INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.
A DYNAMIC GENERAL EQUILIBRIUM ANALYSIS OF STATE TAX INCENTIVES FOR ECONOMIC DEVELOPMENT

Dissertation

Presented in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in the Graduate School of The Ohio State University

by

Chang Kyu Seung

*********

The Ohio State University

1996

Dissertation Committee:

Dr. David Kraybill
Dr. Randall Jackson
Dr. Alan Randall

Approved by:

David Kraybill
Advisor
Department of Agricultural Economics
DEDICATION

To My Mother
ACKNOWLEDGEMENTS

First of all, I would like to thank my advisor, David Kraybill, for his advice on academic and personal matters and for his financial support. Discussions with him on diverse subjects in computable general equilibrium models and regional economics helped me a lot in writing this dissertation. Many thanks are due to the other committee members, Randall Jackson and Alan Randall. I thank Randall Jackson for his course in input-output analysis and helpful comments on my dissertation. Special thanks are extended to Alan Randall for his comments on my dissertation and invaluable courses in resource economics and welfare economics. In his course in welfare economics, I acquired a solid theoretical foundation that proved valuable in the policy analysis section of my dissertation. I also thank Wen Chern for his advice on elements of consumer theory used in this study. His comments were very precise and helpful.

I am grateful to Lynn Forster for his guidance as the Graduate Chair and for helping me out when I was in financial trouble. Thanks also go to Judy Petticord for her guidance in administrative matters.

I benefited much from discussions with Sam-Ryang Kim, who clarified some important macroeconomic issues in my
dissertation. Depth and breadth of his knowledge on macroeconomics was invaluable. I would also like to express my thanks to Neal Blue for helping me edit and proofread my dissertation. Thanks also go to Eun-jik Ro, who assisted me in various ways in completing my dissertation.

I cannot forget the encouragement, prayer, and love of my late mother for me whenever I was in difficulty. I would also like to express my wholehearted gratitude to my brothers, Kyung-Hwan and Charles, and my sister-in-law, Heather, for their encouragement and support.

My ultimate thanks should be given to the Lord for keeping and leading me and for delivering me in difficult times.
VITA

April 6, 1960
Born - Kyungbuk, Korea

February 1984
B.A. in Economics, Hankuk
University of Foreign Studies,
Seoul, Korea

December 1986
M.A. in Economics, Youngstown State
University, Youngstown, Ohio

1985-1986
Teaching Assistant, Department of
Economics, Youngstown State
University, Youngstown, Ohio

1989-1991
Teaching Assistant, Department of
Economics, The Ohio State
University, Columbus, Ohio

1992-1995
Research Associate, Department of
Agricultural Economics, The Ohio
State University, Columbus, Ohio
FIELDS OF STUDY

Major Field: Agricultural Economics


Professors: Gene Mumy, Paul Evans, Donald Haurin, Cameron Thraen, Mario Miranda, Wen Chern, Gary Schnitkey, Alan Randall, Randall Jackson, and David Kraybill

Specialization in Regional Economics, Public Finance, and Taxation

Professors: David Kraybill, Randall Jackson, and Alan Randall
# TABLE OF CONTENTS

DEDICTION ........................................... ii  
ACKNOWLEDGEMENTS ................................. iii  
VITA .................................................. v  
LIST OF TABLES ....................................... x  
LIST OF FIGURES ..................................... xi

