (Rich Mobile) -10.4, +6.4, +5.0 -3.8 +,- +12.7 +0.02 +1.92

2. Elasticities of factor substitution are all equal to 1.5
   25. (Rich Immobile) +3.2, +3.5, +4.9 -11.7 +,- NA +3.77 -0.11
   26. (Rich Mobile) -10.2, +10.6, +5.2 -0.7 +,- +35.2 +0.38 +5.43

3. Elasticities of factor substitution are all equal to .1
   27. (Rich Immobile) -2.5, -1.5, +4.1 -1.4 +,- NA +3.32 -1.79
   28. (Rich Mobile) -17.4, -7.1, +1.6 -1.8 +,- +1.1 +1.08 -3.28

4. Elasticities of labor factor substitution only are all equal to .1
   29. (Rich Immobile) -1.5, +1.8, +4.7 -8.3 +,- NA +2.67 -0.91
   30. (Rich Mobile) -10.9, +0.1, +4.5 -8.6 +,- +1.0 -0.04 -1.54

Numbers are percentages (100% = 100)
Abbreviations: "-" means "negative" "+" means "positive" "NA" means "not applicable"
# Table 9.3 Simulations 31-42 Results (bottom half of page)

<table>
<thead>
<tr>
<th>Simulation</th>
<th>(Rich,Poor)</th>
<th>(Rich,Poor)</th>
<th>(Rich,Poor)</th>
<th>(Rich,Poor)</th>
<th>(Rich,Poor)</th>
<th>(Rich,Poor)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BALANCED BUDGET:</strong> Texas increases tax revenue by 25% in each case (Rich Immobile)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business Capital Tax</td>
<td>-0.4,-0.1</td>
<td>+0.3</td>
<td>-4.3</td>
<td>NA</td>
<td>NA</td>
<td>-0.66</td>
</tr>
<tr>
<td>Business Labor Tax</td>
<td>-3.3,-3.3</td>
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<td>+0.2</td>
<td>NA</td>
<td>NA</td>
<td>-1.13</td>
</tr>
<tr>
<td>Corporate Tax</td>
<td>-1.9,-1.7</td>
<td>+0.2</td>
<td>-2.6</td>
<td>NA</td>
<td>NA</td>
<td>-1.03</td>
</tr>
<tr>
<td>Sales Tax</td>
<td>-2.1,-1.9</td>
<td>+0.2</td>
<td>-2.8</td>
<td>NA</td>
<td>NA</td>
<td>-1.08</td>
</tr>
<tr>
<td>Household Tax</td>
<td>+1.2,+1.2</td>
<td>+0.02</td>
<td>+0.3</td>
<td>-,+</td>
<td>NA</td>
<td>-3.28</td>
</tr>
<tr>
<td><strong>(Rich Mobile)</strong></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>Business Capital Tax</td>
<td>+1.2,-0.3</td>
<td>+0.2</td>
<td>-4.6</td>
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<tr>
<td>Business Labor Tax</td>
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<td>+0.9,-2.5</td>
<td>+0.25</td>
<td>-3.3</td>
<td>NA</td>
<td>-2.6</td>
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</tr>
<tr>
<td>Household Tax</td>
<td>+13.5,-.84</td>
<td>+0.2</td>
<td>-1.1</td>
<td>-,+</td>
<td>-9.1</td>
<td></td>
</tr>
<tr>
<td><strong>DIFFERENTIAL INCIDENCE:</strong> Texas household income tax replaces business capital tax (Rich Immobile)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Rich Immobile)</td>
<td>+0.8,+0.6</td>
<td>-0.2</td>
<td>+2.3</td>
<td>-,+</td>
<td>NA</td>
<td>-1.36</td>
</tr>
<tr>
<td>(Rich Mobile)</td>
<td>-5.8,-0.1</td>
<td>-0.1</td>
<td>+1.7</td>
<td>-,+</td>
<td>-4.0</td>
<td></td>
</tr>
<tr>
<td><strong>SENSITIVITY ANALYSIS:</strong> Same simulations with Goods elasticity raised from 3 to 10** BALANCED BUDGET: Texas increases tax revenue by 25% in each case (Rich Immobile)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business Capital Tax</td>
<td>-3.3,-2.7</td>
<td>+0.4</td>
<td>-7.3</td>
<td>NA</td>
<td>NA</td>
<td>-1.40</td>
</tr>
<tr>
<td>Business Labor Tax</td>
<td>-4.0,-4.0</td>
<td>+0.04</td>
<td>-0.4</td>
<td>NA</td>
<td>NA</td>
<td>-1.32</td>
</tr>
<tr>
<td>Corporate Tax</td>
<td>-4.2,-3.8</td>
<td>+0.2</td>
<td>-4.7</td>
<td>NA</td>
<td>NA</td>
<td>-1.61</td>
</tr>
<tr>
<td>Sales Tax</td>
<td>-4.5,-4.2</td>
<td>+0.2</td>
<td>-5.0</td>
<td>NA</td>
<td>NA</td>
<td>-1.71</td>
</tr>
<tr>
<td>Household Tax</td>
<td>+0.5,+0.6</td>
<td>+0.03</td>
<td>-0.3</td>
<td>-,+</td>
<td>NA</td>
<td>-3.54</td>
</tr>
<tr>
<td><strong>(Rich Mobile)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business Capital Tax</td>
<td>+0.6,-4.0</td>
<td>+0.5</td>
<td>-8.6</td>
<td>NA</td>
<td>-3.7</td>
<td></td>
</tr>
<tr>
<td>Business Labor Tax</td>
<td>-0.3,-5.4</td>
<td>+0.09</td>
<td>-1.5</td>
<td>NA</td>
<td>-3.9</td>
<td></td>
</tr>
<tr>
<td>Corporate Tax</td>
<td>+0.5,-5.5</td>
<td>+0.35</td>
<td>-6.1</td>
<td>NA</td>
<td>-4.5</td>
<td></td>
</tr>
<tr>
<td>Sales Tax</td>
<td>+0.5,-5.9</td>
<td>+0.35</td>
<td>-6.6</td>
<td>NA</td>
<td>-4.9</td>
<td></td>
</tr>
<tr>
<td>Household Tax</td>
<td>+14.5,-3.2</td>
<td>+0.2</td>
<td>-3.3</td>
<td>-,+</td>
<td>-11.3</td>
<td></td>
</tr>
<tr>
<td><strong>DIFFERENTIAL INCIDENCE:</strong> Texas household income tax replaces business capital tax (Rich Immobile)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Rich Immobile)</td>
<td>+1.7,+1.4</td>
<td>-0.2</td>
<td>+3.2</td>
<td>-,+</td>
<td>NA</td>
<td>-1.05</td>
</tr>
<tr>
<td>(Rich Mobile)</td>
<td>+5.7,+0.3</td>
<td>-0.1</td>
<td>+2.2</td>
<td>-,+</td>
<td>-3.6</td>
<td>-0.10</td>
</tr>
</tbody>
</table>
Guide to Columns of Table #15

"Factor Price Effect" Column: Shows the percentage change in the nominal gross of household tax return per unit of labor to households. The first number is for skilled labor; the second number is for unskilled labor.

"Product Price Effect" Column: Shows the percentage change in the national average price level.

"Capital Migration Effect" Column: Shows the percentage change in the number of units of capital used in Texas.

"Rich Migration Effect" Column: Shows the percentage change in the Rich population of Texas.

"Utility" Columns: Shows the percentage change in the utilities of Rich and Poor households.

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1 All percentage changes are in comparison to the benchmark equilibrium.
Appendix B: One Version of Computer Program Used to Solve General Equilibrium Simulations
'production parameters

'Northeast Good
dgn# = .50419258#: agn# = 2.244899982#: egn# = .9
'labor bundle
dsgn# = .293694549#: asgn# = 1.878015328#: esgn# = .7

'Midwest Good
dgm# = .39603948#: agm# = 2.179521567#: egm# = .9
'labor bundle
dsgm# = .293697601#: asgm# = 1.878019028#: esgm# = .7

'South Good
dgs# = .49127357#: ags# = 2.240320582#: egs# = .9
'labor bundle
dsgs# = .293695084#: asgs# = 1.878015976#: esgs# = .7

'West Good
dgw# = .48022292#: agw# = 2.244256208#: egw# = .9
'labor bundle
dsgw# = .293693507#: asgw# = 1.878014064#: esgw# = .7

'Northeast Regional Public Good
drn# = .597308219999999#: arn# = 2.10510264#: ern# = .95
'labor bundle
dsrn# = .275907: asrn# = 1.8461572#: esrn# = .75

'Midwest Regional Public Good
drm# = .55914751#: arm# = 2.10974208#: erm# = .95
'labor bundle
dsrm# = .2759176: asrm# = 1.8461721#: esrm# = .75

'South Regional Public Good
drs# = .58448472#: ars# = 2.100219098#: ers# = .95
'labor bundle
dsrs# = .2759144: asrs# = 1.8461536#: esrs# = .75

'West Regional Public Good
drw# = .60380011#: arw# = 2.0938422#: erw# = .95
'labor bundle
dsrw# = .2759045: asrw# = 1.8461536#: esrw# = .75

'Northeast Federal Public Good
dfn# = .31124422#: afn# = 1.966039002#: efn# = .95
'labor bundle
dsf# = .2758633: asufn# = 1.8460957#: esufn# = .75

'Midwest Federal Public Good
dFm# = .29516418#: aFm# = 1.919212307#: efm# = .95
'labor bundle
dsf# = .2758938: asufm# = 1.8461386#: esufm# = .75

'South Federal Public Good
dFs# = .2569726#: aFs# = 1.851741566#: efs# = .95
'labor bundle
dsufs# = .2759142: asufs# = 1.8461672#: esufs# = .75
'West Federal Public Good
dFw# = .32523995#: aFw# = 1.9767472#: efw# = .95
'labor bundle
dsuw# = .2759252: asuw# = 1.8461827#: esuw# = .75
'Northeast Services
dvn# = .59735615#: avn# = 2.212416143#: evn# = .99
'labor bundle
dsuvn# = .1953582: asuvn# = 1.6942069#: esuvn# = .8
'Midwest Services
dvm# = .51173191#: avm# = 2.238182784#: evm# = .99
'labor bundle
dsuvm# = .1953651: asuvm# = 1.6942213#: esuvm# = .8
'South Services
dvs# = .61661753#: avs# = 2.19437959#: evs# = .99
'labor bundle
dsuvs# = .1953569:asuvs# = 1.6942042#: esuvs# = .8
'West Services
dvw# = .5925666000000001#: avw# = 2.2211773#: evw# = .99
'labor bundle
dsuw# = .1953615:asuww# = 1.6942138#: esuw# = .8
'demand parameters
'goods nest
dun# = .471790166#: dum# = .073665443#: dus# = .246619227#: duw# = .2079250678:
eu# = 3
'public goods nest
drf# = .5269435#: erf# = .99
'services/goods nest
dvg# = .1941384#: evg# = .99
'whole utility function
dw# = .1584426#: ew# = .8
'population and factor supplies
'rich
rpopn# = 10196759.01#: rpopm# = 1281857#
rpops# = 5348676.067#: rpopw# = 4553696.002#
rlbr# = .029170151#: rcap# = 6.464051699999999D-02
rlbrn# = rpopn# * rlbr#
rlbrm# = rpopm# * rlbr#
rlbrs# = rpops# * rlbr#
rlbrw# = rpopw# * rlbr#
rcapn# = rpopn# * rcap#
rcapm# = rpopm# * rcap#
rcaps# = rprops# * rcap#
rcapw# = rpopw# * rcap#

'poor
ppopn# = 43000523.87#: ppopm# = 5371263.46#
pops# = 22494739.57#: ppopw# = 19419763.68#
plbr# = .014232408#: pcap# = .006252458#
plbrn# = ppopn# * plbr#
plbrm# = ppopm# * plbr#
plbrs# = pprops# * plbr#
plbrw# = ppopw# * plbr#
pcapn# = ppopn# * pcap#
pcapm# = ppopm# * pcap#
pcaps# = pprops# * pcap#
pcapw# = ppopw# * pcap#

'capital/labor ownership ratios
rratio# = rcap# / ribr#
pratio# = pcap# / plbr#

'initial factor prices
pk# = 1
plsm# = 1: plss# = 1
plun# = 1: plus# = 1
plsm# = 1: plsw# = 1
plum# = 1: pluw# = 1

'accuracy level
hi = .0005

'initialize iteration counter
eye = 1

'initial 3* "Goods" National Wages, Interest, Sales (needed for state corp tax)
gwages# = 3 * (816993# + 442030#)
ginterest# = 3 * 1333305#
gsales# = 3 * 2592328#

'initial 3* "RPG" National Wages, Interest, Sales (needed for state corp tax)
rwages# = 3 * (130114# + 63104#)
rinterest# = 3 * 141632#
rsales# = 3 * 334850#

'initial 3* "FPG" National Wages, Interest, Sales (needed for state corp tax)
fwages# = 3 * (59429# + 28822#)
finterest# = 3 * 218756#/fsales# = 3 * 307007#

'initial 3**"V" National Wages, Interest, Sales (needed for state corp tax)
vwages# = 3 * (278455# + 89731#)
vinterest# = 3 * 252897#
vsales# = 3 * 621083#

'state corporate tax "rates"
corp#g = 21180.05455#: corp# = 692.3712181#: corp#f = 608.4187276#
mcorp# = 0#: mcorp# = 0#: mcorp#f = 0#
ncorpv# = 5287.61251#: mcorp#v = 0#

scorp#g = 12449.34646#: scorp# = 377.1401623#: scorp#f = 333.2548431#
wcorp#g = 20424.2186#: wcorp# = 658.0615529#: wcorp#f = 577.3792704#
scorp# = 2979.724512#: wcorp#v = 4918.893663#

'initial regional government revenue estimate
mrev# = 205228#: srev# = 90645#
mrev# = 21096#: wrev# = 92205#

'initial federal government revenue estimate
nfrev# = 394792.0764#: sfrev# = 207431.8962#
mfrev# = 49708.07127#: wfrev# = 177607.6639#

'regional govt business capital tax rate
ntpkg# = 2 * .028497311#: ntpkr# = 2 * .02837#: ntpkv# = 2 * .02845#: ntpkv# = 2 * .02828#

mtpkg# = .018484902#: mtpkr# = .01849#: mtpkv# = .01849#: mtpkv# = .01849#
mtpkg# = .017862451#: stpkg# = .01786#: stpkg# = .01786#: stpkg# = .01786#

wtpkg# = .019889436#: wtpkr# = .01989#: wtpkv# = .01989#: wtpkv# = .01989#

'regional govt business labor tax rate
ntplg# = .007742#: ntplr# = .007725#: ntplf# = .007743#: ntplv# = .00772#
mtplg# = .0062633#: mtplr# = .0062633#: mtplf# = .0062633#: mtplv# = .0062633#
stplg# = .0059453#: stplr# = .0059453#: stplf# = .0059453#: stplv# = .0059453#

wtplg# = .0081#: wtplr# = .00809#: wtplf# = .00809#: wtplv# = .00809#

'regional sales tax rates
ngtxs# = .043464381#: ntntxs# = .043404737#
mgtxs# = .054571473#: ntntxs# = .054953165#

sgtxs# = .05107742#: ntntxs# = .051456732#

wgtxs# = .049725379#: wntntxs# = .05#

'federal govt business capital tax rate
nftpkg# = .036606329#: nftpkr# = .010835#: nftpkv# = .006447#: nftpkv# = .045423#
mftpkg# = .025989633#: mftpkr# = .009476#: mftpkv# = .004321#: mftpkv# = .034951#
sftpkg# = .03667374#: stftpkr# = .010466#: stftpkv# = .006243#: stftpkv# = .047703#
wftpkg# = .03475582#: wftpkr# = .010889#: wftpkv# = .006521#: wftpkv# = .044456#

'federal govt business labor tax rate
nftplg# = 6.877999999999999D-02: nftplr# = .0835#: nftplf# = .0813#: nftplv# = 6.877999999999999D-02
mftplg# = 6.877999999999999D-02: mftplr# = .0835#: mftplf# = .0813#: mftplv# = 6.877999999999999D-02
sftplg# = 6.877999999999999D-02: sftplr# = .0835#: sftplf# = .0813#: sftplv# = 6.877999999999999D-02
wftplg# = 6.877999999999999D-02: wftplr# = .0835#: wftplf# = .0813#: wftplv# = 6.877999999999999D-02

'***************begin main loop and internal loop***************
DO
DO
'national total of capital and labor endowments, for debugging purposes
   trlbr# = rlbrn# + rlbrm# + plbrn# + plbrw#
   tcap# = rcapn# + rcapm# + rcapn# + rcapw#
   tplbr# = plbrn# + plbrm# + plbrs# + plbrw#
   tpcap# = pcapn# + pcapm# + pcaps# + pcapw#
'regional total factor endowments
'northeast
   tlabrn# = plbrn# + rlbrn#: tcapn# = pcapn# + rcapn#
'midwest
   tlabrm# = plbrm# + rlbrm#: tcapm# = pcapm# + rcapm#
'south
   tlabrs# = plbrs# + rlbrs#: tcaps# = pcaps# + rcapss#
'west
   tlabrw# = plbrw# + rlbrw#: tcapw# = pcapw# + rcapw#

'factor requirements per unit of production, and gross factor prices
'but first, state corporate tax stuff
'northeast corp tax stuff
   yokng# = (ncorpg# / ginterest#) + (ncorpg# / gsales#)
   yokmr# = (ncorpr# / ginterest#) + (ncorpr# / rsales#)
   yokmf# = (ncorpf# / finterest#) + (ncorpf# / fsales#)
   yoknv# = (ncorpv# / vinterest#) + (ncorpv# / vsales#)

   yolng# = (ncorpg# / gwages#) + (ncorpg# / gsales#)
   yolmr# = (ncorpr# / rwages#) + (ncorpr# / rsales#)
   yolmf# = (ncorpf# / fwages#) + (ncorpf# / fsales#)
   yolnv# = (ncorpv# / vwages#) + (ncorpv# / vsales#)