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>A. Trends in State Economic Development Policy</td>
<td>1</td>
</tr>
<tr>
<td>B. An Economic Perspective on Current State Economic Development Policy</td>
<td>2</td>
</tr>
<tr>
<td>1. Market Intervention</td>
<td>2</td>
</tr>
<tr>
<td>(a) Market Distortions</td>
<td>2</td>
</tr>
<tr>
<td>(b) Rationale for Government Intervention</td>
<td>4</td>
</tr>
<tr>
<td>(c) Dynamics of Economic Growth</td>
<td>4</td>
</tr>
<tr>
<td>2. Welfare Evaluation</td>
<td>5</td>
</tr>
<tr>
<td>(a) National vs. Regional</td>
<td>5</td>
</tr>
<tr>
<td>(b) Benefit-cost Analysis with Unemployment</td>
<td>6</td>
</tr>
<tr>
<td>C. Empirical Evidence of Effectiveness of Economic Development Policy</td>
<td>8</td>
</tr>
<tr>
<td>D. Problem Definition</td>
<td>8</td>
</tr>
<tr>
<td>E. Objectives</td>
<td>9</td>
</tr>
<tr>
<td>F. Organization of the Study</td>
<td>10</td>
</tr>
<tr>
<td>II. THEORETICAL FRAMEWORK</td>
<td>11</td>
</tr>
<tr>
<td>A. Computable General Equilibrium (CGE) Models</td>
<td>11</td>
</tr>
<tr>
<td>1. Comparison of Regional Economic</td>
<td></td>
</tr>
</tbody>
</table>
Models ........................................ 11
2. A Brief Overview of a Generic CGE Model Structure .................................. 12
3. CGE Models .................................... 15
   (a) Country and Multi-country Models ............................................. 15
   (b) Regional Models ......................................................... 16
B. Capital Taxation Theory and Cost of Capital ....................................... 17
   1. Capital Taxation Theory .................................................. 17
   2. Cost of Capital .......................................................... 19
C. Measurement of Welfare Change .................................................. 21
   1. Benefit-cost Analysis .................................................... 21
   2. Measurement of Welfare Change in the Present Study .................. 23

III. MODEL EQUATIONS AND ASSUMPTIONS ......................................... 28
A. Import Demand .................................................. 28
B. Production ...................................................... 29
C. Export Supply ..................................................... 31
D. Consumption ....................................................... 32
E. Public Good ......................................................... 33
   1. A Brief Overview ......................................................... 33
   2. Public Good in Production .............................................. 35
   3. Public Good in Household Consumption .................................. 38
F. Budget of Households .................................................. 40
G. Budgets of State and Local Governments .................................... 42
H. Federal Government ...................................................... 44
I. Labor Market and Labor Mobility ........................................... 45
J. Capital Income and Capital Mobility ........................................ 48
K. Investment ......................................................... 50
   1. Total Savings as a Residual .............................................. 50
   2. Determination of Investment .......................................... 51
   3. Financing Investment ................................................ 54
   4. Investment as a Component of Final Demand ......................... 55
L. Savings ...................................................... 57
M. Market Equilibrium Conditions ........................................... 58
   1. Commodity Market ...................................................... 58
   2. Factor Markets ........................................................ 58
   3. Savings and Investment ................................................ 59
N. Dynamics .................................................. 59
   1. Dynamic CGE Models ................................................... 59
   2. Dynamics in the Model for the Present Study ....................... 60

IV. DATA AND PARAMETERS ................................................... 64
A. Data .................................................. 64
1. Social Accounting Matrix (SAM) .......... 64
2. Data Sources ............................. 65
   (a) IMPLAN ................................ 65
   (b) Sectoral Aggregation and Adjustment of
       Accounts .............................. 66
3. Other Data Sources ....................... 66
B. Parameter Calibration .................... 67
   1. Tax Rates ............................. 67
   2. Capital and Investment ............... 68
   3. Public Capital ....................... 71
   4. Consumer Demand Function .......... 72
   5. Other Parameters .................... 73
V. EXPERIMENTS AND ANALYSIS OF RESULTS .... 74
   A. Equal Yield ............................ 74
   B. Experiments ............................ 75
      1. Derivation of a Balanced Growth Path for
         the Continuous Benchmark .......... 76
      2. Experiment 1 .......................... 77
      3. Experiment 2 .......................... 83
      4. Experiment 3 .......................... 91
   C. Sensitivity Analysis ................... 98
VI. CONCLUSION .............................. 101
   A. Summary and Conclusions ............... 101
   B. Future Research Initiatives .......... 103
REFERENCES ................................... 105
APPENDICES ................................... 113
   A. SOCIAL ACCOUNTING MATRIX AND SECTORAL
      AGGREGATION ................................ 113
   B. PARAMETER VALUES ...................... 116
   C. LIST OF VARIABLES ..................... 120
   D. LIST OF EQUATIONS ..................... 125
   E. GAMS CODE FOR THE DYNAMIC OHIO CGE MODEL.. 135
<table>
<thead>
<tr>
<th>TABLE</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Structure of the Ohio CGE Model</td>
</tr>
<tr>
<td>5.1</td>
<td>Effects of Corporate Tax Cut</td>
</tr>
<tr>
<td>5.2</td>
<td>Effects of Corporate Tax Cut with Public Capital in Production in Private Sectors</td>
</tr>
<tr>
<td>5.3</td>
<td>Effects of Corporate Tax Cut with Public Good in Household Consumption</td>
</tr>
<tr>
<td>5.4</td>
<td>Present Value of Welfare Gain</td>
</tr>
<tr>
<td>A.1</td>
<td>Social Accounting Matrix for Ohio CGE</td>
</tr>
<tr>
<td>A.2</td>
<td>Social Accounting Matrix for Ohio, 1990</td>
</tr>
<tr>
<td>A.3</td>
<td>Mapping of IMPLAN 528 Sectors into 2 Sectors</td>
</tr>
<tr>
<td>B.1</td>
<td>Parameter Values</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Transition Path and Welfare Approximation</td>
<td>27</td>
</tr>
<tr>
<td>3.1</td>
<td>The Relationship among Tax Policy, Public Expenditure, and Factor Supplies</td>
<td>36</td>
</tr>
<tr>
<td>3.2</td>
<td>Financing of Total Investment</td>
<td>56</td>
</tr>
<tr>
<td>5.1</td>
<td>Net Investment in Sector 1 (Experiment 1)</td>
<td>79</td>
</tr>
<tr>
<td>5.2</td>
<td>Real Gross Regional Product (Experiment 1)</td>
<td>80</td>
</tr>
<tr>
<td>5.3</td>
<td>Change in Real Gross Regional Product (Experiment 1)</td>
<td>81</td>
</tr>
<tr>
<td>5.4</td>
<td>Net Investment in Sector 1 (Experiment 2)</td>
<td>85</td>
</tr>
<tr>
<td>5.5</td>
<td>Real Gross Regional Product (Experiment 2)</td>
<td>86</td>
</tr>
<tr>
<td>5.6</td>
<td>Change in Real Gross Regional Product (Experiment 2)</td>
<td>87</td>
</tr>
<tr>
<td>5.7</td>
<td>Change in Public Capital Stock (Experiment 2)</td>
<td>88</td>
</tr>
<tr>
<td>5.8</td>
<td>Net Investment in Sector 1 (Experiment 3)</td>
<td>93</td>
</tr>
<tr>
<td>5.9</td>
<td>Real Gross Regional Product (Experiment 3)</td>
<td>94</td>
</tr>
<tr>
<td>5.10</td>
<td>Change in Real Gross Regional Product (Experiment 3)</td>
<td>95</td>
</tr>
<tr>
<td>5.11</td>
<td>Labor Migration (Experiment 3)</td>
<td>96</td>
</tr>
<tr>
<td>5.12</td>
<td>Change in Public Good Flow (Experiment 3)</td>
<td>97</td>
</tr>
</tbody>
</table>
A. Trends in State Economic Development Policy

Regional policy makers are interested in designing policies that induce economic growth when their regions are economically stagnant and depressed. Successful economic development policy means political rewards to regional politicians and increased welfare to voters. One of the goals of those economic policies is job creation. Economic policies are likely to face political difficulties if they fail to increase job growth (Vaughan, Pollard, and Dyer, 1985). The opinion of many state and local politicians and voters was expressed by Mario Cuomo, the former governor of New York who said that "while there are no panaceas, nothing comes closer than one simple word: jobs" (Eisinger, 1988).

Over the past 30 years, states in the U.S. have adopted various kinds of economic development programs (Industrial Development and Manufactures Record 135, 1966; Eisinger, 1988; The Council of State Governments, 1989). Many state and local governments now employ tax incentives to attract firms into their regions. According to a report of The Council of State Governments, the number of states in
the U.S. adopting tax incentives for creation of jobs increased from twenty-seven in 1984 to thirty-five in 1988 (The Council of State Governments, 1989).

B. An Economic Perspective on Current State Economic Development Policy

1. Market Intervention
   (a) Market Distortions

   Regional economic development policy often takes the form of market intervention. The behavior of a free market economy is a reference point from which government intervention may be justified. The basic theorems of welfare economics state that under perfect competition and with a full set of markets, the economy is Pareto-efficient assuming that an equilibrium exists; i.e., no one can be made better off without someone else being made worse off (Atkinson and Stiglitz, 1980).