'midwest corp tax stuff
   yokng# = (ncorpg# / ginterest#) + (ncorpg# / gsales#)
   yokmr# = (ncorpr# / ginterest#) + (ncorpr# / rsales#)
   yokmf# = (ncorpf# / finterest#) + (ncorpf# / fsales#)
yokmv# = (mcorgv# / vinterest#) + (mcorgv# / vsales#)

yolmg# = (mcorgg# / gwages#) + (mcorgg# / gsales#)
yolmr# = (mcorgr# / rwages#) + (mcorgr# / rsales#)
yolmf# = (mcorgf# / fwages#) + (mcorgf# / fsales#)
yolmv# = (mcorgv# / vwages#) + (mcorgv# / vsales#)

'south corp tax stuff'
yoksg# = (scorpg# / ginterest#) + (scorpg# / gsales#)
yoksr# = (scorpr# / rinterest#) + (scorpr# / rsales#)
yoksf# = (scorpf# / finterest#) + (scorpf# / fsales#)
yoksv# = (scorpv# / vinterest#) + (scorpv# / vsales#)

yolsg# = (scorpg# / gwages#) + (scorpg# / gsales#)
yolsr# = (scorpr# / rwages#) + (scorpr# / rsales#)
yolsf# = (scorpf# / fwages#) + (scorpf# / fsales#)
yolsv# = (scorpv# / vwages#) + (scorpv# / vsales#)

'west corp tax stuff'
yokwg# = (wcorgg# / ginterest#) + (wcorgg# / gsales#)
yokwr# = (wcorgr# / rinterest#) + (wcorgr# / rsales#)
yokwf# = (wcorgf# / finterest#) + (wcorgf# / fsales#)
yokwv# = (wcorgv# / vinterest#) + (wcorgv# / vsales#)

yolwg# = (wcorgg# / gwages#) + (wcorgg# / gsales#)
yolwr# = (wcorgr# / rwages#) + (wcorgr# / rsales#)
yolwf# = (wcorgf# / fwages#) + (wcorgf# / fsales#)
yolwv# = (wcorgv# / vwages#) + (wcorgv# / vsales#)

'midwest good'
gspkm# = (1 + mtpkg# + mftpkg# + yokmg# + mgtxs#) * pk#
gspsm# = (1 + mtplg# + mftplg# + yolmg# + mgtxs#) * plsm#
gspum# = (1 + mtplg# + mftplg# + yolmg# + mgtxs#) * plum#
q# = dsugm# * (gsplsm#)
r# = (1 - dsugm#) * (gsplum#)
gsplm# = q# + r#
a# = 1 / agm#
b# = 1 - dgm#
c# = 1 - egm#
d# = egm# / (1 - egm#)
e# = (dgm# * gspkm# / ((1 - dgm#) * gsplm#)) ^ c#
f# = (b# * e# + dgm#) ^ d#
lgm# = a# * f#
asu# = 1 / asugm#
bsu# = 1 - dsugm#
csu# = 1 - esugm#
dsugm# = esugm# / (1 - esugm#)
esu# = (dsugm# * gsplm# / ((1 - dsugm#) * gsplsm#)) ^ csu#
fsu# = (bsu# * esu# + dsugm#) ^ dsu#
'skilled labor requirement
lgm# = asu# * fsu# + lgm#
gsu# = (((1 - dsugm#) * gsplm#) / (dsugm# * gsplm#)) ^ csu#
hsu# = (dsugm# * gsu# + bsu#) ^ dsu#
'unskilled labor requirement
lgs# = asu# + lgs#
gsps# = 1 + stpkg# + stplg# + yoks# + sgtxs#) * pk#
gspsm# = 1 + stpkg# + stplg# + yoks# + sgtxs#) * plss#
gGPLs# = 1 + stpkg# + stplg# + yoks# + sgtxs#) * plus#
t# = dsugs# * (gsplss#)
rg# = (1 - dsugs#) * (gsplss#)
gsps# = t# + r#
'south good
gsps# = (1 + stpkg# + stplg# + yoks# + sgtxs#) * pk#
gspsm# = (1 + stpkg# + stplg# + yoks# + sgtxs#) * plss#
gGPLs# = (1 + stpkg# + stplg# + yoks# + sgtxs#) * plus#
t# = dsugs# * (gsplss#)
rg# = (1 - dsugs#) * (gsplss#)
gsps# = t# + r#
asu# = 1 / asug#
bsu# = 1 - dsug#
csu# = 1 - esug#
dsug# = esug# / (1 - esug#)
esu# = (dsug# * gsplus# / ((1 - dsug#) * gsplss#)) ^ csu#
fsu# = (bsu# * esu# + dsug#) ^ dsu#
'skilled labor requirement
lgs# = asu# * fsu# + lgs#
gsu# = (((1 - dsug#) * gsplss#) / (dsug# * gsplss#)) ^ csu#
hsu# = (dsug# * gsu# + bsu#) ^ dsu#
'unskilled labor requirement
lugs# = asu# * hsu# * lgs#

g# = (((1 - dgs#) * gspls#) / (dgs# * gspks#)) ^ c#
h# = (dgs# * g# + b#) ^ d#
'capital requirement
kgs# = a# * h#

'west good
gspkw# = (1 + wtpkg# + wftpkg# + yokwg# + wgtxs#) * pk#
gspslsw# = (1 + wtplg# + wftplg# + yolwg# + wgtxs#) * plsw#
gspluuv# = (1 + wtplg# + wftplg# + yolwg# + wgtxs#) * pluw#
q# = dsugw# * (gsplsw#)
r# = (1 - dsugw#) * (gspluw#)
gspltw# = q# + r#
a# = 1 / agw#
b# = 1 - dgw#
c# = 1 - egw#
d# = egw# / (1 - egw#)
e# = (dgw# * gspkw# / ((1 - dgw#) * gspltw#)) ^ c#
f# = (b# * e# + dgw#) ^ d#
lgw# = a# * f#

asu# = 1 / asugw#
bsu# = 1 - dsugw#
csu# = 1 - esugw#
dsugw# = esugw# / (1 - esugw#)
esugw# = (dsugw# * gspluuv# / ((1 - dsugw#) * gsplsw#)) ^ csu#
fsugw# = (bsu# * esu# + dsugw#) ^ dsu#
'skilled labor requirement
lsgw# = asu# * fsu# * lgw#
gsu# = (((1 - dsugw#) * gsplsw#) / (dsugw# * gspluuv#)) ^ csu#
hsu# = (dsugw# * gsu# + bsu#) ^ dsu#
'unskilled labor requirement
lugw# = asu# * hsu# * lgw#

g# = (((1 - dgw#) * gsplw#) / (dgw# * gspkw#)) ^ c#
h# = (dgw# * g# + b#) ^ d#
kgw# = a# * h#

'northeast regional public good
rsplkn# = (1 + ntpkr# + nftpkr# + yoknr#) * pk#
rsplsn# = (1 + ntplr# + nftpilr# + yolnr#) * plsn#
rsp lun# = (1 + ntplr# + nftpilr# + yolnr#) * plun#
\[ \begin{align*}
q\# &= dsurn\# \times (rsplsn\#) \\
r\# &= (1 - dsurn\#) \times (rsplun\#) \\
rspln\# &= q\# + r\# \\
a\# &= 1 / arn\# \\
b\# &= 1 - drn\# \\
c\# &= 1 - ern\# \\
d\# &= ern\# / (1 - ern\#) \\
e\# &= (drn\# \times rsplkn\# / ((1 - drn\#) \times rspln\#)) \times c\# \\
f\# &= (b\# \times e\# + drn\#) \times d\# \\
lrn\# &= a\# \times f\# \\
\end{align*} \]

\[ \begin{align*}
asu\# &= 1 / asurn\# \\
bsu\# &= 1 - dsurn\# \\
csu\# &= 1 - esurn\# \\
dsu\# &= esurn\# / (1 - esurn\#) \\
esu\# &= (dsurn\# \times rsplun\# / ((1 - dsurn\#) \times rsplsn\#)) \times csu\# \\
fsu\# &= (bsu\# \times esu\# + dsurn\#) \times dsu\# \\
'\text{skilled labor requirement} \\
lsm\# &= asu\# \times fsu\# \times lrn\# \\
gsu\# &= (((1 - dsurn\#) \times rsplsn\#) / (dsurn\# \times rsplun\#)) \times csu\# \\
hsu\# &= (dsurn\# \times gsu\# + bsu\#) \times dsu\# \\
'\text{unskilled labor requirement} \\
lurn\# &= asu\# \times hsu\# \times lrn\# \\
\end{align*} \]

\[ \begin{align*}
g\# &= (((1 - drn\#) \times rspln\#) / (drn\# \times rsplkn\#)) \times c\# \\
h\# &= (drn\# \times g\# + b\#) \times d\# \\
krm\# &= a\# \times h\# \\
\end{align*} \]

'\text{midwest regional public good} \\
rsplkm\# &= (1 + mtpkr\# + mftpkr\# + yolkm\#) \times pk\# \\
rspslm\# &= (1 + mtplr\# + mftplr\# + yolmr\#) \times plsm\# \\
rspum\# &= (1 + mtplr\# + mftplr\# + yolmr\#) \times plum\# \\
q\# &= dsurn\# \times (rspslm\#) \\
r\# &= (1 - dsurn\#) \times (rplum\#) \\
rsplm\# &= q\# + r\# \\
a\# &= 1 / arn\# \\
b\# &= 1 - drn\# \\
c\# &= 1 - ern\# \\
d\# &= ern\# / (1 - ern\#) \\
e\# &= (drm\# \times rsplkm\# / ((1 - drm\#) \times rsplm\#)) \times c\# \\
f\# &= (b\# \times e\# + drm\#) \times d\# \\
lrn\# &= a\# \times f\# \\
\end{align*} \]

\[ \begin{align*}
asu\# &= 1 / asurn\# \\
\end{align*} \]
bsu# = 1 - dsurm#
csu# = 1 - esurm#
dsu# = esurm# / (1 - esurm#)
esu# = (dsurm# * rsplum# / ((1 - dsurm#) * rsplsm#)) ^ csu#
fsu# = (bsu# * esu# + dsurm#) ^ dsu#
'skilled labor requirement
lsrm# = asu# * fsu# ^ lrm#
gsu# = (((1 - dsurm#) * rsplsm#) / (dsurm# * rsplsm#)) ^ csu#
hsu# = (dsurm# * gsu# + bsu#) ^ dsu#
'unskilled labor requirement
lurs# = asu# * hsu# ^ lrm#

g# = (((1 - drm#) * rsplm#) / (drm# * rsplkm#)) ^ c#
h# = (drm# * g# + b#/) ^ d#
krm# = a# * h#
'south regional public good
rpsks# = (1 + stpkr# + sftpkr# + yoks#) * pk#
rpslss# = (1 + stpkr# + sftpkr# + yols#) * plss#
rpslus# = (1 + stpkr# + sftpkr# + yols#) * plus#
q# = dsurs# * (rpslss#)
r# = (1 - dsurs#) * (rpslus#)
rpsls# = q# + r#
a# = 1 / ars#
b# = 1 - drs#
c# = 1 - ers#
d# = ers# / (1 - ers#)
e# = (drs# * rpsks# / ((1 - drs#) * rpsls#)) ^ c#
f# = (b# * e# + drs#) ^ d#
lrs# = a# * f#}
asu# = 1 / asurs#
bsu# = 1 - dsurs#
csu# = 1 - esurs#
dsu# = esurs# / (1 - esurs#)
esu# = (dsurs# * rsplus# / ((1 - dsurs#) * rsplss#)) ^ csu#
fsu# = (bsu# * esu# + dsurs#) ^ dsu#
'skilled labor requirement
lsrs# = asu# * fsu# * lrs#
gsu# = (((1 - dsurs#) * rsplss#) / (dsurs# * rsplus#)) ^ csu#
hsu# = (dsurs# * gsu# + bsu#) ^ dsu#
'unskilled labor requirement
lurs# = asu# * hsu# * lrs#
g# = (((1 - drs#) * rspls#) / (drs# * rspks#)) ^ c#
    h# = (drs# * g# + b#) ^ d#
    krs# = a# * h#

'west regional public good
    rspkw# = (1 + wtpkr# + wftpkr# + yokwr#) * pk#
    rsplsw# = (1 + wtplr# + wftp# + yolwr#) * plsw#
    rsplu# = (1 + wtpl# + wftp# + yolwr#) * plu#
    q# = dsurw# * (rsplsw#)
    r# = (1 - dsurw#) * (rsplu#)
    rsplw# = q# + r#
    a# = 1 / arw#
    b# = 1 - drw#
    c# = 1 - erw#
    d# = erw#/ (1 - erw#)
    e# = (drw# * rspkw#) / ((1 - drw#) * rsplw#) ^ c#
    f# = (b# * e# + drw#) ^ d#
    lrw# = a# * f#

    asu# = 1 / asurw#
    bsu# = 1 - dsurw#
    csu# = 1 - esurw#
    dsu# = esurw# / (1 - esurw#)
    esu# = (dsurw# * rspluw#) / ((1 - dsurw#) * rsplsw#) ^ csu#
    fsu# = (bsu# * esu# + dsurw#) ^ dsu#

'skilled labor requirement
    lsrw# = asu# * fsu# * lrw#
    gsu# = (((1 - dsurw#) * rsplsw#) / (dsurw# * rspluw#)) ^ csu#
    hsu# = (dsurw# * gsu# + bsu#) ^ dsu#

'unskilled labor requirement
    lurw# = asu# * hsu# * lrw#

    g# = (((1 - drw#) * rsplw#) / (drw# * rspkw#)) ^ c#
    h# = (drw# * g# + b#) ^ d#
    krw# = a# * h#

'northeast federal public good
    fspkn# = (1 + ntpkf# + nftpkf# + yoknf#) * pk#
    fspln# = (1 + ntplf# + nftp# + yolnf#) * pln#
    fspplun# = (1 + ntpf# + nftp# + yolnf#) * plun#
    q# = dsufn# * (fspln#)
    r# = (1 - dsufn#) * (fspplun#)
    fspln# = q# + r#
    a# = 1 / afn#
\[ b\# = 1 - d\#
\]
\[ c\# = 1 - e\#
\]
\[ d\# = e\# / (1 - e\#)
\]
\[ e\# = (d\# * fspkn\# / ((1 - d\#) * fspln\#)) ^ c\#
\]
\[ f\# = (b\# * e\# + d\#) ^ d\#
\]
\[ lfn\# = a\# * f\#
\]
\[ asu\# = 1 / asufn\#
\]
\[ bsu\# = 1 - dsufn\#
\]
\[ csu\# = 1 - esufn\#
\]
\[ dsu\# = esufn\# / (1 - esufn\#)
\]
\[ esu\# = (dsufn\# * fspln\# / ((1 - dsufn\#) * fsplsn\#)) ^ csu\#
\]
\[ fsu\# = (bsu\# * esu\# + dsufn\#) ^ dsu\#
\]
\[ 'skilled labor requirement
\]
\[ lsfn\# = asu\# * fsu\# * lfn\#
\]
\[ gsu\# = (((1 - dsufn\#) * fsplsn\#) / (dsufn\# * fspln\#)) ^ csu\#
\]
\[ hsu\# = (dsufn\# * gsu\# + bsu\#) ^ dsu\#
\]
\[ 'unskilled labor requirement
\]
\[ lufn\# = asu\# * hsu\# * lfn\#
\]
\[ g\# = (((1 - d\#) * fspln\#) / (dfn\# * fspkn\#)) ^ c\#
\]
\[ h\# = (dfn\# * g\# + b\#) ^ d\#
\]
\[ kfn\# = a\# * h\#
\]
\[ 'midwest Federal public good
\]
\[ fspkm\# = (1 + mtpkf\# + mftpkf\# + yokm\#) * pk\#
\]
\[ fsplsm\# = (1 + mtplf\# + mftplf\# + yolm\#) * plsm\#
\]
\[ fsplum\# = (1 + mtplf\# + mftplf\# + yolm\#) * plum\#
\]
\[ q\# = dsufm\# * (fsplsm\#)
\]
\[ r\# = (1 - dsufm\#) * (fsplum\#)
\]
\[ fsplm\# = q\# + r\#
\]
\[ a\# = 1 / aFm\#
\]
\[ b\# = 1 - dFm\#
\]
\[ c\# = 1 - eFm\#
\]
\[ d\# = eFm\# / (1 - eFm\#)
\]
\[ e\# = (dFm\# * fspkm\# / ((1 - dFm\#) * fsplm\#)) ^ c\#
\]
\[ f\# = (b\# * e\# + dFm\#) ^ d\#
\]
\[ lfn\# = a\# * f\#
\]
\[ asu\# = 1 / asufm\#
\]
\[ bsu\# = 1 - dsufm\#
\]
\[ csu\# = 1 - esufm\#
\]
\[ dsu\# = esufm\# / (1 - esufm\#)
\]
\[ esu\# = (dsufm\# * fsplm\# / ((1 - dsufm\#) * fsplsm\#)) ^ csu\#]
fsu# = (bsu# * esu# + dsufm#) ^ dsu#
'skilled labor requirement
lsfm# = asu# * fsu# * lfm#
gsu# = (((1 - dsufm#) * fsplsm#) / (dsufm# * fsplum#)) ^ csu#
hsu# = (dsufm# * gsu# + bsu#) ^ dsu#
'unskilled labor requirement
lufm# = asu# * hsu# * lfm#
g# = (((1 - dFm#) * fsplm#) / (dFm# * fspkm#)) ^ c#
h# = (dFm# * g# + b#) ^ d#
kfm# = a# * h#

'south federal public good
fspks# = (1 + stpkf# + sttplt# + yoksfl#) * pk#
fsplss# = (1 + stplf# + stplf# + yolsfl#) * plss#
fsplus# = (1 + stplf# + stplf# + yolsfl#) * plus#
q# = dsufs# * (fsplss#)
r# = (1 - dsufs#) * (fsplus#)
fspls# = q# + r#
a# = 1 / aFs#
b# = 1 - dF#
c# = 1 - efs#
d# = efs#/ (1 - efs#)
e# = (dFs# * fsplks# / ((1 - dFs#) * fspls#)) ^ c#
f# = (b# * e# + dFs#) ^ d#
lfs# = a# * f#

asu# = 1 / asufs#
bsu# = 1 - dsufs#
csu# = 1 - esufs#
dsu# = esufs# / (1 - esufs#)
esu# = (dsufs# * fsplus# / ((1 - dsufs#) * fsplss#)) ^ csu#
fsu# = (bsu# * esu# + dsufs#) ^ dsu#
'skilled labor requirement
lsfs# = asu# * fsu# * lfs#
gsu# = (((1 - dsufs#) * fsplss#) / (dsufs# * fsplus#)) ^ csu#
hsu# = (dsufs# * gsu# + bsu#) ^ dsu#
'unskilled labor requirement
lufs# = asu# * hsu# * lfs#
g# = (((1 - dF#) * fspls#) / (dF# * fspkm#)) ^ c#
h# = (dF# * g# + b#) ^ d#
kfs# = a# * h#
'west Federal public good
fspkw# = (1 + wtpkf# + wftpkf# + yokwf#) * pk#
fsplsw# = (1 + wtplf# + wftplf# + yolwf#) * plsw#
fspluw# = (1 + wtplf# + wftplf# + yolwf#) * pluw#
q# = dsufw# * (fsplsw#)
r# = (1 - dsufw#) * (fspluw#)
fsplw# = q# + r#
a# = 1 / aFw#
b# = 1 - dFw#
c# = 1 - efw#
d# = efw# / (1 - efw#)
e# = (dFw# * fspkw# / ((1 - dFw#) * fsplw#)) ^ c#
f# = (b# * e# + dFw#) ^ d#
lfw# = a# * f#

asu# = 1 / asufw#
bsu# = 1 - dsufw#
csu# = 1 - esufw#
dsu# = esufw# / (1 - esufw#)
esu# = (dsufw# * fspluw# / ((1 - dsufw#) * fsplsw#)) ^ csu#
fsu# = (bsu# * esu# + dsufw#) ^ dsu#
'skilled labor requirement
lsfw# = asu# * fsu# * lfw#
gsu# = (((1 - dsufw#) * fsplsw#) / (dsufw# * fspluw#)) ^ csu#
hsu# = (dsufw# * gsu# + bsu#) ^ dsu#
'unskilled labor requirement
lufw# = asu# * hsu# * lfw#

g# = (((1 - dFw#) * fsplw#) / (dFw# * fspkw#)) ^ c#
h# = (dFw# * g# + b#) ^ d#
kfw# = a# * h#

'northeast service
vsplkn# = (1 + ntpkv# + nftpkv# + yoknv# + nvtxs#) * pk#
vspln# = (1 + ntplv# + nftpvl# + yolnv# + nvtxs#) * plsn#
vsplnu# = (1 + ntpvl# + nftpvl# + yolnv# + nvtxs#) * plnu#
q# = dsuvn# * (vspln#)
r# = (1 - dsuvn#) * (vspln#)
vspln# = q# + r#
a# = 1 / avn#
b# = 1 - dvn#
c# = 1 - evn#
d# = evn# / (1 - evn#)
e# = (dvn# * vspkn# / ((1 - dvn#) * vspln#)) ^ c#
\[ f_\# = (b_\# \times e_\# + dv_\#) \times d_\# \]
\[ lvn_\# = a_\# \times f_\# \]
\[ asu_\# = 1 \div asuvn_\# \]
\[ bsu_\# = 1 - dsuvn_\# \]
\[ csu_\# = 1 - esuvn_\# \]
\[ dsu_\# = esuvn_\# \div (1 - esuvn_\#) \]
\[ esu_\# = (dv_\# \times vsplun_\# \div ((1 - dsuvn_\#) \times vsplsn_\#)) \times csu_\# \]
\[ fsu_\# = (bv_\# \times esu_\# + dsuvn_\#) \times dsu_\# \]

'skilled labor requirement
\[ lsuvn_\# = asu_\# \times fsu_\# \times lvn_\# \]
\[ gsu_\# = ((1 - dv_\#) \times vspln_\#) \div (dv_\# \times vspln_\#) \times csu_\# \]
\[ hsu_\# = (dv_\# \times g_\# + bsu_\#) \times dsu_\# \]

'unskilled labor requirement
\[ luvn_\# = asu_\# \times hsu_\# \times lvn_\# \]
\[ g_\# = ((1 - dv_\#) \times vspln_\#) \div (dv_\# \times vspln_\#) \times c_\# \]
\[ h_\# = (dv_\# \times g_\# + b_\#) \times d_\# \]
\[ kvn_\# = a_\# \times h_\# \]

'midwest service
\[ vspkm_\# = (1 + mtpkv_\# + mftpkv_\# + yokmv_\# + mvtxs_\#) \times pk_\# \]
\[ vsplm_\# = (1 + mtpv_\# + mftpiv_\# + yolmv_\# + mvtxs_\#) \times plsm_\# \]
\[ vsplm_\# = (1 + mtpv_\# + mftpiv_\# + yolmv_\# + mvtxs_\#) \times plum_\# \]
\[ q_\# = dsuvn_\# \times (vsplm_\#) \]
\[ r_\# = (1 - dsuvn_\#) \times (vsplm_\#) \]
\[ vsplm_\# = q_\# \div r_\# \]
\[ a_\# = 1 \div avm_\# \]
\[ b_\# = 1 - dv_\# \]
\[ c_\# = 1 - evm_\# \]
\[ d_\# = evm_\# \div (1 - evm_\#) \]
\[ e_\# = (dv_\# \times vsplm_\# \div ((1 - dv_\#) \times vsplm_\#)) \times c_\# \]
\[ f_\# = (b_\# \times e_\# + dv_\#) \times d_\# \]
\[ lvm_\# = a_\# \times f_\# \]
\[ asu_\# = 1 \div asuvm_\# \]
\[ bsu_\# = 1 - dsuvn_\# \]
\[ csu_\# = 1 - esuvn_\# \]
\[ dsu_\# = esuvn_\# \div (1 - esuvn_\#) \]
\[ esu_\# = (dv_\# \times vsplm_\# \div ((1 - dv_\#) \times vsplm_\#)) \times csu_\# \]
\[ fsu_\# = (bv_\# \times esu_\# + dv_\#) \times dsu_\# \]

'skilled labor requirement
\[ lsvm_\# = asu_\# \times fsu_\# \times lvm_\# \]
\[ gsu_\# = ((1 - dsuvn_\#) \times vsplm_\#) \div (dv_\# \times vsplm_\#) \times csu_\# \]
hsu# = (dsuvm# * gsu# + bsu#) ^ dsu#

'unskilled labor requirement

luvm# = asu# * hsu# * lvm#

\[ g# = (((1 - dvm#) * vsplm#) / (dvm# * vspkm#))^c# \]

\[ h# = (dvm# * g# + b#)^d# \]

\[ kvm# = a# * h# \]

'south service

vspkss# = (1 + stpkv# + sftpkv# + yoksv# + svtxs#) * pk#

\[ vspkssl# = (1 + stplv# + sftplv# + yolsv# + svtxs#) * plss# \]

\[ vspkplus# = (1 + stplv# + sftplv# + yolsv# + svtxs#) * plus# \]

\[ q# = dsuvs# * (vspkssl#) \]

\[ r# = (1 - dsuvs#) * (vspkplus#) \]

vspkssl# = q# + r#

\[ a# = 1 / avs# \]

\[ b# = 1 - dvs# \]

\[ c# = 1 - evs# \]

\[ d# = evs# / (1 - evs#) \]

\[ e# = (dvs# * vspsk#) / ((1 - dvs#) * vspls#) ^ c# \]

\[ f# = (b# * e# + dvs#) ^ d# \]

\[ lvs# = a# * f# \]

\[ asu# = 1 / asuvs# \]

\[ bsu# = 1 - dsuvs# \]

\[ csu# = 1 - esuvs# \]

\[ dsu# = esuvs# / (1 - esuvs#) \]

\[ esu# = (dsuvs# * vspkssl#) / ((1 - dsuvs#) * vsplss#) ^ csu# \]

\[ fsu# = (bsu# * esu# + dsuvs#) ^ dsu# \]

'skilled labor requirement

\[ lsus# = asu# * fsu# * lvs# \]

\[ gsu# = (((1 - dsuvs#) * vsplss#) / (dsuvs# * vsplus#))^c# \]

\[ hsu# = (dsuvs# * gsu# + bsu#) ^ dsu# \]

'unskilled labor requirement

\[ luvs# = asu# * hsu# * lvs# \]

\[ g# = (((1 - dvs#) * vspls#) / (dvs# * vspks#))^c# \]

\[ h# = (dvs# * g# + b#)^d# \]

\[ kvs# = a# * h# \]

'west service

vspkw# = (1 + wtstkv# + wtftpkv# + yokvw# + wvtxs#) * pk#

\[ vspksw# = (1 + wtplv# + wtftplv# + yowlv# + wvtxs#) * plsw# \]

\[ vspluw# = (1 + wtplv# + wtftplv# + yowlv# + wvtxs#) * pluw# \]
\[\begin{align*}
q# &= dsuvw# \times (vsp lw#) \\
r# &= (1 - dsuvw#) \times (vsp luw#) \\
vsp lw# &= q# + r# \\
a# &= 1 / avw# \\
b# &= 1 - dvw# \\
c# &= 1 - evw# \\
d# &= evw# / (1 - evw#) \\
e# &= (dvw# \times vsp kw#) / ((1 - dvw#) \times vsp lw#) \times c# \\
f# &= (b# \times e# + dvw#) \times d# \\
lvw# &= a# \times f# \\
\end{align*}\]

\[\begin{align*}
asu# &= 1 / asuvw# \\
bsu# &= 1 - dsuvw# \\
csu# &= 1 - esuvw# \\
dsu# &= esuvw# / (1 - esuvw#) \\
esu# &= (dsuvw# \times vsp luw#) / ((1 - dsuvw#) \times vsp lw#) \times csu# \\
fsu# &= (bsu# \times esu# + dsuvw#) \times dsu# \\
'skilled labor requirement' \\
lsvw# &= asu# \times fsu# \times lvw# \\
gsu# &= (((1 - dsuvw#) \times vsp lw#) / (dsuvw# \times vsp luw#)) \times csu# \\
hsu# &= (dsuvw# * gsu# + bsu#) ^ dsu# \\
'unskilled labor requirement' \\
luvw# &= asu# \times hsu# \times lvw# \\
g# &= (((1 - dvw#) \times vsp lw#) / (dvw# \times vsp kw#)) \times c# \\
h# &= (dvw# \times g# + b#) \times d# \\
kvw# &= a# \times h# \\
'northeast good' \\
gsp kn# &= (1 + ntpkg# + ntpkg# + yokng# + ngtxs#) \times pk# \\
gsp lsn# &= (1 + ntplg# + ntplg# + yolng# + ngtxs#) \times plsn# \\
gsp lu n# &= (1 + ntplg# + ntplg# + yolng# + ngtxs#) \times plun# \\
q# &= dsgun# \times (gsp lsn#) \\
r# &= (1 - dsqun#) \times (gsp lu n#) \\
gsp l n# &= q# + r# \\
a# &= 1 / agn# \\
b# &= 1 - dgn# \\
c# &= 1 - eg n# \\
d# &= eg n# / (1 - eg n#) \\
e# &= (dgn# \times gsp k n#) / ((1 - dgn#) \times gsp l n#) \times c# \\
f# &= (b# \times e# + dgn#) \times d# \\
lgn# &= a# \times f# \\
asu# &= 1 / asug n# 
\end{align*}\]
bsu# = 1 - dsugn#
csu# = 1 - esugn#
dsu# = esugn# / (1 - esugn#)
esu# = (dsugn# * gsplun# / ((1 - dsugn#) * gsplsn#)) ^ csu#
fsu# = (bsu# * esu# + dsu#) ^ dsu#
'skilled labor requirement
lsgn# = asu# * f3u# * lgn#
gsu# = ((((1 - dsugn#) * gsplsn#) / (dsugn# * gsplun#)) ^ csu#
hsu# = (dsugn# * gsu# + bsu#) ^ dsu#
'unskilled labor requirement
lugn# = asu# * hsu# * lgn#

g# = (((1 - dgn#) * gspln#) / (dgn# * gspkn#)) ^ c#
h# = (dgn# * g# + b#) ^ d#
kgn# = a# * h#

cost-minimizing goods prices (=households' cost per unit of product bought)
pgn# = gspln# * lgn# + gspkn# * kgn#
pqm# = gsplm# * lgm# + gspkm# * kgm#
pnm# = rslpnm# / (1 + rspkn# * krn#)
prm# = rslpm# / (1 + rspkm# * krm#)
pfn# = fspln# * lfn# + fspkn# / (1 + fspkm# * kf#)
pfm# = fsplm# / (1 + fspkm# * kfm#)
pvn# = vspln# * lvn# +vspkn# * kvn#
pvm# = vsplm# / (1 + vsplm# * kvm#)

pgs# = gspls# * lgs# + gspks# * kgs#
pgw# = gsplw# * lgw# + gspkw# * kgw#
prs# = rslps# * lrs# + rspks# * krs#
prw# = rslpw# / (1 + rspkw# * krw#)
pfs# = fslps# * ffs# + fspks# * kfs#
pfw# = fsplw# * lfw# + fspkw# * kfw#
pvs# = vspls# * lvs# + vspl# * kvs#
pvw# = vsplw# * lvw# + vsplkw# * kvw#

disposable personal incomes of rich and poor populations by region
'northeast
'rich household receives half per capita transfer as poor one, reg.govt
rtrann# = (.145715984# * nrev# * rpopn#) / (rpopn# + 2 * ppopn#)
ptrann# = .145715984# * nrev# - rtrann#
'rich household receives same per capita transfer as poor one,FED.govt
rtrann# = (.77710039# * nrev# * rpopn#) / (rpopn# + ppopn#)
ptrann# = .77710039# * nrev# - rtrann#
each household pays regional PIT
  rtaxn# = .067983791# * (rlbrn# * plsn# + rcapn# * pk#)
  ptxan# = .0339919# * (plbrn# * plun# + pcapn# * pk#)

each household pays fed PIT on gross earned income
  rftaxn# = .1641918 * (rlbrn# * plsn# + rcapn# * pk#)
  ptfattaxn# = .1641918 * (plbrn# * plun# + pcapn# * pk#)

disposable income of rich, poor population groups
  ryn# = rlbrn# * plsn# + rcapn# * pk# + rtranf# + rtranf# - rftaxn# - rtaxn#
  pyn# = plbrn# * plun# + pcapn# * pk# + ptranf# + ptranf# - ptfattaxn# - ptaxn#

midwest

rich household receives half per capita transfer as poor one, reg.govt
  rtranf# = (.110110477# * mrev# * rpopm#) / (rpopm# + 2 * ppopm#)
  ptranf# = .110110477# * mrev# - rtranf#

rich household receives same per capita transfer as poor one, FED.govt
  rtranf# = (.5038230339999999# * mrev# * rpopm#) / (rpopm# + ppopm#)
  ptranf# = .5038230339999999# * mrev# - rtranf#

each household pays regional PIT
  rtaxn# = .026917117# * (rlbrn# * plsm# + rcapm# * pk#)
  ptxan# = .01345856# * (plbrn# * plun# + pcapm# * pk#)

each household pays fed PIT on gross earned income
  rftaxn# = .1641918 * (rlbrn# * plsm# + rcapm# * pk#)
  ptfattaxn# = .1641918 * (plbrn# * plun# + pcapm# * pk#)

disposable income of rich, poor population groups
  ryn# = rlbrn# * plsm# + rcapm# * pk# + rtranf# + rtranf# - rftaxn# - rtaxn#
  pyn# = plbrn# * plun# + pcapm# * pk# + ptranf# + ptranf# - ptfattaxn# - ptaxn#

south

rich household receives half per capita transfer as poor one, reg.govt
  rtranf# = (9.510761700000001D-02 * srev# * rpop#) / (rpop# + 2 * ppop#)
  ptranf# = 9.510761700000001D-02 * srev# - rtranf#

rich household receives same per capita transfer as poor one, FED.govt
  rtranf# = (.333482446# * sfrev# * rpop#) / (rpop# + ppop#)
  ptranf# = .333482446# * sfrev# - rtranf#

each household pays regional PIT
  rtaxn# = .047472065# * (rlbrn# * plss# + rcaps# * pk#)
  ptxan# = .02373603# * (plbrn# * plus# + pcaps# * pk#)

each household pays fed PIT on gross earned income
  rftaxn# = .1641918 * (rlbrn# * plss# + rcaps# * pk#)
  ptfattaxn# = .1641918 * (plbrn# * plus# + pcaps# * pk#)

disposable income of rich, poor population groups
  ryn# = rlbrn# * plss# + rcaps# * pk# + rtranf# + rtranf# - rftaxn# - rtaxn#
  pyn# = plbrn# * plus# + pcaps# * pk# + ptranf# + ptranf# - ptfattaxn# - ptaxn#
'west

'rich household receives half per capita transfer as poor one, reg govt
rtranw# = (1.14012874# * wrev# * rpopw#) / (rpopw# + 2 * ppopw#)
ptranw# = 1.14012874# * wrev# - rtranw#

'rich household receives same per capita transfer as poor one, FED govt
rtranw# = (0.604175302# * wrev# * rpopw#) / (rpopw# + ppopw#)
ptranw# = 0.604175302# * wrev# - rtranw#