   However, modern economic analysis shows that the necessary conditions for Pareto-efficiency are violated if the economy is not perfectly competitive. The conditions of perfect competition cannot be satisfied if the economy is characterized by public goods, monopoly, failure to attain full equilibria in some markets, and government actions that distort incentives, including tariffs, subsidies, and many kinds of taxes. In principle, efficiency could be improved
by removing the sources of distortion or by implementing some corrective policy (Randall, 1987).

However, economists are faced with a problem when they seek efficiency-improving measures. The theory of the second best (Lipsey and Lancaster, 1956-1957) implies that the necessary conditions of Pareto-efficiency cannot be used as a frame of reference for "piecemeal" policy when the real world is abundant with inefficiencies and simultaneous removal of those inefficiencies is impossible (Randall, 1987).

The theory of the second best does not imply that the optimal conditions do not exist or cannot be found, but that the optimal conditions are different from the standard conditions for Pareto-efficiency (Randall, 1987). Economic theory does not provide a simple answer to whether a government policy designed to attain those optimal conditions will improve efficiency. Rather the approach taken in this dissertation is one advocated by Varian (1989) who argues for the explicit specification of a general equilibrium model for conducting cost-benefit analysis when rent-seeking activities and other distortions exist. Varian suggests the following approach: "there is only one correct way to do cost-benefit analysis. First, formulate an economic model that determines the entire list of prices and incomes in an economy. Next, forecast the impact of some proposed change on this list of prices and incomes."
Finally, use the utility functions of the individual agents to value the pre- and post-change equilibria. The resulting list of utility changes can then be summarized in various ways and presented to decision makers" (Varian, 1989, p. 84). A computable general equilibrium (CGE) model is a means of implementing Varian's suggestion. Such a model quantifies the effects of policy change and can be used to evaluate welfare effects in a "second-best" economy.

(b) Rationale for Government Intervention

According to Hewings (1977), some of the conditions that justify government interventions are (i) distributional problems, (ii) failure of the government to achieve or sustain a high level of output and employment level, (iii) shortages or surpluses observed in some markets, and (iv) the existence of social costs associated with migration of factors of production that are not reflected in market prices.

(c) Dynamics of Economic Growth

The issues of market distortions and government intervention are typically formulated from a static perspective. This static perspective ignores the possibility that economic policy may have a permanent growth effect. Fundamental to any regional dynamic economic
process is the treatment of capital accumulation and interregional movement of labor.

This dissertation adopts a dynamic perspective, in which the time path of growth induced by tax incentives is examined. The CGE model developed below incorporates behavioral micro-theoretic principles (expressed as equations) that determine the rate of capital accumulation and interregional movement of labor. The process of capital accumulation is based on Jorgenson's "cost of capital" concept. The process of interregional labor mobility is based on regional economic theories that focus on real wage differentials among regions.

2. Welfare Evaluation
   (a) National vs. Regional

   It is often argued that regional policies produce at best a zero-sum result for the nation as a whole (Bailey, 1986). The argument is that the growth in one area caused by economic development programs comes at the cost of economic activity in some other area, thus overall national growth or welfare is unaffected.

   However, Bartik (1991) argued that since the social benefits of hiring unemployed persons are higher in high-unemployment areas than low-unemployment areas, reshuffling jobs among geographic areas through regional economic development policy may benefit the nation as a whole. He
also argued that state and local competition for jobs may increase national growth (welfare). It is implied in Myrdal (1957) that a growing region can serve as a market for the products of adjacent lagging regions and the diffusion of innovation is possible, thus inducing economic growth of the adjacent lagging regions ("spread effect"). Myrdal also suggested that growth in one region may produce "backwash effects" in lagging regions if mobile resources, such as labor, move to the growing region.

Interregional spillovers of the effects of economic development policy can be significant depending upon the degree of interregional economic linkage, including backward and forward linkages (Hamilton et al., 1991). According to Miller and Blair (1985), spillovers can induce interregional feedback so that economic development in one region spills over, inducing economic growth in the regions that have economic linkages with the region that initially implements the economic development program. The induced development outside the "target" region in turn spills back to further stimulate economic activity.