'each household pays regional PIT
rtaxw# = 6.524611800000001D-02 * (rbrw# * psw# + rcapw# * pk#)
ptaxw# = 0.03262306# * (plbrw# * pluw# + pcapw# * pk#)

'each household pays fed PIT on gross earned income
rftaxw# = 0.1641918# * (rbrw# * psw# + rcapw# * pk#)
ptftaxw# = 0.1641918# * (plbrw# * pluw# + pcapw# * pk#)

'disposable income of rich, poor population groups
ryw# = rbrw# * psw# + rcapw# * pk# + rtranw# + rtranw# - rftaxw# - rtaxw#
pyw# = plbrw# * pluw# + pcapw# * pk# + ptranw# + ptranw# - ptftaxw# - ptaxw#

'demand for goods by rich and poor, by region
b# = dun# * (pgn# ^ (1 - eu#)) + dum# * (pgm# ^ (1 - eu#))
c# = dus# * (pgs# ^ (1 - eu#)) + duw# * (pgw# ^ (1 - eu#))

'rich in Northeast

'northeast goods
rngm# = dun# * (1 - 0.187144604#) * ryn# / ((pgn# ^ eu#) * (b# + c#))

'midwest goods
rgmg# = dum# * (1 - 0.187144604#) * ryn# / ((pgm# ^ eu#) * (b# + c#))

'south goods
rngs# = dus# * (1 - 0.187144604#) * ryn# / ((pgs# ^ eu#) * (b# + c#))

'west goods
rngw# = duw# * (1 - 0.187144604#) * ryn# / ((pgw# ^ eu#) * (b# + c#))

'rich in midwest

'northeast goods
rgmn# = dun# * (1 - 0.207553457#) * rym# / ((pgn# ^ eu#) * (b# + c#))

'midwest goods
rgmg# = dum# * (1 - 0.207553457#) * rym# / ((pgm# ^ eu#) * (b# + c#))

'south goods
rgms# = dus# * (1 - 0.207553457#) * rym# / ((pgs# ^ eu#) * (b# + c#))

'west goods
rgmw# = duw# * (1 - 0.207553457#) * rym# / ((pgw# ^ eu#) * (b# + c#))

'poor in Northeast

'northeast goods
pngn# = dun# * (1 - 0.187144604#) * pyn# / ((pgn# ^ eu#) * (b# + c#))

'midwest goods
pngm# = dum# * (1 - 0.187144604#) * pyn# / ((pgm# ^ eu#) * (b# + c#))
'southern goods
pngs# = dus# * (1 - .187144604#) * pyn# / ((pgs# ^ eu#) * (b# + c#))

'western goods
pngw# = duw# * (1 - .187144604#) * pyn# / ((pgw# ^ eu#) * (b# + c#))

'poor in midwest
  'northeast goods
pmgn# = dun# * (1 - .207553457#) * pyn# / ((pgn# ^ eu#) * (b# + c#))
  'midwest goods
pmgm# = dum# * (1 - .207553457#) * pyn# / ((pgm# ^ eu#) * (b# + c#))
  'southern goods
pmgs# = dus# * (1 - .207553457#) * pyn# / ((pgs# ^ eu#) * (b# + c#))
  'western goods
pmgw# = duw# * (1 - .207553457#) * pyn# / ((pgw# ^ eu#) * (b# + c#))

'rich in South
  'northeast goods
rsgn# = dun# * (1 - .186771883#) * rys# / ((pgn# ^ eu#) * (b# + c#))
  'midwest goods
rsgm# = dum# * (1 - .186771883#) * rys# / ((pgm# ^ eu#) * (b# + c#))
  'southern goods
rsgs# = dus# * (1 - .186771883#) * rys# / ((pgs# ^ eu#) * (b# + c#))
  'western goods
rsgw# = duw# * (1 - .186771883#) * rys# / ((pgw# ^ eu#) * (b# + c#))

'rich in west
  'northeast goods
rwgn# = dun# * (1 - .214735#) * ryw# / ((pgn# ^ eu#) * (b# + c#))
  'midwest goods
rwgm# = dum# * (1 - .214735#) * ryw# / ((pgm# ^ eu#) * (b# + c#))
  'southern goods
rwgs# = dus# * (1 - .214735#) * ryw# / ((pgs# ^ eu#) * (b# + c#))
  'western goods
rwgw# = duw# * (1 - .214735#) * ryw# / ((pgw# ^ eu#) * (b# + c#))

'poor in south
  'northeast goods
psgn# = dun# * (1 - .186771883#) * pys# / ((pgn# ^ eu#) * (b# + c#))
  'midwest goods
psgm# = dum# * (1 - .186771883#) * pys# / ((pgm# ^ eu#) * (b# + c#))
  'southern goods
psgs# = dus# * (1 - .186771883#) * pys# / ((pgs# ^ eu#) * (b# + c#))
  'western goods
psgw# = duw# * (1 - .186771883#) * pys# / ((pgw# ^ eu#) * (b# + c#))

'poor in west
  'northeast goods
pwgn# = dun# * (1 - .214735#) * pyw# / ((pgn# ^ eu#) * (b# + c#))
'midwest goods
\[ pwgm\# = \text{dum}\# \times (1 - 0.214735\#) \times \text{pyw}\# / ((\text{pgm}\# \wedge \text{eu}\#) \times (b\# + c\#)) \]

'south goods
\[ pwgs\# = \text{dus}\# \times (1 - 0.214735\#) \times \text{pyw}\# / ((\text{pgs}\# \wedge \text{eu}\#) \times (b\# + c\#)) \]

'west goods
\[ pwgw\# = \text{duw}\# \times (1 - 0.214735\#) \times \text{pyw}\# / ((\text{pgw}\# \wedge \text{eu}\#) \times (b\# + c\#)) \]

'demand for services by rich and poor populations, by region
'rich in Northeast
\[ r\text{vn}\# = (0.187144604\# \times \text{ryn}\#) / \text{pvn}\# \]

'rich in Midwest
\[ r\text{vm}\# = (0.207553457\# \times \text{rym}\#) / \text{pvm}\# \]

'poor in Northeast
\[ p\text{dvn}\# = (0.187144604\# \times \text{pyn}\#) / \text{pvn}\# \]

'poor in Midwest
\[ p\text{dvm}\# = (0.207553457\# \times \text{pym}\#) / \text{pvm}\# \]

'rich in South
\[ r\text{vs}\# = (0.186771883\# \times \text{rys}\#) / \text{pvs}\# \]

'rich in West
\[ r\text{vw}\# = (0.214735\# \times \text{ryw}\#) / \text{pvw}\# \]

'poor in South
\[ p\text{dvs}\# = (0.186771883\# \times \text{psy}\#) / \text{pvs}\# \]

'poor in West
\[ p\text{dvw}\# = (0.214735\# \times \text{pyw}\#) / \text{pvw}\# \]

'regional public goods provided by each government
'northeast government
\[ \text{torn}\# = (1 - 0.145715984\#) \times \text{nrev}\# / \text{prn}\# \]

'rich household receives half per capita amount as poor one
'(the below numbers are amounts for the entire population groups)
\[ r\text{rn}\# = (\text{torn}\# \times \text{rpop}\#) / (\text{rpop}\# + 2 \times \text{ppop}\#) \]
\[ p\text{drm}\# = \text{torn}\# - r\text{rn}\# \]

'midwest government
\[ \text{torm}\# = (1 - 0.110110477\#) \times \text{mrev}\# / \text{prm}\# \]

'rich household receives half per capita amount as poor one
'(the below numbers are amounts for the entire population groups)
\[ r\text{rm}\# = (\text{torm}\# \times \text{rpop}\#) / (\text{rpop}\# + 2 \times \text{ppop}\#) \]
\[ p\text{drm}\# = \text{torm}\# - r\text{rm}\# \]

'south government
\[ \text{tort}\# = (1 - 0.91076170000001D-02) \times \text{srev}\# / \text{prs}\# \]

'rich household receives half per capita amount as poor one
'(the below numbers are amounts for the entire population groups)
\[ r\text{rs}\# = (\text{tort}\# \times \text{rprops}\#) / (\text{rprops}\# + 2 \times \text{pprops}\#) \]
\[ p\text{drs}\# = \text{tort}\# - r\text{rs}\# \]
west government

totrw# = (1 - .114012874#) * wrev# / prw#
'rich household receives half per capita amount as poor one
'(the below numbers are amounts for the entire population groups)
rrw# = (totrw# * rpopw#) / (rpopw# + 2 * ppopw#)
pd# = totrw# - rrw#

federal public goods provided by each government

northeast federal government

totfn# = (1 - .77710039#) * nfrev# / pf#n#
'rich household receives same per capita amount as poor one
'(the below numbers are amounts for the entire population groups)
rfn# = (totfn# * rpopn#) / (rpopn# + ppopn#)
pd# = totfn# - rfn#

midwest federal government

totfm# = (1 - .5038230339999999#) * mfrev# / pf#m#
'rich household receives same per capita amount as poor one
'(the below numbers are amounts for the entire population groups)
rfm# = (totfm# * rpopm#) / (rpopm# + ppopm#)
pd# = totfm# - rfm#

south federal government

tots# = (1 - .333482446#) * sfrev# / ps#f#
'rich household receives same per capita amount as poor one
'(the below numbers are amounts for the entire population groups)
rfs# = (tots# * rprops#) / (rprops# + ppops#)
pd# = tots# - rfs#

west federal government

totfw# = (1 - .604175302#) * wfrev# / pf#w#
'rich household receives same per capita amount as poor one
'(the below numbers are amounts for the entire population groups)
rfw# = (totfw# * rpopw#) / (rpopw# + ppopw#)
pd# = totfw# - rfw#

REM Federal good provides no utility?

pure# = totfn# + totfm# + totfs# + totfw#

demandgn# = rngn# + pngn# + rmgn# + pmgn# + rsgn# + psgn# + rwgn# + pwgn#
demandgm# = rmg# + pngm# + rmgm# + pmgm# + rsgm# + psgm# + rwgm# + pwgm#
demands# = rns# + pns# + rmsg# + pmss# + rsgs# + psgs# + rwgs# + pwgs#
demandgw# = rngw# + ppng# + rmgw# + pmgw# + rsgw# + psgw# + rwgw# + pwgw#
demandrn# = rnn# + prn#
demandrm# = rrm# + pdrm#
demandrs# = rrs# + pdrs#
demandrw# = rrw# + pdrw#
demandfn# = rfn# + pdfn#
demandfm# = rfm# + pdfm#
demandfs# = rfs# + pdfs#
demandfw# = rfw# + pdfw#
demandvn# = rvn# + pdvn#
demandvm# = rvm# + pdvm#
demandvs# = rvs# + pdvs#
demandvw# = rvw# + pdvw#

'derived demand for factors
'northeast
'skilled and unskilled labor
dlbrsgn# = lsgn# * demandgn#
dlbrugn# = lugn# * demandgn#
dlbrsrm# = lsrm# * (rsm# + pdrm#)
dlbrurm# = lurm# * (rrm# + pdrm#)
dlbrsfm# = lsfm# * (rfm# + pdfm#)
dlbrufm# = lufm# * (rfm# + pdfm#)
dlbrsfn# = lsfn# * (rfn# + pdfn#)
dlbrufn# = lufn# * (rfn# + pdfn#)
dlbrsvn# = lsvn# * (rvn# + pdvn#)
dlbruvn# = luvn# * (rvn# + pdvn#)
dlbrsfn# = dlbrsgn# + dlbrsrm# + dlbrsfm# + dlbrsvn#
dlbrurm# = dlbrugn# + dlbrurm# + dlbrufm# + dlbruvn#
'capital
dcapgn# = kgn# * demandgn#
dcaprn# = krm# * (rrm# + pdrm#)
dcapfn# = kfn# * (rfm# + pdfm#)
dcapvn# = kvn# * (rvn# + pdvn#)
dcapn# = dcapgn# + dcaprn# + dcapfn# + dcapvn#

'midwest
'skilled and unskilled labor
dlbrsgm# = lsgm# * demandgm#
dlbrugm# = lugm# * demandgm#
dlbrsrn# = lsrn# * (rsm# + pdrm#)
dlbrurn# = lurm# * (rrm# + pdrm#)
dlbrsfm# = lsfm# * (rfm# + pdfm#)
dlbrufm# = lufm# * (rfm# + pdfm#)
dlbrsvm# = lsvm# * (rvm# + pdvm#)
dlbruvm# = luvm# * (rvm# + pdvm#)
dlbrsrm# = dlbrsgm# + dlbrsrn# + dlbrsfm# + dlbrsvm#
dlbrurm# = dlbrugm# + dlbrurm# + dlbrufm# + dlbruvm#
dcapgm# = kgm# * demandgm#  
dcaprm# = krm# * (rrm# + pdrm#)  
dcapfm# = kfm# * (rfm# + pdfm#)  
dcapvm# = kvm# * (rvm# + pdvm#)  
    dcapm# = dcapgm# + dcaprm# + dcapfm# + dcapvm#

'south'  
'skilled and unskilled labor'  
dlbtrs#s = lsrs# * demandgs#  
dlbbrgs# = lugs# * demandgs#  
    dlbbrsrs# = lsrs# * (rrs# + pdrs#)  
    dlbbrurs# = lurrs# * (rrs# + pdrs#)  
    dlbbrfs#s = lsf#s * (rfs# + pdfs#)  
    dlbbrufs# = lufs# * (rfs# + pdfs#)  
    dlbbrsvs# = lsvs# * (rvs# + pdvs#)  
    dlbbruv#s = luv#s * (rvs# + pdvs#)  
        dlbbrs#s = dlbbrgs# + dlbbrsrs# + dlbbrfs#s + dlbbrsvs#  
        dlbbrus# = dlbbrgs# + dlbbrurs# + dlbbrufs# + dlbbruv#s

'capital'  
dcapgs# = kgs# * demandgs#  
dcaprs# = krs# * (rrs# + pdrs#)  
dcapfs#s = kfs#s * (rfs# + pdfs#)  
dcapvs#s = kvvs# * (rvs# + pdvs#)  
    dcap#s = dcapgs# + dcaprs# + dcapfs#s + dcapvs#s

'west'  
'skilled and unskilled labor'  
dlbbrsgw# = lsgw# * demandgw#  
dlbbrugw# = lugw# * demandgw#  
    dlbbrsrw# = lsrw# * (rrw# + pdrw#)  
    dlbbrurw# = lurw# * (rrw# + pdrw#)  
    dlbbrsfw# = lsfw# * (rfw# + pdfw#)  
    dlbbrufw# = lufw# * (rfw# + pdfw#)  
    dlbbrsvw# = lsvw# * (rvw# + pdvw#)  
    dlbbruvw# = luvw# * (rvw# + pdvw#)  
        dlbbrsw# = dlbbrsgw# + dlbbrsrw# + dlbbrsfw# + dlbbrsvw#  
        dlbbruw# = dlbbrugw# + dlbbrurw# + dlbbrufw# + dlbbruvw#

dcapgw# = kgw# * demandgw#  
dcaprw# = krw# * (rrw# + pdrw#)  
dcapfw# = kf#s * (rfw# + pdfw#)  
dcapv#w = kvw# * (rvw# + pdvw#)  
    dcapw# = dcapgw# + dcaprw# + dcapfw# + dcapv#w

'derived tax revenue'
regional business capital taxes

ncaptxg# = (ntpkg# * pk# * dcapgn#)
naptxr# = (ntptkr# * pk# * dcaprn#)
naptxf# = (ntpkg# * pk# * dcapfn#)
naptxv# = (ntpkv# * pk# * dcapvn#)

ncaprevest# = naptxg# + naptx# + naptxf# + naptxv#
mcaptxg# = (mtpkg# * pk# * dcapgm#)
maptxr# = (mtptkr# * pk# * dcaprm#)
maptxf# = (mtpkg# * pk# * dcapfm#)
maptxv# = (mtpkg# * pk# * dcapvm#)
mcaprevest# = mcaptxg# + mcaptx# + mcapxf# + mcapxv#

scaptxg# = (stpkg# * pk# * dcaps#)
scaptx# = (stptkr# * pk# * dcaps#)
scaptxf# = (stpkg# * pk# * dcapfs#)
scaptxv# = (stpkg# * pk# * dcapvs#)

scaprevest# = scaptxg# + scaptx# + scaptxf# + scaptxv#
wcaptxg# = (wtpkg# * pk# * dcapg#
wcaptx# = (wtpktkr# * pk# * dcaprw#)
wcaptxf# = (wtpkg# * pk# * dcapfw#)
wcaptxv# = (wtpktkr# * pk# * dcapvw#)
wcaprevest# = wcaptxg# + wcaptx# + wcaptxf# + wcaptxv#

'regional business labor taxes

nlbrtxg# = ntlpg# * (plsl# * dlbssgn# + plun# * dlbrugn#)
nlbrtxr# = ntlpr# * (plsl# * dlbssrn# + plun# * dlbrurn#)
nlbrtxf# = ntlpf# * (plsl# * dlbssfhn# + plun# * dlbru#)
nlbrtxv# = ntlpv# * (plsl# * dlbssvn# + plun# * dlbru#)

nlbrepvest# = nlbrtxg# + nlbrtxr# + nlbrtxf# + nlbrtxv#
mlbtxg# = mtlpg# * (plsm# * dlbssgm# + plum# * dlbrugm#)
mlbtxr# = mtlpr# * (plsm# * dlbssrm# + plum# * dlbrurm#)
mlbtxf# = mtlpf# * (plsm# * dlbssfm# + plum# * dlbrufm#)
mlbtxv# = mtlpv# * (plsm# * dlbssvm# + plum# * dlbruvm#)

mlbrepvest# = mlbtxg# + mlbtxr# + mlbtxf# + mlbtxv#

slbrtxg# = stpkg# * (plss# * dlbssgs# + plus# * dlbrugs#)
slbrtxr# = stplt# * (plss# * dlbssrs# + plus# * dlbru#)
slbrtxf# = stplt# * (plss# * dlbssfs# + plus# * dlbru#)
slbrtxv# = stpltv# * (plss# * dlbssvs# + plus# * dlbruv#

slbrepvest# = slbrtxg# + slbrtxr# + slbrtxf# + slbrtxv#
wlbrtxg# = wtpltg# * (plsww# * dlbssgw# + pluw# * dlbrugw#)
wlbtxr# = wtplt# * (plsww# * dlbssrw# + pluw# * dlbrurw#)
wlbtxf# = wtplt# * (plsww# * dlbssfw# + pluw# * dlbru#)
wlbtxv# = wtpltv# * (plsww# * dlbssvw# + pluw# * dlbruv#)
wlbrevest# = wlbtxg# + wlbtxr# + wlbtxf# + wlbtxv#

'regional corporate taxes

goods

g# = pk# * dcaps

g1# = pk# * dcapgm

g2# = pk# * dcaps

g4# = pk# * dcapgw

g3n# = g# / (3 * (g# + g1# + g2# + g4#))
g3m# = g1# / (3 * (g# + g1# + g2# + g4#))
g3s# = g2# / (3 * (g# + g1# + g2# + g4#))
g3w# = g4# / (3 * (g# + g1# + g2# + g4#))
gb# = (plsn# * dlbrsgn#) + (plun# * dlbrgn#)
gb1# = (plsm# * dlbrsgm#) + (plum# * dlbrgm#)
gb2# = (plss# * dlbrsgs#) + (plus# * dlbrugs#)
gb4# = (plsw# * dlbrsgw#) + (pluw# * dlbrgw#)
gb3n# = gb# / (3 * (gb# + gb1# + gb2# + gb4#))
gb3m# = gb1# / (3 * (gb# + gb1# + gb2# + gb4#))
gb3s# = gb2# / (3 * (gb# + gb1# + gb2# + gb4#))
gb3w# = gb4# / (3 * (gb# + gb1# + gb2# + gb4#))
gc# = g# + gb#
gc1# = g1# + gb1#
gc2# = g2# + gb2#
gc4# = g4# + gb4#
gc3n# = gc# / (3 * (gc# + gc1# + gc2# + gc4#))
gc3m# = gc1# / (3 * (gc# + gc1# + gc2# + gc4#))
gc3s# = gc2# / (3 * (gc# + gc1# + gc2# + gc4#))
gc3w# = gc4# / (3 * (gc# + gc1# + gc2# + gc4#))
ncorptxg# = ncorpg# * (g3n# + gb3n# + gc3n#)
ncorptxg = ncorpg# * (g3m# + gb3m# + gc3m#)
ncorptxg = ncorpg# * (g3s# + gb3s# + gc3s#)
ncorptxg = ncorpg# * (g3w# + gb3w# + gc3w#)

'regional public goods

ra# = pk# * dcaprn#
ra1# = pk# * dcaprm#
ra2# = pk# * dcaps#
ra4# = pk# * dcaprw#
ra3n# = ra# / (3 * (ra# + ra1# + ra2# + ra4#))
ra3m# = ra1# / (3 * (ra# + ra1# + ra2# + ra4#))
ra3s# = ra2# / (3 * (ra# + ra1# + ra2# + ra4#))
ra3w# = ra4# / (3 * (ra# + ra1# + ra2# + ra4#))
rb# = (plsn# * dlbrsgn#) + (plun# * dlbrgn#)
rb1# = (plsm# * dlbrsm#) + (plum# * dlbrum#)
rb2# = (plss# * dlbrs#) + (plus# * dlbrs#)
rb4# = (plsw# * dlbrsw#) + (pluw# * dlbruw#)
rb3n# = rb# / (3 * (rb# + rb1# + rb2# + rb4#))
rb3m# = rb1# / (3 * (rb# + rb2# + rb2# + rb4#))
rb3s# = rb2# / (3 * (rb# + rb1# + rb2# + rb4#))
rb3w# = rb4# / (3 * (rb# + rb1# + rb2# + rb4#))
rc# = ra# + rb#
rc1# = ra1# + rb1#
rc2# = ra2# + rb2#
rc4# = ra4# + rb4#
rc3n# = rc# / (3 * (rc# + rc1# + rc2# + rc4#))
rc3m# = rc1# / (3 * (rc# + rc1# + rc2# + rc4#))
rc3s# = rc2# / (3 * (rc# + rc1# + rc2# + rc4#))
rc3w# = rc4# / (3 * (rc# + rc1# + rc2# + rc4#))
ncorptxr# = ncorpr# * (ra3n# + rb3n# + rc3n#)
mcorptxr# = mcorpr# * (ra3m# + rb3m# + rc3m#)
scorptxr# = scorpr# * (ra3s# + rb3s# + rc3s#)
wcorptxr# = wcorpr# * (ra3w# + rb3w# + rc3w#)

federal public goods
fa# = pk# * dcapfm#
fa1# = pk# * dcapfm#
fa2# = pk# * dcapfs#
fa4# = pk# * dcapfw#
fa3n# = fa# / (3 * (fa# + fa1# + fa2# + fa4#))
fa3m# = fa1# / (3 * (fa# + fa1# + fa2# + fa4#))
fa3s# = fa2# / (3 * (fa# + fa1# + fa2# + fa4#))
fa3w# = fa4# / (3 * (fa# + fa1# + fa2# + fa4#))
fb# = (plsn# * dlbrsfn#) + (plum# * dlbrufn#)
fb1# = (plsm# * dlbrsfn#) + (plum# * dlbrufm#)
fb2# = (plss# * dlbrsfs#) + (plus# * dlbrufs#)
fb4# = (plsw# * dlbrsw#) + (pluw# * dlbrufw#)
fb3n# = fb# / (3 * (fb# + fb1# + fb2# + fb4#))
fb3m# = fb1# / (3 * (fb# + fb1# + fb2# + fb4#))
fb3s# = fb2# / (3 * (fb# + fb1# + fb2# + fb4#))
fb3w# = fb4# / (3 * (fb# + fb1# + fb2# + fb4#))
fc# = fa# + fb#
fc1# = fa1# + fb1#
fc2# = fa2# + fb2#
fc4# = fa4# + fb4#
fc3n# = fc# / (3 * (fc# + fc1# + fc2# + fc4#))
fc3m# = fc1# / (3 * (fc# + fc1# + fc2# + fc4#))
fc3s# = fc2# / (3 * (fc# + fc1# + fc2# + fc4#))
\[
\begin{align*}
f_{c3w} &= f_{c4} / (3 \ast (f_{c1} + f_{c2} + f_{c4})) \\
n_{corptxf} &= n_{corpfi} \ast (f_{a3n} + f_{b3n} + f_{c3n}) \\
m_{corptxf} &= m_{corpfi} \ast (f_{a3m} + f_{b3m} + f_{c3m}) \\
sc_{orptxf} &= sc_{orpfi} \ast (f_{a3s} + f_{b3s} + f_{c3s}) \\
w_{corptxf} &= w_{corpfi} \ast (f_{a3w} + f_{b3w} + f_{c3w}) \\
\end{align*}
\]

'services
\[
\begin{align*}
va# &= pk\ast dcapvn# \\
va1# &= pk\ast dcapvnm# \\
va2# &= pk\ast dcapvs# \\
va4# &= pk\ast dcapvww# \\
va3n# &= va# / (3 \ast (va# + va1# + va2# + va4#)) \\
va3m# &= va1# / (3 \ast (va# + va1# + va2# + va4#)) \\
va3s# &= va2# / (3 \ast (va# + va1# + va2# + va4#)) \\
va3w# &= va4# / (3 \ast (va# + va1# + va2# + va4#)) \\
vb# &= (plsn# \ast dlbrsn#) + (plun# \ast dlbrvn#) \\
vb1# &= (plsm# \ast dlbrsnn#) + (plum# \ast dlbruu#) \\
vb2# &= (plss# \ast dlbrsv#) + (plus# \ast dlbruv#) \\
vb4# &= (plsw# \ast dlbrsv#) + (pluw# \ast dlbruu#) \\
vb3n# &= vb# / (3 \ast (vb# + vb1# + vb2# + vb4#)) \\
vb3m# &= vb1# / (3 \ast (vb# + vb1# + vb2# + vb4#)) \\
vb3s# &= vb2# / (3 \ast (vb# + vb1# + vb2# + vb4#)) \\
vb3w# &= vb4# / (3 \ast (vb# + vb1# + vb2# + vb4#)) \\
vc# &= va# + vb# \\
vc1# &= va1# + vb1# \\
vc2# &= va2# + vb2# \\
vc4# &= va4# + vb4# \\
vc3n# &= vc# / (3 \ast (vc# + vc1# + vc2# + vc4#)) \\
vc3m# &= vc1# / (3 \ast (vc# + vc1# + vc2# + vc4#)) \\
vc3s# &= vc2# / (3 \ast (vc# + vc1# + vc2# + vc4#)) \\
vc3w# &= vc4# / (3 \ast (vc# + vc1# + vc2# + vc4#)) \\
n_{corptxv#} &= n_{corpvi} \ast (va3n# + va3m# + va3n#) \\
m_{corptxv#} &= m_{corpfi} \ast (va3m# + va3m# + va3m#) \\
sc_{orptxv#} &= sc_{orpfi} \ast (va3s# + va3s# + va3s#) \\
w_{corptxv#} &= w_{corpfi} \ast (va3w# + va3w# + va3w#) \\
\end{align*}
\]

'total regional corporate taxes
\[
\begin{align*}
n_{corprevest#} &= n_{corptxg} + n_{corptxr} + n_{corptxfi} + n_{corptxv} \\
m_{corprevest#} &= m_{corptxg} + m_{corptxr} + m_{corptxfi} + m_{corptxv} \\
sc_{orprevest#} &= sc_{orpixg} + sc_{orptxr} + sc_{orptxfi} + sc_{orptxv} \\
w_{corprevest#} &= w_{corptxg} + w_{corptxr} + w_{corptxfi} + w_{corptxv} \\
\end{align*}
\]

'total regional business taxes
\[
\begin{align*}
n_{bustxest#} &= n_{caprevest} + n_{lbrevest} + n_{corprevest} \\
m_{bustxest#} &= m_{caprevest} + m_{lbrevest} + m_{corprevest} \\
\end{align*}
\]
sbustxest# = scaprevest# + slbrrevest# + scorprevest#
wbustxest# = wcaprevest# + wlbrrrevest# + wcorprevest#

'total sales taxes
nslstxest# = ngtxs# * (ga# + gb# + va# + vb#)
mslstxest# = mgtxs# * (ga1# + gb1# + va1# + vb1#)
sslstxest# = sgtxs# * (ga2# + gb2# + va2# + vb2#)
wslstxest# = wgtxs# * (ga4# + gb4# + va4# + vb4#)

'total regional PIT
npitestr# = rtaxn# + ptaxn#
mpitestr# = rtaxm# + ptaxm#
spitestr# = rtaxs# + ptaxs#
wpitestr# = rtaxw# + ptaxw#

'total regional taxes
mrevest# = nbustxest# + nslstxest# + npitestr#
mrevest# = mbustxest# + mslstxest# + mpitestr#
srevest# = sbustxest# + sslstxest# + spitestr#
wrevest# = wbustxest# + wslstxest# + wpitestr#

'federal gov't tax PIT revenue
nfpitestr# = rftaxn# + ptaxn#
mfpitestr# = rftaxm# + ptaxm#
sfpitestr# = rftaxs# + ptaxs#
wfpitestr# = rftaxw# + ptaxw#

'federal business capital taxes
nfcapptxg# = (nftpkg# * pk# * dcapgn#)
mncapptxr# = (nftpkg# * pk# * dcaprn#)
ncapptxf# = (nftpkg# * pk# * dcapfn#)
ncapptxv# = (nftpkg# * pk# * dcapvn#)
ncaprevest# = ncapptxg# + mncapptxr# + ncapptxf# + ncapptxv#
mcapptxg# = (mftpkg# * pk# * dcapgm#)
mncapptxr# = (mftpkg# * pk# * dcaprm#)
ncapptxf# = (mftpkg# * pk# * dcapfm#)
ncapptxv# = (mftpkg# * pk# * dcapvm#)
ncaprevest# = mncapptxg# + mncapptxr# + mncapptxf# + mncapptxv#
sfcapptxg# = (sftpkg# * pk# * dcapgs#)
sfcapptxr# = (sftpkg# * pk# * dcaprs#)
sfcapptxf# = (sftpkg# * pk# * dcapfs#)
sfcapptxv# = (sftpkg# * pk# * dcapvs#)
wfcapptxg# = (wftpkg# * pk# * dcapgw#)
wfcapptxr# = (wftpkg# * pk# * dcaprw#)
wfcapptxf# = (wftpkg# * pk# * dcapfw#)
wfcapptxv# = (wftpkg# * pk# * dcapvv#)
wfcaprevest# = wfcapptxg# + wfcapptxr# + wfcapptxf# + wfcapptxv#
'federal business labor taxes

nflbrtxg# = nftplg# * (plsn# * dlbrsgn# + plun# * dlbrugn#)
nflbrtxr# = nftplr# * (plsn# * dlbrsrn# + plun# * dlbrurm#)
nflbrtxf# = nftplf# * (plsn# * dlbrsfn# + plun# * dlbrufm#)
nflbrtxv# = nftplv# * (plsn# * dlbrsvn# + plun# * dlbruvn#)
nflbrrevest# = nflbrtxg# + nflbrtxr# + nflbrtxf# + nflbrtxv#
mflbrtxg# = mftplg# * (plsm# * dlbrsgm# + plum# * dlbrugm#)
mflbrtxr# = mftplr# * (plsm# * dlbrsrn# + plum# * dlbrurm#)
mflbrtxf# = mftplf# * (plsm# * dlbrsfn# + plum# * dlbrufm#)
mflbrtxv# = mftplv# * (plsm# * dlbrsvn# + plum# * dlbruvn#)
mflbrrevest# = mflbrtxg# + mflbrtxr# + mflbrtxf# + mflbrtxv#
sflbrtxg# = stfplg# * (plss# * dlbrsgs# + plus# * dlbrugs#)
sflbrtxr# = stfplr# * (plss# * dlbrsrss# + plus# * dlbrurs#)
sflbrtxf# = stfplf# * (plss# * dlbrsfs# + plus# * dlbrufs#)
sflbrtxv# = stfplv# * (plss# * dlbrsvs# + plus# * dlbruvn#)
sflbrrevest# = sflbrtxg# + sflbrtxr# + sflbrtxf# + sflbrtxv#
wfbrtxg# = wftplg# * (pws# * dlbrsgw# + pluw# * dlbrugw#)
wfbrtxr# = wftplr# * (pws# * dlbrsrw# + pluw# * dlbrurm#)
wfbrtxf# = wftplf# * (pws# * dlbrsfw# + pluw# * dlbrufm#)
wfbrtxv# = wftplv# * (pws# * dlbrsvw# + pluw# * dlbruvw#)
wfbrrevest# = wfbrtxg# + wfbrtxr# + wfbrtxf# + wfbrtxv#

'federal total tax revenue

nfrevest# = nfpitest# + nfcaprevest# + nflbrrevest#
mfrevest# = mfpitest# + mfcaprevest# + nflbrrevest#
sfrevest# = spitese# + sfcaprevest# + sflbrrevest#
wfrevest# = wfpitest# + wfcaprevest# + wfbrrevest#

'excess supply of factors in the regions (and % for reiteration check)

'northeast

xslbrsn# = rlbmn# - dlbrsn#
perxslnrsn# = (rlbrn# - dlbrsn#) / ((rlbrn# + dlbrsn#) / 2)
xslbrun# = plbrn# - dlbrun#
perxslbrun# = (plbrn# - dlbrun#) / ((plbrn# + dlbrun#) / 2)
xscapn# = tcapn# - dcapn#

'midwest

xslbrsm# = rlbmn# - dlbrsm#
perxslnbrsm# = (rlbrm# - dlbrsm#) / ((rlbrm# + dlbrsm#) / 2)
xslbrum# = plbrm# - dlbrum#
perxslbrum# = (plbrm# - dlbrum#) / ((plbrm# + dlbrum#) / 2)
xscapm# = tcapm# - dcapm#

'south

xslbrsn# = rlbrs# - dlbrss#
perxslnbssn# = (rlbss# - dlbrss#) / ((rlbss# + dlbrss#) / 2)
xslbrus# = plbrs# - dlbrus#
  perxslbrus# = (plbrs# - dlbrus#) / ((plbrs# + dlabrus#) / 2)
xscaps# = tcaps# - dcaps#
  'west
xslbrsw# = rlbrw# - dlbrsw#
  perxslbrsw# = (rlbrw# - dlbrsw#) / ((rlbrw# + dlabrsw#) / 2)
xslbruw# = plbrw# - dlbruw#
  perxslbruw# = (plbrw# - dlbruw#) / ((plbrw# + dlabrws#) / 2)
xscapw# = tcapw# - dcapw#

'government revenue misestimate (and % for reiteration check)
xsmrev# = nrev# - nrevest#
  perxsmrev# = (nrev# - nrevest#) / ((nrev# + nrevest#) / 2)
xfnrev# = mrev# - mrevest#
  perxfnrev# = (mrev# - mrevest#) / ((mrev# + mrevest#) / 2)
xsmfrev# = mfrev# - mfrevest#
  perxsmfrev# = (mfrev# - mfrevest#) / ((mfrev# + mfrevest#) / 2)

xssrev# = srev# - srevest#
  perxssrev# = (srev# - srevest#) / ((srev# + srevest#) / 2)
xswrev# = wrev# - wrevest#
  perxswrev# = (wrev# - wrevest#) / ((wrev# + wrevest#) / 2)
xssfrev# = sfrev# - sfrevest#
  perxssfrev# = (sfrev# - sfrevest#) / ((sfrev# + sfrevest#) / 2)
xswfrev# = wfrev# - wfrevest#
  perxswfrev# = (wfrev# - wfrevest#) / ((wfrev# + wfrevest#) / 2)