(b) Benefit-cost Analysis with Unemployment

The usual assumption in benefit-cost analysis is that resources are fully-employed and the economy is perfectly competitive so that market costs of any factor of production in a project evaluation are equal to their opportunity costs.
(real social costs). However, when unemployment exists, market prices exceed opportunity costs and should be adjusted accordingly in project analysis (Haveman and Krutilla, 1968; Stabler et al., 1988; Hamilton et al., 1991). The measurement of the spillover effects using benefit-cost analysis also depends on the assumptions made about employment and mobility of factors of production (Haveman and Krutilla, 1968). The weakness of the Haveman and Krutilla (1968) analysis is that it is ad hoc—in other words, even if it presents a strong theoretical framework for explaining the existence of unemployment, it does not present a theoretical basis for estimating changes in investment or changes in population. If we assume full employment of most primary factors of production, perfect mobility of resources, and absence of scale economies as in Howe and Easter (1971) or Margolis (1957), then there can be no spillover effects (i.e., secondary effects) since the assumptions imply equality across sectors and regions of opportunity costs and market costs of relevant factors of production. However, if factor unemployment or immobility is assumed, then spillovers are a possibility (Hamilton et al., 1991).
C. Empirical Evidence of Effectiveness of Economic Development Policy

Although there has been much debate surrounding the effectiveness of economic development policies, recent studies show that some state and local tax abatement programs may be more effective than was previously thought to be the case. Earlier studies (before 1980, both econometric and case studies) reported little or no effects. However, 67 percent of 69 econometric studies conducted after 1980 and summarized by Bartik (1991) show that tax variables have at least some effects. In a study by Walker and Greenstreet (1989) in which a wide variety of incentives, including site-specific infrastructure, tax breaks, and job training are provided to firms, it was found that 37 percent of plants that were offered incentives claimed the policies (incentives) were decisive in final location choice of firms. Many other researchers also report significant effects of state and local business taxes on business activity.

D. Problem Definition

One of the most frequently implemented policies for state economic development is provision of tax incentives to attract firms. Economists often rely on such concepts as market failure, market distortion, and government intervention. Those concepts are appropriate for explaining
issues of economic growth from a static perspective. However, evaluations of economic policies based on single period, static equilibria can be misleading (Ballard et al., 1985). Welfare calculations based on static equilibria cannot be used as meaningful measures of welfare change in the real world where dynamic elements abound. This is because economic policies such as corporate income tax abatement may have permanent effects on the time horizon, and therefore, the time path of the effects is a more appropriate object of analysis than the (comparative) static results of the policy effects. For situations where the dynamics of capital accumulation and interregional population movements are involved, a growth perspective is needed. This study takes such a perspective to analyze the effects of corporate income tax abatements.

E. Objectives

This dissertation has the following objectives:

(i) to create a multi-period, multisectoral model that accounts for scarce resources in project analysis;

(ii) to use this model to assist state policy-makers in understanding how tax reduction influences major economic variables that affect welfare of residents of Ohio;

(iii) to use this model to examine the effect of a tax cut
when public goods affect the productivity of capital in private industries and when public goods affect household utility.

I transform a static single region model of Ohio by Kraybill and Pai (1995) into a dynamic framework. The contributions of this study are the transformation to dynamics and reprogramming of the model. This dissertation uses the concepts of "cost of capital" (Hall and Jorgenson, 1967), the desired level of capital, and a partial adjustment process for updating factor stocks (labor and capital).

F. Organization of the Study

The present study uses a single-region CGE model to identify the effect of corporate tax abatement on the economy of Ohio. A benchmark sequence of equilibria is compared with a counterfactual sequence of equilibria to measure the effect of policy changes. Chapter II provides a theoretical explanation of a generic CGE model, capital taxation, and the cost of capital. In Chapter III, model specifications are given. In Chapter IV, data and calibration procedures are presented. Chapter V explains the simulation methods and presents results. Sensitivity analyses are also given in Chapter V. A conclusion is presented in Chapter VI.
A. Computable General Equilibrium (CGE) Models

1. Comparison of Regional Economic Models

There have been several types of regional economic models used to analyze economic impacts. The export base (EB) and input-output (IO) models are major tools that regional economists have employed for regional analysis. Though these models remain useful for the analysis of some issues, they are inappropriate for the study of economies facing factor constraints or shifts in relative prices. The regional input-output model tends to overestimate the effects of policies on economic growth because of constant multipliers and unlimited supplies of inputs implied by the model (Hunter, 1989; Miller and Blair, 1985). Output is driven entirely by demand. In addition, the behaviors of firms and households are not derived from constrained optimization. Instead, the IO model assumes fixed factor ratios in production and fixed expenditure ratios in consumption.

In contrast, CGE models are based on the Walrasian general equilibrium structure, which was formalized in the
1950s by Kenneth Arrow, Gerard Debreu, and others. The models explicitly incorporate supply constraint, identify prices and quantities separately, and have smooth, twice differentiable production and preference surfaces. Thus, substitution effects in production and in consumption are allowed in CGE models. Factor and commodity markets attain their equilibrium through the adjustment of prices.

2. A Brief Overview of a Generic CGE Model Structure

This section borrows from Kraybill and Lugani (1992). CGE models are based on the assumption that the economy under consideration is initially in equilibrium; this equilibrium is called the "benchmark equilibrium". The equilibrium values of the model variables are likely to change with the introduction of exogenous policy changes. The newly obtained equilibrium is called the "counterfactual equilibrium". The effect of the policy changes is measured as the counterfactual values of the model variables minus benchmark values of those variables.

Production

In CGE models, the firm’s profit maximization yields factor demand functions. The factor demands are functions of relative prices of factors of production and the prices of commodities. The factor proportions are determined by the relative prices of the factor inputs. For determining
the level of intermediate input usage, many CGE models follow the IO assumption that the levels of intermediate input usage are proportional to the level of output. The value added function is given by

\[ V_i = V_i(L_i, K_i; \Omega_i) \]

where \( V_i \) denotes a quasi-concave value-added function, \( L_i \) and \( K_i \) are labor and capital employed in sector \( i \), and \( \Omega_i \) is a vector of parameters. In most CGE models, Cobb-Douglas (CD) or Constant Elasticity of Substitution (CES) value-added functions are used because those functions are convenient forms in terms of (i) consistency with the theoretical restrictions and (ii) analytical tractability (Shoven and Whalley, 1992).

**Factor Demand**

Factor demands are derived from the firm’s profit-maximization problem. Those demand functions are given by

\[ L_i = L_i(X_i, w_i, r_i, I_i) \]

\[ K_i = K_i(X_i, w_i, r_i, I_i) \]

where \( X_i \) is level of production in sector \( i \) and \( w_i \) and \( r_i \) are the wage rate and the return to capital in sector \( i \), respectively. Since it is generally assumed in CGE models that the quantities of factors have their limits,
substitution effects arise if the relative prices of factors change.

Consumption

Consumption demand is derived from utility maximization subject to a budget constraint. The Linear Expenditure System (LES) is one of the most often used demand systems because of its desirable properties of adding-up, homogeneity, symmetry, and negativity, although substitution effects are ignored in the system (Deaton and Muellbauer, 1980). The LES demand function is based upon a Stone-Geary utility function (Stone, 1954). Some CGE modelers use the Constant Elasticity of Substitution (CES) demand functions or other more flexible demand functions which allow for substitution effects.

Imports

In most CGE models, imports are determined by an import demand function, which is derived from cost-minimization by economic agents subject to a trade aggregation function which indicates preferences for domestic goods versus imported goods. The difference between the prices of the domestic version and the imported version of each good determines imports. CGE models frequently employ the "Armington assumption" that products produced in different regions are different from each other
in quality (Armington, 1969). Thus, demand has two stages. In the first stage, utility-maximization subject to a budget constraint yields demand by commodity type. In the second stage, quantities of the import version and the domestic version of a commodity are determined by cost-minimization subject to the level of the commodity given by stage one.

**Budget Constraints**

By definition, commodity markets clear in equilibrium. In CGE models, market equilibrium conditions are expressed with explicit prices and quantities. Household budget constraints, budget constraints of various levels of governments, and the balance of payments must be satisfied in equilibrium. Also, Walras' law implies that the sum of savings from all sources must be equal to gross private investment. CGE models are calibrated so that all these conditions are met in the benchmark equilibrium.

3. CGE Models

(a) Country and Multi-country Models

This section borrows from Shoven and Whalley (1984). CGE models have been used for dealing with the issues of efficiency, distortionary, and distributional effects of tax and trade policies. Many CGE tax models are based on Harberger's (1959, 1962, 1966) analysis on corporate and capital income taxes in the United States. Models dealing
with the impacts of change in trade policies have as their theoretical background pure trade theory formulated by Heckscher and Ohlin. A survey of CGE models of tax and trade policies is available in Shoven and Whalley (1984).