'printout
PRINT "iteration"; eye
PRINT "xslbrsm#"; xslbrn#; "xslbrun"; xslbrun#; "xscapn#"; xscapn#
PRINT "xslbrsm#"; xslbrsm#; "xslbrun"; xslbrum#; "xscapn#"; xscapn#
PRINT "xslbrss#"; xslbrss#; "xslbrus"; xslbrus#; "xscaps#"; xscaps#
PRINT "xslbrsw#"; xslbrsw#; "xslbruw"; xslbruw#; "xscapw#"; xscapw#
PRINT "plsn#"; plsn#; "plsm#"; plsm#
PRINT "plun#"; plun#; "plum#"; plum#
PRINT "plss#"; plss#; "plsw#"; plsw#
PRINT "plus#"; plus#; "pluw#"; pluw#
PRINT "xsmrev=#"; xsmrev#; "xsfrev#"; xsfrev#
PRINT "xsmrev=#"; xsmrev#; "xsfrev#"; xsfrev#
PRINT "xsmrev=#"; xsmrev#; "xsfrev#"; xsfrev#
PRINT "xsmrev=#"; xsmrev#; "xsfrev#"; xsfrev#
PRINT "rpopn#"; rpopn#; "rpopm#"; rpopm#
PRINT "rprops#", rprops#; "rpopw#": rpopw#
PRINT "rtrann#", rtrann#: "rtranm#": rtranm#
PRINT "ptrann#": ptrann#: "ptranmf#": ptranmf#
PRINT "rtrans#": rtrans#: "rtranw#": rtranw#
PRINT "ptrans#": ptrans#: "ptranw#": ptranw#

REM DEBUG
'INPUT i
eye = eye + 1

'adjusting price of labor for reiteration
newplsn# = plsn# * (dlbrsn#/ rlbbrn#)
newplun# = plun# * (dlbrun#/ plbrn#)
newplsm# = plsm# * (dlbrsm#/ rlbbrm#)
newplum# = plum# * (dlbrum#/ plbrm#)
newplss# = plss# * (dlbrss#/ rlbrs#)
newplus# = plus# * (dlbrus#/ plbrs#)
newplsw# = plsw# * (dlbrsw#/ rlbrw#)
newpluw# = pluw# * (dlbruw#/ plbrw#)

IF ABS(perxslbrsn#) > hi THEN plsn# = newplsn#
IF ABS(perxslbrun#) > hi THEN plun# = newplun#
IF ABS(perxslbrsm#) > hi THEN plsm# = newplsm#
IF ABS(perxslbrum#) > hi THEN plum# = newplum#
IF ABS(perxslbrss#) > hi THEN plss# = newplss#
IF ABS(perxslbrus#) > hi THEN plus# = newplus#
IF ABS(perxslbrsw#) > hi THEN plsw# = newplsw#
IF ABS(perxslbruw#) > hi THEN pluw# = newpluw#

'adjusting tax revenue estimate for reiteration
IF ABS(perxsnrev#) > hi THEN nrev# = nrevest#
IF ABS(perxsmrev#) > hi THEN mrev# = mrevest#
IF ABS(perxsnfrev#) > hi THEN nfrev# = nfrevest#
IF ABS(perxsmfrev#) > hi THEN mfrev# = mfrevest#
IF ABS(perxssrev#) > hi THEN srev# = srevest#

IF ABS(perxswrev#) > hi THEN wrev# = wrevest#

IF ABS(perxssfrev#) > hi THEN sfrev# = sfrevest#

IF ABS(perxswfrev#) > hi THEN wfreq# = wfrevest#

ginterest# = 3 * (ga# + ga1# + ga2# + ga4#)
gwages# = 3 * (gb# + gb1# + gb2# + gb4#)
gsales# = 3 * (gc# + gc1# + gc2# + gc4#)
rinterest# = 3 * (ra# + ra1# + ra2# + ra4#)
rwages# = 3 * (rb# + rb1# + rb2# + rb4#)
rsales# = 3 * (rc# + rc1# + rc2# + rc4#)
finterest# = 3 * (fa# + fa1# + fa2# + fa4#)
fwages# = 3 * (fb# + fb1# + fb2# + fb4#)
fsales# = 3 * (fc# + fc1# + fc2# + fc4#)
vinterest# = 3 * (va# + va1# + va2# + va4#)
vwages# = 3 * (vb# + vb1# + vb2# + vb4#)
vsales# = 3 * (vc# + vc1# + vc2# + vc4#)

c1 = ABS(perxlsbrsm#)
c2 = ABS(perxlsbrsn#)
c3 = ABS(perxsnrev#)
c4 = ABS(perxsmrev#)
c5 = ABS(perxsfrev#)
c6 = ABS(perxsmrev#)
c7 = ABS(perxlsbrum#)
c8 = ABS(perxlsbrun#)
c9 = ABS(perxlsbrsw#)
c10 = ABS(perxlsbrss#)
c11 = ABS(perxssrev#)
c12 = ABS(perxswrev#)
c13 = ABS(perxssfrev#)
c14 = ABS(perxswfrev#)
c15 = ABS(perxlsbruw#)
c16 = ABS(perxlsbrus#)

***************************************************************************
internal loop ends***************************************************************************

LOOP UNTIL c1 < hi AND c2 < hi AND c3 < hi AND c4 < hi AND c5 < hi AND c6 < hi AND c7 < hi AND c8 < hi AND c9 < hi AND c10 < hi AND c11 < hi AND c12 < hi AND c13 < hi AND c14 < hi AND c15 < hi AND c16 < hi
'Calculating utilities
REM public utilities no utility

'Rich population's in northeast utility from the four goods
a# = (eu# - 1) / eu#
b# = eu# / (eu# - 1)
d# = 1 / eu#
c# = ((dum# ^ d#) * rngm# ^ a# + (dum# ^ d#) * rngm# ^ a#)
ce# = ((dus# ^ d#) * rmgs# ^ a# + (duw# ^ d#) * rngw# ^ a#)
cee# = (c# + ce#) ^ b#

'same population's utility from services
cvf# = rvn#

'same population's utility from the goods/services bundle
a# = (evg# - 1) / evg#
b# = evg# / (evg# - 1)
d# = 1 / evg#
cvg# = ((dvg# ^ d#) * cv# ^ a# + ((1 - dvg#) ^ d#) * cee# ^ a#) ^ b#

'same population's utility from the 2 public goods
a# = (erf# - 1) / erf#
b# = erf# / (erf# - 1)
d# = 1 / erf#
REM cpf# = ((drf# ^ d#) * rrn# ^ a# + ((1 - drf#) ^ d#) * rfn# ^ a#) ^ b#
cpf# = ((drf# ^ d#) * rmns# ^ a#) ^ b#

'same population's total utility
fl# = (ew# - 1) / ew#
g# = ew# / (ew# - 1)
h# = (dw# * cpf# ^ fl# + (1 - dw#) * cvg# ^ fl#)
i# = h# ^ g#

'Per capita total utility
'SHIFT FACTOR=1.021761
utyrn# = 1.021761 * (i# * 10000 / rpopn#)

'Rich population in midwest utility from the two goods
a# = (eu# - 1) / eu#
b# = eu# / (eu# - 1)
d# = 1 / eu#
c# = ((dum# ^ d#) * rngm# ^ a# + (dum# ^ d#) * rngm# ^ a#)
ce# = ((dus# ^ d#) * rmgs# ^ a# + (duw# ^ d#) * rngw# ^ a#)
cee# = (c# + ce#) ^ b#

'same population's utility from services
cvf# = rvn#

'same population's utility from the goods/services bundle
a# = (evg# - 1) / evg#
b# = evg# / (evg# - 1)
d# = 1 / evg#
$$cvg# = ((dvg# \cdot d#) \cdot cv# \cdot a# + ((1 - dvg#) \cdot d#) \cdot cee# \cdot a#) \cdot b#$$

'same population's utility from the 2 public goods

$$a# = (erf# - 1) / erf#$$
$$b# = erf# / (erf# - 1)$$
$$d# = 1 / erf#$$

REM $$cpf# = ((drf# \cdot d#) \cdot rrm# \cdot a# + ((1 - drf#) \cdot d#) \cdot rfim# \cdot a#) \cdot b#$$

$$cpf# = ((drf# \cdot d#) \cdot rrm# \cdot a#) \cdot b#$$

'same population's total utility

$$f# = (ew# - 1) / ew#$$
$$g# = ew# / (ew# - 1)$$
$$h# = (dw# \cdot cpf# \cdot f# + (1 - dw#) \cdot cvg# \cdot f#)$$
$$i# = h# \cdot g#$$

'per capita total utility

REM SHIFT FACTOR IS 0

$$utyrm# = (i# \cdot 10000 / rpopn#)$$

'poor population in northeast's utility from the two goods

$$a# = (eu# - 1) / eu#$$
$$b# = eu# / (eu# - 1)$$
$$d# = 1 / eu#$$

$$c# = (du# \cdot d#) \cdot pngn# \cdot a# + (du# \cdot d#) \cdot pngm# \cdot a#$$

$$cee# = (du# \cdot d#) \cdot pngs# \cdot a# + (duw# \cdot d#) \cdot pngw# \cdot a#$$

$$cee# = (c# + ce#) \cdot b#$$

'same population's utility from services

$$cv# = pdvn#$$

'same population's utility from the goods/services bundle

$$a# = (evg# - 1) / evg#$$
$$b# = evg# / (evg# - 1)$$
$$d# = 1 / evg#$$

$$cvg# = ((dvg# \cdot d#) \cdot cv# \cdot a# + ((1 - dvg#) \cdot d#) \cdot cee# \cdot a#) \cdot b#$$

'same population's utility from the 2 public goods

$$a# = (erf# - 1) / erf#$$
$$b# = erf# / (erf# - 1)$$
$$d# = 1 / erf#$$

REM $$cpf# = ((drf# \cdot d#) \cdot pdrm# \cdot a# + ((1 - drf#) \cdot d#) \cdot pdfm# \cdot a#) \cdot b#$$

$$cpf# = ((drf# \cdot d#) \cdot pdrm# \cdot a#) \cdot b#$$

'same population's total utility

$$f# = (ew# - 1) / ew#$$
$$g# = ew# / (ew# - 1)$$
$$h# = (dw# \cdot cpf# \cdot f# + (1 - dw#) \cdot cvg# \cdot f#)$$
$$i# = h# \cdot g#$$

'per capita total utility

$$utypn# = i# \cdot 10000 / ppopn#$$
'Poor population in midwest's utility from the two goods
a# = (eu# - 1) / eu#
b# = eu# / (eu# - 1)
d# = 1 / eu#
c# = ((dum# ^ d#) * pmgn# ^ a# + (dum# ^ d#) * pmgw# ^ a#)
ce# = ((dus# ^ d#) * pmsg# ^ a# + (dus# ^ d#) * pmgw# ^ a#)
cee# = (c# + ce#) ^ b#
  'same population's utility from services
cv# = pdvm#
  'same population's utility from the goods/services bundle
a# = (evg# - 1) / evg#
b# = evg# / (evg# - 1)
d# = 1 / evg#
cvg# = ((dvg# ^ d#) * cv# ^ a# + ((1 - dvg#) ^ d#) * cee# ^ a#) ^ b#
  'same population's utility from the 2 public goods
a# = (erf# - 1) / erf#
b# = erf# / (erf# - 1)
d# = 1 / erf#
REM cpf# = ((drf# ^ d#) * pdrm# ^ a# + ((1 - drf#) ^ d#) * pdfm# ^ a#) ^ b#
cpf# = ((drf# ^ d#) * pdrm# ^ a#) ^ b#
  'same population's total utility
f# = (ew# - 1) / ew#
g# = ew# / (ew# - 1)
h# = (dhw# * cpf# ^ f# + (1 - dhw#) * cvg# ^ f#)
i# = h# ^ g#
  'per capita total utility
utypm# = i# * 10000 / ppopm#

'Rich population's in south utility from the four goods
a# = (eu# - 1) / eu#
b# = eu# / (eu# - 1)
d# = 1 / eu#
c# = ((dum# ^ d#) * rsng# ^ a# + (dum# ^ d#) * rsnm# ^ a#)
ce# = ((dus# ^ d#) * rsng# ^ a# + (dus# ^ d#) * rsnm# ^ a#)
cee# = (c# + ce#) ^ b#
  'same population's utility from services
cv# = rvs#
  'same population's utility from the goods/services bundle
a# = (evg# - 1) / evg#
b# = evg# / (evg# - 1)
d# = 1 / evg#
cvg# = ((dvg# ^ d#) * cv# ^ a# + ((1 - dvg#) ^ d#) * cee# ^ a#) ^ b#
  'same population's utility from the 2 public goods
a# = (erf# - 1) / erf#
b# = erf#/ (erf# - 1)
d# = 1 / erf#
REM cpf# = ((draf# ^ d#) * rrs# ^ a# + ((1 - draf#) ^ d#) * rf# ^ a#) ^ b#
cpf# = ((draf# ^ d#) * rrs# ^ a#) ^ b#

'same population's total utility
f# = (ew# - 1) / ew#
g# = ew# / (ew# - 1)
h# = (dw# * cpf# ^ f# + (1 - dw#) * cvg# ^ f#)
i# = h# ^ g#

'per capita total utility
REM SHIFT FACTOR IS 1.0417627
utyrs# = (# * 10000 / rpop#) * 1.0417627#

'Rich population in west utility from the two goods
a# = (eu# - 1) / eu#
b# = eu# / (eu# - 1)
d# = 1 / eu#
c# = ((dum# ^ d#) * rwgn# ^ a# + (dum# ^ d#) * rwgm# ^ a#)
ce# = ((dus# ^ d#) * rwgs# ^ a# + (duw# ^ d#) * rwgw# ^ a#)
cee# = (c# + ce#) ^ b#

'same population's utility from services
cv# = rvw#

'same population's utility from the goods/services bundle
a# = (evg# - 1) / evg#
b# = evg# / (evg# - 1)
d# = 1 / evg#
cvg# = ((dvgs# ^ d#) * cvv# ^ a# + ((1 - dvgs#) ^ d#) * cee# ^ a#) ^ b#

'same population's's utility from the 2 public goods
a# = (erf# - 1) / erf#
b# = erf# / (erf# - 1)
d# = 1 / erf#
REM cpf# = ((draf# ^ d#) * rrw# ^ a# + ((1 - draf#) ^ d#) * rw# ^ a#) ^ b#
cpf# = ((draf# ^ d#) * rrw# ^ a#) ^ b#

'same population's total utility
f# = (ew# - 1) / ew#
g# = ew# / (ew# - 1)
h# = (dw# * cpf# ^ f# + (1 - dw#) * cvg# ^ f#)
i# = h# ^ g#

'per capita total utility
REM SHIFT FACTOR IS 1.0375738
utyrrw# = (i# * 10000 / rpopw#) * 1.0375738#
'poor population in south's utility from the two goods
a# = (eu# - 1) / eu#
b# = eu# / (eu# - 1)
d# = 1 / eu#
c# = ((dum# ^ d#) * psgn^ a# + (dum# ^ d#) * psgm^ a#)
ce# = ((dus# ^ d#) * psgs# ^ a# + (duw# ^ d#) * psgw# ^ a#)
cee# = (c# + ce#) ^ b#
'same population's utility from services
cv# = pdvs#
'same population's utility from the goods/services bundle
a# = (evg# - 1) / evg#
b# = evg# / (evg# - 1)
d# = 1 / evg#
cvg# = ((dvg# ^ d#) * cv# ^ a# + ((1 - dvg#) ^ d#) * cee# ^ a#) ^ b#
'same population's utility from the 2 public goods
a# = (erf# - 1) / erf#
b# = erf# / (erf# - 1)
d# = 1 / erf#
REM cpf# = ((drf# ^ d#) * pdrs# ^ a# + ((1 - drf#) ^ d#) * pdfs# ^ a#) ^ b#
cpf# = ((drf# ^ d#) * pdrs# ^ a#) ^ b#
'same population's total utility
f# = (ew# - 1) / ew#
g# = ew# / (ew# - 1)
h# = (dw# * cpf# ^ f# + (1 - dw#) * cvg# ^ f#)
i# = h# ^ g#
'per capita total utility
utyps# = i# * 10000 / pprops#
'poor population in west's utility from the two goods
a# = (eu# - 1) / eu#
b# = eu# / (eu# - 1)
d# = 1 / eu#
c# = ((dum# ^ d#) * pwgn# ^ a# + (dum# ^ d#) * pwgm# ^ a#)
ce# = ((dus# ^ d#) * pwgs# ^ a# + (duw# ^ d#) * pwgw# ^ a#)
cee# = (c# + ce#) ^ b#
'same population's utility from services
cv# = pdvw#
'same population's utility from the goods/services bundle
a# = (evg# - 1) / evg#
b# = evg# / (evg# - 1)
d# = 1 / evg#
cvg# = ((dvg# ^ d#) * cv# ^ a# + ((1 - dvg#) ^ d#) * cee# ^ a#) ^ b#
same population's utility from the 2 public goods
\[ a# = (\text{erf}\# - 1) / \text{erf}\# \]
\[ b# = \text{erf}\# / (\text{erf}\# - 1) \]
\[ d# = 1 / \text{erf}\# \]
\[ \text{cpf}\# = ((\text{drf}\# \wedge d#) \ast \text{pdrw}\# \wedge a#) + ((1 - \text{drf}\# \wedge d#) \ast \text{pdfw}\# \wedge a#) \wedge b# \]
\[ \text{cpf}\# = ((\text{drf}\# \wedge d#) \ast \text{pdrw}\# \wedge a#) \wedge b# \]

same population's total utility
\[ f# = (\text{ew}\# - 1) / \text{ew}\# \]
\[ g# = \text{ew}\# / (\text{ew}\# - 1) \]
\[ h# = (\text{dw}\# \ast \text{cpf}\# \wedge f#) + (1 - \text{dw}\#) \ast \text{cvg}\# \wedge f# \]
\[ i# = h# \wedge g# \]

per capita total utility
\[ \text{utypw}\# = i# \ast 10000 / \text{ppopw}\# \]

difference in rich utilities
\[ \text{utyrnmddf}\# = (\text{utyrn}\# - \text{utyrn}\#) / ((\text{utyrn}\# + \text{utyrn}\#) / 2) \]
\[ \text{utyrnrsddf}\# = (\text{utyrn}\# - \text{utyrn}\#) / ((\text{utyrn}\# + \text{utyrn}\#) / 2) \]
\[ \text{utyrnwddf}\# = (\text{utyrn}\# - \text{utyrnw}\#) / ((\text{utyrn}\# + \text{utyrnw}\#) / 2) \]
\[ \text{utyrnsmddf}\# = (\text{utyrn}\# - \text{utyrn}\#) / ((\text{utyrn}\# + \text{utyrn}\#) / 2) \]
\[ \text{utyrnswddf}\# = (\text{utyrn}\# - \text{utyrn}\#) / ((\text{utyrn}\# + \text{utyrn}\#) / 2) \]
\[ \text{utyrnwmdddf}\# = (\text{utyrnw}\# - \text{utyrnw}\#) / ((\text{utyrnw}\# + \text{utyrnw}\#) / 2) \]

pre inter-regional labor locations (for reference purposes)
\[ \text{oldrlbrn}\# = \text{rlbrn}\#; \text{oldrlbrm}\# = \text{rlbrm}\# \]
\[ \text{oldrlbrs}\# = \text{rlbss}\#; \text{oldrlbrw}\# = \text{rlbrw}\# \]

moving them rich folk
\[ \text{IF} \ \text{ABS}(\text{utyrnmddf}\#) > .00005\# \text{ THEN} \]
\[ \text{rlbrm}\# = \text{rlbrm}\# \ast (1 - .35 \ast \text{utyrnmddf}\#); \text{rcapm}\# = \text{rlbrm}\# \ast \text{rratio}\# \]
\[ \text{rpopm}\# = \text{rlbrm}\# / \text{rlbr}\# \]
\[ \text{rlbrn}\# = \text{rlbrn}\# + (\text{oldrlbrm}\# - \text{rlbrm}\#); \text{rcapn}\# = \text{rlbrn}\# \ast \text{rratio}\# \]
\[ \text{rpopn}\# = \text{rlbrn}\# / \text{rlbr}\# \]
\[ \text{END IF} \]

\[ \text{IF} \ \text{ABS}(\text{utyrnrsddf}\#) > .00005\# \text{ THEN} \]
\[ \text{rlbrs}\# = \text{rlbss}\# \ast (1 - .35 \ast \text{utyrnrsddf}\#); \text{rcaps}\# = \text{rlbss}\# \ast \text{rratio}\# \]
\[ \text{rpopps}\# = \text{rlbrs}\# / \text{rlbr}\# \]
\[ \text{rlbrn}\# = \text{rlbrn}\# + (\text{oldrlbss}\# - \text{rlbss}\#); \text{rcapn}\# = \text{rlbrn}\# \ast \text{rratio}\# \]
\[ \text{rpopn}\# = \text{rlbrn}\# / \text{rlbr}\# \]
\[ \text{END IF} \]

\[ \text{IF} \ \text{ABS}(\text{utyrnwddf}\#) > .00005\# \text{ THEN} \]
\[ \text{rlbrw}\# = \text{rlbrw}\# \ast (1 - .35 \ast \text{utyrnwddf}\#); \text{rcapw}\# = \text{rlbrw}\# \ast \text{rratio}\# \]
rpoww# = rlbrw# / rlbr#
rlbr# = rlbr# + (oldrlbrw# - rlbrw#); rcapn# = rlbrm# * rratio#
rpopn# = rlbrm# / rlbr#
END IF

IF ABS(utyrsmdf#) > .00005# THEN
rlbrm# = rlbrm# * (1 - .35 * utyrsmdf#); rcapm# = rlbrm# * rratio#
rpopm# = rlbrm# / rlbr#
rlbrs# = rlbrs# + (oldrlbrw# - rlbrw#); rcaps# = rlbrs# * rratio#
rpops# = rlbrs# / rlbr#
END IF

IF ABS(utyrsd#) > .00005# THEN
rlbrw# = rlbrw# * (1 - .35 * utyrsd#); rcapw# = rlbrw# * rratio#
rpopw# = rlbrw# / rlbr#
rlbrs# = rlbrs# + (oldrlbrw# - rlbrw#); rcaps# = rlbrs# * rratio#
rpops# = rlbrs# / rlbr#
END IF

IF ABS(utyrwm#) > .00005# THEN
rlbrw# = rlbrw# * (1 - .35 * utyrwm#); rcapw# = rlbrw# * rratio#
rpopw# = rlbrw# / rlbr#
rlbrw# = rlbrw# + (oldrlbrw# - rlbrw#); rcapw# = rlbrw# * rratio#
rpopw# = rlbrw# / rlbr#
END IF

'printing utilities
PRINT "utyrn#="; utyrn#, "utyrm#="; utyrm#
PRINT "utypn#="; utypn#, "utypm#="; utypm#
PRINT "utyrs#="; utyrs#, "utyrw#="; utyrw#
PRINT "utyps#="; utyps#, "utypw#="; utypw#
PRINT "rpopn#="; rpopn#, "rpopm#="; rpopm#
PRINT "rpops#="; rpops#, "rpoww#="; rpoww#
PRINT "utyrnmdf#="; utyrnmdf#, "utyrnsdf#="; utyrnsdf#
PRINT "utyrnmdf#="; utyrnmdf#, "utyrnsdf#="; utyrnsdf#
PRINT "utyrwmdf#="; utyrwmdf#, "utyrwsdf#="; utyrwmdf#
PRINT "utyrwmdf#="; utyrwmdf#, "utyrwsdf#="; utyrwmdf#
'INPUT f

"!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
LOOP UNTIL ABS(utyrnmdf#) <= .00005# AND ABS(utyrnmdf#) <= .00005# AND
ABS(utyrwm#) <= .00005# AND ABS(utyrwm#) <= .00005# AND ABS(utyrwm#) <= .00005# AND ABS(utyrwm#) <= .00005#
BEEP
OPEN "c:\winword\4251146.doc" FOR OUTPUT AS #1
PRINT #1, "Double NEMW Business Capital Tax Rate(balanced budget)"
PRINT #1, pgn#, pgm#, pgs#, pgw#, pvn#, pvm#, pvs#, pvw#
PRINT #1, prn#, prn#, prs#, prw#, prn#, pfm#, pfn#, pfw#
PRINT #1, "Population of Rich Households in Each Region"
PRINT #1, "Northeast Rich Population", rpopn#
PRINT #1, "Midwest Rich Population", rpopm#
PRINT #1, "South Rich Population", rpopn#
PRINT #1, "West Rich Population", rpopw#
PRINT #1, "Rich Household Utility Levels"
PRINT #1, "Northeast Rich Household", utyrn#
PRINT #1, "Midwest Rich Household", utyrm#
PRINT #1, "South Rich Household", utyrs#
PRINT #1, "West Rich Household", utyrw#
PRINT #1, "Per Capita Consumption of Products"
PRINT #1, "Northeast Residents"
PRINT #1, "Rich"
PRINT #1, "NE Goods", rngs# * 1000000 / rpopn#, "MW Goods", rngm# * 1000000 / rpopn#
PRINT #1, "South Goods", rngs# * 1000000 / rpopn#, "West Goods", rngw# * 1000000 / rpopn#
PRINT #1, "Services", rvn# * 1000000 / rpopn#
PRINT #1, "Regional Govt Goods", rgn# * 1000000 / rpopn#, "Federal Govt Goods",
re# * 1000000 / rpopn#
PRINT #1, "Poor"
PRINT #1, "NE Goods", pngs# * 1000000 / ppopn#, "MW Goods", pngm# * 1000000 / ppopn#
PRINT #1, "South Goods", pngs# * 1000000 / ppopn#, "West Goods", pngw# * 1000000 / ppopn#
PRINT #1, "Services", pdvn# * 1000000 / ppopn#
PRINT #1, "Regional Govt Goods", pdrn# * 1000000 / ppopn#, "Federal Govt Goods",
pdn# * 1000000 / ppopn#
PRINT #1, "Midwest Residents"
PRINT #1, "Rich"
PRINT #1, "NE Goods", rmgns# * 1000000 / rpopm#, "MW Goods", rmgm# * 1000000 / rpopm#
PRINT #1, "South Goods", rmgns# * 1000000 / rpopm#, "West Goods", rmgw# * 1000000 / rpopm#
PRINT #1, "Services", rvm# * 1000000 / rpopm#
PRINT #1, "Regional Govt Goods", rrm# * 1000000 / rpopm#, "Federal Govt Goods",
rfm# * 1000000 / rpopm#
PRINT #1, "Poor"
PRINT #1, "NE Goods", pmgns# * 1000000 / ppopm#, "MW Goods", pmgm# * 1000000 / ppopm#
PRINT #1, "South Goods", pmgns# * 1000000 / ppopm#, "West Goods", pmsgw# * 1000000 / ppopm#
PRINT #1, "Services", pdvm# * 1000000 / ppopm#
PRINT #1, "Regional Govt Goods", pdrm# * 1000000 / ppopm#, "Federal Govt Goods",
pdfm# * 1000000 / ppopm#
PRINT #1, "South Residents"
PRINT #1, "Rich"
PRINT #1, "NE Goods", rsgn# * 1000000 / rpop#, "MW Goods", rsgm# * 1000000 /
 rpop#
PRINT #1, "South Goods", rsgs# * 1000000 / rpop#, "West Goods", rsgw# * 1000000 /
 rpop#
PRINT #1, "Services", rvs# * 1000000 / rpop#
PRINT #1, "Regional Govt Goods", rrs# * 1000000 / rpop#, "Federal Govt Goods", rfs#
 * 1000000 / rpop#
PRINT #1, "Poor"
PRINT #1, "NE Goods", psgn# * 1000000 / ppop#, "MW Goods", psgm# * 1000000 /
 ppop#
PRINT #1, "South Goods", psgs# * 1000000 / ppop#, "West Goods", psgw# * 1000000 /
pop#
PRINT #1, "Services", pds# * 1000000 / ppop#
PRINT #1, "Regional Govt Goods", pdrs# * 1000000 / ppop#, "Federal Govt Goods",
pdfs# * 1000000 / ppop#
PRINT #1, "West Residents"
PRINT #1, "Rich"
PRINT #1, "NE Goods", rwgn# * 1000000 / rpopw#, "MW Goods", rwgm# * 1000000 /
rpopw#
PRINT #1, "South Goods", rwgs# * 1000000 / rpopw#, "West Goods", rwgw# * 1000000 /
rpopw#
PRINT #1, "Services", rww# * 1000000 / rpopw#
PRINT #1, "Regional Govt Goods", rrw# * 1000000 / rpopw#, "Federal Govt Goods",
rfw# * 1000000 / rpopw#
PRINT #1, "Poor"
PRINT #1, "NE Goods", pwgn# * 1000000 / ppopw#, "MW Goods", pwgm# * 1000000 /
popw#
PRINT #1, "South Goods", pwgs# * 1000000 / ppopw#, "West Goods", pwgw# * 1000000 /
popw#
PRINT #1, "Services", pdvw# * 1000000 / ppopw#
PRINT #1, "Regional Govt Goods", pdrw# * 1000000 / ppopw#, "Federal Govt Goods",
pdfw# * 1000000 / ppopw#

PRINT #1, " Poor Household Utility Levels"
PRINT #1, "Northeast Poor Household", utypn#
PRINT #1, "Midwest Poor Household", utypm#
PRINT #1, "South Poor Household", utyps#
PRINT #1, "West Poor Household", utypw#
PRINT #1, " Unit Factor Prices NET of All Taxes"
PRINT #1, "Net Price of Capital", pk#
PRINT #1, "Northeast"
PRINT #1, "Net Price of Skilled Labor", plsnn#
PRINT #1, "Net Price of Unskilled Labor", plumn#
PRINT #1, "Midwest"
PRINT #1, "Net Price of Skilled Labor", plsm#
PRINT #1, "Net Price of Unskilled Labor", plum#
PRINT #1, "South"
PRINT #1, "Net Price of Skilled Labor", plss#
PRINT #1, "Net Price of Unskilled Labor", plus#
PRINT #1, "West"
PRINT #1, "Net Price of Skilled Labor", plsw#
PRINT #1, "Net Price of Unskilled Labor", pluw#
PRINT #1, "Unit Factor Prices GROSS of Taxes on Producers"
PRINT #1, "Northeast"
PRINT #1, "Gross Price of Capital", gsmpkn#
PRINT #1, "Gross Price of Skilled Labor", gsplsmn#
PRINT #1, "Gross Price of Unskilled Labor", gsplumn#
PRINT #1, "Midwest"
PRINT #1, "Gross Price of Capital", gsmpkm#
PRINT #1, "Gross Price of Skilled Labor", gsplsm#
PRINT #1, "Gross Price of Unskilled Labor", gsplumn#
PRINT #1, "South"
PRINT #1, "Gross Price of Capital", gsmpks#
PRINT #1, "Gross Price of Skilled Labor", gsplss#
PRINT #1, "Gross Price of Unskilled Labor", gsplus#
PRINT #1, "West"
PRINT #1, "Gross Price of Capital", gspkw#
PRINT #1, "Gross Price of Skilled Labor", gsplsw#
PRINT #1, "Gross Price of Unskilled Labor", gspluw#
PRINT #1, "EARNED INCOME of Each Household in Each Region"
PRINT #1, "Northeast"
PRINT #1, "Rich Household", (rlbrn# * plsn# + rcapn# * pk#) * 1000000 / rpopn#, "Poor Household", (plbrn# * plun# + pcapn# * pk#) * 1000000 / ppopn#
PRINT #1, "Midwest"
PRINT #1, "Rich Household", (rlbrm# * plsm# + rcapm# * pk#) * 1000000 / rpopm#, "Poor Household", (plbrm# * plum# + pcapm# * pk#) * 1000000 / ppopm#
PRINT #1, "South"
PRINT #1, "Rich Household", (rlbrs# * plss# + rcaps# * pk#) * 1000000 / rposs#, "Poor Household", (plbrs# * plus# + pcaps# * pk#) * 1000000 / pposs#
PRINT #1, "West"
PRINT #1, "Rich Household", (rlbrw# * plsw# + rcapw# * pk#) * 1000000 / rpopw#, "Poor Household", (plbrw# * pluw# + pcapw# * pk#) * 1000000 / ppopw#
PRINT #1, "Northeast Capital Income", rcapn# * pk# + pcapn# * pk#
PRINT #1, "Texas Capital Income", rcapm# * pk# + pcapm# * pk#
PRINT #1, "South Capital Income", rcaps# * pk# + pcaps# * pk#
PRINT #1, "West Capital Income", rcapw# * pk# + pcapw# * pk#
PRINT #1,
PRINT #1, "TRANSFER PAYMENT Per Household"
PRINT #1, " Northeast"
PRINT #1, "Rich Household", (trann# + rtrannf#) * 1000000 / rpopn#, "Poor Household", (ptrann# + ptrannf#) * 1000000 / ppopn#
PRINT #1, " Midwest"
PRINT #1, "Rich Household", (trann# + rtrannf#) * 1000000 / rpopm#, "Poor Household", (ptrann# + ptrannf#) * 1000000 / ppopm#
PRINT #1, " South"
PRINT #1, "Rich Household", (trann# + rtrannf#) * 1000000 / rprops#, "Poor Household", (ptrann# + ptrannf#) * 1000000 / pprops#
PRINT #1, " West"
PRINT #1, "Rich Household", (trannw# + rtrannw#) * 1000000 / rpopw#, "Poor Household", (ptrannw# + ptrannw#) * 1000000 / ppopw#
PRINT #1, "DISPOSABLE INCOME of Each Household in Each Region"
PRINT #1, " Northeast"
PRINT #1, "Rich Household", ryn# * 1000000 / rpopn#, "Poor Household", pyn# * 1000000 / ppopn#
PRINT #1, " Midwest"
PRINT #1, "Rich Household", rym# * 1000000 / rpopm#, "Poor Household", pym# * 1000000 / ppopm#
PRINT #1, " South"
PRINT #1, "Rich Household", rys# * 1000000 / rprops#, "Poor Household", pys# * 1000000 / pprops#
PRINT #1, " West"
PRINT #1, "Rich Household", ryw# * 1000000 / rpopw#, "Poor Household", pyw# * 1000000 / ppopw#
PRINT #1, " CAPITAL ENDOWMENTS of Each Region's Population (millions)"
PRINT #1, "Northeast Capital Endowment", tcapn#
PRINT #1, "Midwest Capital Endowment", tcapm#
PRINT #1, "South Capital Endowment", tcapw#
PRINT #1, "West Capital Endowment", tcapw#
PRINT #1, " Capital Used by Each Region's Producers (millions)"
PRINT #1, "Capital Used in Northeast", dcapn#
PRINT #1, "Capital Used in Midwest", dcapm#
PRINT #1, "Capital Used in South", dcapw#
PRINT #1, "Capital Used in West", dcapw#
PRINT #1, "GROSS REGIONAL PRODUCT ($millions)"
PRINT #1, " Northeast", " Midwest"
PRINT #1, "Goods", demandgn#, " demandgm#
PRINT #1, "Services", demandvn#, " demandvm#
PRINT #1, "Regional Govt", demandr#, , demandr# 
PRINT #1, "Federal Govt", demandf#, , demandf# 
PRINT #1, "South", , "West" 
PRINT #1, "Goods", demandgs#, , demandgw# 
PRINT #1, "Services", demandvs#, , demandvw# 
PRINT #1, "Regional Govt", demands#, , demandw# 
PRINT #1, "Federal Govt", demands#, , demandw# 
PRINT #1, "TAX REVENUE of REGIONAL GOVERNMENTS($millions)"
PRINT #1, "Regional Corporation Income Tax Revenue"
PRINT #1, "Northeast", ncprevest#, "Midwest", mncprevest# 
PRINT #1, "South", scprevest#, "West", wcprevest# 
PRINT #1, "Regional Business Capital Tax Revenue"
PRINT #1, "Northeast", ncaprevest#, "Midwest", mcaprevest# 
PRINT #1, "South", scaprevest#, "West", wcaprevest# 
PRINT #1, "Regional Business Labor Tax Revenue"
PRINT #1, "Northeast", nlbrrevest#, "Midwest", mlbrrevest# 
PRINT #1, "South", slbrrevest#, "West", wlbbrrevest# 
PRINT #1, "Regional Sales Tax Revenue"
PRINT #1, "Northeast", nsstxest#, "Midwest", msstxest# 
PRINT #1, "South", ssstxest#, "West", wsstxest# 
PRINT #1, "Regional Personal Income Tax Revenue"
PRINT #1, "Northeast", npitestate#, "Midwest", mpitestate# 
PRINT #1, "South", spitestate#, "West", wpitestate# 
PRINT #1, "Regional TOTAL Tax Revenue"
PRINT #1, "Northeast", nrevest#, "Midwest", mrevest# 
PRINT #1, "South", srevest#, "West", wrevest# 
PRINT #1, "TAX REVENUE of Federal GOVERNMENTS ($millions)"
PRINT #1, "Federal Corporation Income Tax Revenue"
PRINT #1, "Northeast", nfcaprevest#, "Midwest", mfcaprevest# 
PRINT #1, "South", scaprevest#, "West", wcaprevest# 
PRINT #1, "Federal Business Labor Tax Revenue"
PRINT #1, "Northeast", nlbrrevest#, "Midwest", mlbrrevest# 
PRINT #1, "South", slbrrevest#, "West", wlbbrrevest# 
PRINT #1, "Federal Personal Income Tax Revenue"
PRINT #1, "Northeast", npitestate#, "Midwest", mpitestate# 
PRINT #1, "South", spitestate#, "West", wpitestate# 
PRINT #1, "Federal TOTAL Tax Revenue"
PRINT #1, "Northeast", nfrevest#, "Midwest", mfrevest# 
PRINT #1, "South", sfrevest#, "West", wfrevest#
CLOSE #1
Appendix C: List of Variables
AF  Scale parameter in Federal public goods production
AG  Scale parameter in Goods production
AR  Scale parameter in Region. public goods production
AV  Scale parameter in Services production
bF  Distribution parameter in Federal public goods production
bG  Distribution parameter in Goods production
bR  Distribution parameter in Regional public good production
bV  Distribution parameter in Services production
cF  Skilled/unskilled distribution parameter in Goods prod.
cG  Skill/unskill distrib. parameter in Fed. public goods prod.
cR  Skill/unskill distrib. parameter in Region. public goods prod
cV  Skilled/unskilled distribution parameter in Services prod.
CAP  Capital
CAPFM  Capital in Texas used for Federal public goods production
CAPFM1  Capital per unit in Texas used for Federal public goods
CAPFN  Capital in Nor/Mid used for Federal public goods prod.
CAPFN1  Capital per unit in Nor/Mid used for Federal public goods
CAPFS  Capital in South used for Federal public goods production
CAPFS1  Capital per unit in South used for Federal public goods prod
CAPFW  Capital in West used for Federal public goods production
CAPFW1  Capital per unit in West used for Federal public goods prod
CAPGM  Capital in Texas used for Goods production
CAPGM1  Capital per unit in Texas used for Goods production
CAPGN  Capital in Nor/Mid used for Goods production.
CAPGN1  Capital per unit in Nor/Mid used for Goods production.
CAPGS  Capital in South used for Goods production
CAPGS1  Capital per unit in South used for Goods production
CAPGW  Capital in West used for Goods production
CAPGW1  Capital per unit in West used for Goods production
CAPNAT  National Endowment of Capital
CAPRM  Capital in Texas used for Regional public goods production
CAPRM1  Capital per unit in Texas used for Regional public goods
CAPRN  Capital in Nor/Mid used for Regional public goods prod.
CAPRN1  Capital per unit in Nor/Mid used for Regional public goods
CAPRS  Capital in South used for Regional public goods production
CAPRS1  Capital per unit in South used for Regional public goods
CAPRW  Capital in West used for Regional public goods production
CAPRW1  Capital per unit in West used for Regional public goods
CAPVM  Capital in Texas used for Services production
CAPVM1  Capital per unit in Texas used for Services production
CAPVN  Capital in Nor/Mid used for Services production.
CAPVNI  Capital per unit in Nor/Mid used for Services production.
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<th>Symbol</th>
<th>Description</th>
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<tr>
<td>CAPVS</td>
<td>Capital in South used for Services production</td>
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<td>CAPVS1</td>
<td>Capital per unit in South used for Services production</td>
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<td>CAPVW</td>
<td>Capital in West used for Services production</td>
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<td>CAPVW1</td>
<td>Capital per unit in West used for Services production</td>
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<td>d1</td>
<td>Utility function distribution parameter</td>
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<td>d2</td>
<td>Distribution parameter between Goods bundle, services</td>
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<td>d3</td>
<td>Distribution parameter between Regional &amp; Federal public goods</td>
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<td>Distribution parameter between the 4 region's Goods</td>
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<td>Elasticity of factor substitution in Goods sector</td>
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<tr>
<td>eGL</td>
<td>Elasticity of sub between skilled/unskilled labor, Goods</td>
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<td>Elasticity of factor substitution in Regional public goods</td>
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<td>Elasticity of sub between skilled/unskilled, Regional pub gd</td>
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<td>eV</td>
<td>Elasticity of factor substitution in Services sector</td>
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<td>eVL</td>
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<td>Quantity of Federal public good produced in the Nor/Mid</td>
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<tr>
<td>FS</td>
<td>Quantity of Federal public good produced in the South</td>
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<td>FW</td>
<td>Quantity of Federal public good produced in the West</td>
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<td>G</td>
<td>Goods</td>
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<td>GM</td>
<td>Quantity of Goods produced in Texas</td>
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<td>GMH</td>
<td>Consumption of Texas Goods by a typical household</td>
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<td>GN</td>
<td>Quantity of Goods produced in the Nor/Mid</td>
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<td>GNH</td>
<td>Consumption of Nor/Mid Goods by a typical household</td>
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<td>GS</td>
<td>Quantity of Goods produced in the South</td>
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<td>GSH</td>
<td>Consumption of South Goods by a typical household</td>
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<td>GW</td>
<td>Quantity of Goods produced in the West</td>
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<td>GWH</td>
<td>Consumption of West Goods by a typical household</td>
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<td>GOODH</td>
<td>Bundle of Nor/Mid, Texas, South, and West Goods Consumed</td>
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<td>Elasticity of substitution between Goods bundle &amp; Services</td>
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<td>i3</td>
<td>Elasticity of sub. between Regional &amp; Federal public goods</td>
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<td>i4</td>
<td>Elast. of sub. between Nor/Mid, South, Texas &amp; West Goods</td>
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<tr>
<td>j</td>
<td>Measure of congestion in Regional public good, 0 &lt; j &lt; 1</td>
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<td>Skilled/unskilled labor bundle used in N.E. Fed. Publ. Goods</td>
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<td>LABORFS</td>
<td>Skilled/unskilled labor bundle used in South Fed. Publ. Goods</td>
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<td>LABORFW</td>
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<td>LABORGM</td>
<td>Skilled/unskilled labor bundle used in Texas Goods</td>
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<tr>
<td>LABORGN</td>
<td>Skilled/unskilled labor bundle used in Nor/Mid Goods</td>
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</tbody>
</table>
LABORGs  Skilled/unskilled labor bundle used in South Goods
LABORGW  Skilled/unskilled labor bundle used in West Goods
LABORRM  Skilled/unskilled labor bundle used in N.E. Reg. Publ.Gds
LABORRN  Skilled/unskilled labor bundle used in South Reg. Publ.Goods
LABORRS  Skilled/unskilled labor bundle used in West Reg. Publ.Goods
LABORRW  Skilled/unskilled labor bundle used in Texas Services
LABORVM  Skilled/unskilled labor bundle used in Nor/Mid Services
LABORVS  Skilled/unskilled labor bundle used in South Services
LABORVV  Skilled/unskilled labor bundle used in West Services
M    Texas
N    Nor/Mid
PCAPFN  Gross price of capital to Nor/Mid Fed. Pub. Goods sector
PCAPGM  Gross price of capital to Texas Goods sector
PCAPGN  Gross price of capital to Nor/Mid Goods sector
PCAPGS  Gross price of capital to South Goods sector
PCAPGW  Gross price of capital to West Goods sector
PCAPRM  Gross price of capital to Texas Reg. Pub. Goods sector
PCAPRN  Gross price of capital to Nor/Mid Reg. Pub. Goods sector
PCAPRS  Gross price of capital to South Regional Pub. Goods sector
PCAPRW  Gross price of capital to West Regional Public Goods sector
PCAPVM  Gross price of capital to Texas Services sector
PCAPVN  Gross price of capital to Nor/Mid Services sector
PCAPVS  Gross price of capital to South Services sector
PCAPVV  Gross price of capital to West Services sector
PFM    Avg. cost of producing Federal public good in Texas
PFN    Avg. cost of producing Federal public good in Nor/Mid
PFSS   Avg. cost of producing Federal public good in South
PFWS   Avg. cost of producing Federal public good in West
PGMH   Gross price of Texas Goods to a household
PGNH   Gross price of Nor/Mid Goods to a household
PGOODH Price index of Nor/Mid,South,Texas,West Goods to household
PGSH   Gross price of South Goods to a household
PGWH   Gross price of West Goods to a household
PLABORFM Skilled/unskilled labor price index, Texas Fed. Publ.Gds
PLABORFN Skilled/unskilled labor price index, N.E. Fed. Publ.Goods
PLABORFS Skilled/unskilled labor price index, South Fed. Publ.Goods
PLABORFW Skilled/unskilled labor price index, West Fed. Publ.Goods
PLABORGM Skilled/unskilled labor price index, Texas Goods
PLABORGN Skilled/unskilled labor price index, Nor/Mid Goods
PLABORGS Skilled/unskilled labor price index, South Goods
PLABORGW  Skilled/unskilled labor price index, West Goods
PLABORRM  Skilled/unskilled labor price index, Texas Reg. Publ.Gds
PLABORRN  Skilled/unskilled labor price index, N.E. Reg. Publ.Goods
PLABORRS  Skilled/unskilled labor price index, South Reg. Publ.Goods
PLABORRW  Skilled/unskilled labor price index, West Reg. Publ.Goods
PLABORVM  Skilled/unskilled labor price index, Texas Services
PLABORVN  Skilled/unskilled labor price index, Nor/Mid Services
PLABORVS  Skilled/unskilled labor price index, South Services
PLABORVV  Skilled/unskilled labor price index, West Services
PNETCAPFN  Net price of capital to Nor/Mid Fed. Pub. Goods sector
PNETCAPGM  Net price of capital to Texas Goods sector
PNETCAPGN  Net price of capital to Nor/Mid Goods sector
PNETCAPGS  Net price of capital to South Goods sector
PNETCAPGW  Net price of capital to West Goods sector
PNETCAPRM  Net price of capital to Texas Reg. Pub. Goods sector
PNETCAPRN  Net price of capital to Nor/Mid Reg. Pub. Goods sector
PNETCAPRS  Net price of capital to South Regional Pub. Goods sector
PNETCAPRW  Net price of capital to West Regional Public Goods sector
PNETCAPVM  Net price of capital to Texas Services sector
PNETCAPVN  Net price of capital to Nor/Mid Services sector
PNETCAPVS  Net price of capital to South Services sector
PNETCAPVV  Net price of capital to West Services sector
PNETGM  Price of Texas Goods net of retail sales taxes
PNETGN  Price of Nor/Mid Goods net of retail sales taxes
PNETGS  Price of South Goods net of retail sales taxes
PNETGW  Price of West Goods net of retail sales taxes
PNETSKILM  Net cost to business of skilled labor in Texas
PNETSKILN  Net cost to business of skilled labor in Nor/Mid
PNETSKILS  Net cost to business of skilled labor in South
PNETSKILW  Net cost to business of skilled labor in West
PNETUNSKILM  Net cost to business of unskilled labor in Texas
PNETUNSKILN  Net cost to business of unskilled labor in Nor/Mid
PNETUNSKILS  Net cost to business of unskilled labor in South
PNETUNSKILW  Net cost to business of unskilled labor in West
PNETVM  Price of Texas Services net of retail sales taxes
PNETVN  Price of Nor/Mid Services net of retail sales taxes
PNETVS  Price of South Services net of retail sales taxes
PNETVW  Price of West Services net of retail sales taxes
PPOORCAPM  Poor household's net return on capital in Texas
PPOORCAPN  Poor household's net return on capital in Nor/Mid
PPOORCAPS  Poor household's net return on capital in South
Poor household's net return on capital in West
Unskilled wage net of household taxes in Texas
Unskilled wage net of household taxes in Nor/Mid
Unskilled wage net of household taxes in South
Unskilled wage net of household taxes in West
Rich household's net return on capital in Texas
Rich household's net return on capital in Nor/Mid
Rich household's net return on capital in South
Skilled wage net of household taxes in Texas
Skilled wage net of household taxes in Nor/Mid
Skilled wage net of household taxes in South
Skilled wage net of household taxes in West
Avg. cost of producing Regional public good in Texas
Avg. cost of producing Regional public good in Nor/Mid
Avg. cost of producing Regional public good in South
Avg. cost of producing Regional public good in West
Gross cost of skilled labor in Texas Federal public goods
Gross cost of skilled labor in Nor/Mid Fed. public goods
Gross cost of skilled labor in South Federal public goods
Gross cost of skilled labor in West Federal public goods
Gross cost of skilled labor in Texas Goods
Gross cost of skilled labor in Nor/Mid Goods
Gross cost of skilled labor in South Goods
Gross cost of skilled labor in West Goods
Gross cost of skilled labor in Texas Regional public goods
Gross cost of skilled labor in Nor/Mid Reg. public goods
Gross cost of skilled labor in South Regional public goods
Gross cost of skilled labor in West Regional public goods
Gross cost of skilled labor in Texas Services
Gross cost of skilled labor in Nor/Mid Services
Gross cost of skilled labor in South Services
Gross cost of skilled labor in West Services
Gross cost of unskilled labor in Texas Fed. public goods
Gross cost of unskilled labor in Nor/Mid Fed. public goods
Gross cost unskilled labor in South Federal public goods
Gross cost of unskilled labor in West Federal public goods
Gross cost of unskilled labor in Texas Goods
Gross cost of unskilled labor in Nor/Mid Goods
Gross cost of unskilled labor in South Goods
Gross cost of unskilled labor in West Goods
Gross cost of unskilled labor in Texas Regl. public goods
Gross cost of unskilled labor in Nor/Mid Reg. public goods
Gross cost of unskilled labor in South Regional public goods
Gross cost of unskilled labor in West Regional public goods
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<th>Symbol</th>
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<td>PUNSKILVM</td>
<td>Gross cost of unskilled labor in Texas Services</td>
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<td>PUNSKILVN</td>
<td>Gross cost of unskilled labor in Nor/Mid Services</td>
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<td>PUNSKILVS</td>
<td>Gross cost of unskilled labor in South Services</td>
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<td>PVMH</td>
<td>Gross price of Texas Services to a household</td>
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<td>PVNH</td>
<td>Gross price of Nor/Mid Services to a household</td>
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<td>PVSH</td>
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<td>Gross price of West Services to a household</td>
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<td>POOR</td>
<td>National population of Poor households</td>
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<tr>
<td>POORCAP</td>
<td>Poor household's endowment of capital</td>
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<td>POORFH</td>
<td>Poor household's consumption of Federal public good</td>
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<tr>
<td>POORGMH</td>
<td>Typical Poor demand for Texas Goods (example only)</td>
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<td>POORGMMH</td>
<td>Texas Poor household's consumption of Texas Goods</td>
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<td>Nor/Mid Poor household's consumption of Texas Goods</td>
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<td>South Poor household's consumption of Texas Goods</td>
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<td>POORGMHW</td>
<td>West Poor household's consumption of Texas Goods</td>
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<td>Typical Poor demand for Nor/Mid Goods (example only)</td>
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<td>POORGNHH</td>
<td>Texas Poor household's consumption of Nor/Mid Goods</td>
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<td>Nor/Mid Poor household's consumption of Nor/Mid Goods</td>
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<td>South Poor household's consumption of Nor/Mid Goods</td>
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<td>Poor household demand for N.E.&amp;South&amp;Texas&amp;West Gd bundle</td>
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<td>Typical Poor demand for South Goods (example only)</td>
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<td>Typical Poor demand for West Goods (example only)</td>
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<td>POORGWHM</td>
<td>Nor/Mid Poor household's consumption of West Goods</td>
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<td>Poor population in Nor/Mid</td>
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<td>Poor household's endowment of unskilled labor</td>
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<td>Nor/Mid poor household's consumption of Services</td>
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<td>Poor population in West</td>
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<td>Quantity of Regional public good produced in Texas</td>
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<td>RS</td>
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<td>Typical Rich demand for Texas Goods (example only)</td>
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<td>Typical Rich demand for Nor/Mid Goods (example only)</td>
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Unskilled lbr per unit in West used for Services production

Services

Consumption of Services by a typical household
Quantity of Services produced in Texas
Quantity of Services produced in the Nor/Mid
Quantity of Services produced in the South
Quantity of Services produced in the West

West
References