(b) Regional Models

An increasing number of regional economists use CGE models because of their theoretical strengths. Harrigan and McGregor (1988) used a two-region model of Malaysia to analyze the effects of change in world demand for commodities produced in Malaysia. The authors simulated the effects (i) under a neoclassical closure, in which labor markets clear continuously, and (ii) under a Keynesian closure which assumes rigid nominal wages.

Despotakis (1988) developed a CGE model to determine the effects of change in the price of oil on the California economy. An innovative feature of this model is that the model uses a generalized Leontief cost function, which enables the author to explain the factor substitution effect induced by changes in input prices. Morgan, Mutti, and Partridge (1989) used a six-region model of the U.S. to study the impacts of unilateral and multilateral removal of regional (state and local) and federal taxes.

Jones and Whalley (1989) developed a six-region Canadian CGE model to estimate how federal and local fiscal policies influence regional economies. A creative feature
of the model is that each region has a distribution of individuals, each of whom has a different locational preference. Using a two-region model of the U.S., Kraybill, Johnson, and Orden (1992) examined regional impacts of the federal budget deficit and international trade imbalances. The results of their analysis show that federal fiscal policies have important implications for the pattern of income distribution across regions.

For analyzing the effects of eliminating corporate income taxes, Rickman (1992) developed a two-region model of the U.S. The effects were studied under alternative Keynesian and neoclassical closures. A detailed survey of regional CGE models is found in Kraybill and Lugani (1992).

B. Capital Taxation Theory and the Cost of Capital
1. Capital Taxation Theory

The analysis in this section follows that of Harberger (1962) and Mieszkowski (1967). In the short run, from a general equilibrium perspective, as the capital tax is reduced in a region, firms will continue production on the same scale. This increases the net return to the previously invested capital by the amount of the tax reduction since the supply of capital to firms is fixed in the short run.

In the long run, the capital invested in the firms will increase because of the inflow of capital from outside
the region until the net rate of return to capital is equalized over all regions under the assumption of perfect capital mobility. The increased stock of capital will lower per-unit production costs, leading to an increase in output in each industry in the region. Also new firms might be created. The increased output of some products will lower the prices of these products within the region, and lead to an increase in the export of products from the region.

In factor markets, there are two effects (Mieszkowski, 1967). The first is an increase in the stock of capital, which leads to an increase in the capital-labor ratio (the substitution effect). The second is an increase in demand for capital and labor resulting from the increase of output in the region (the output effect). Therefore, the resulting changes in factor markets and employment of factors in each industry depend on (i) the relative strengths of the substitution and output effects, (ii) factor intensities of the firms in the economy, and (iii) elasticities of substitution in factor use in the firms. Thus, the factor markets will be equilibrated by variations in factor prices, and net returns to capital will be equalized intersectorally and interregionally. Following a capital tax reduction, the net change in employment of labor in the industries will depend on (i) the change in employment resulting from the increase in production, (ii) the in (or out)-migration of labor from (to) the rest of
U.S., and (iii) the decrease in use of labor by factor substitution.

2. Cost of Capital

The present study uses a "cost of capital" framework (Hall and Jorgenson, 1967; Jorgenson and Yun, 1991). The cost of capital is an annualization factor that transforms the acquisition price (per unit) of investment goods into the price (per unit) of capital inputs (i.e., the rental price of capital). This concept makes it possible to represent the economically relevant features of highly complex tax structures in a succinct form. Also, the cost of capital concept summarizes information about the future consequences of investment decisions required for current decisions about capital allocation (Jorgenson and Yun, 1991).

Following Hall and Jorgenson (1967), determination of the optimal level of investment for a firm can be explained in two different-but-equivalent ways. First, the problem the firm faces is maximization of its present value given its technology. In this case, the firm accumulates capital for providing capital services to itself. Second, the firm faces the problem of maximizing its profit in the current period subject to its technology. The capital services are provided by renting capital from itself or from another firm.
In a simple case where there is no tax but capital depreciates every period at a rate of $q$, the price ($PK_t$) of a new unit of the capital good is calculated as the sum of discounted values of future rental prices ($rpc$):

$$PK_t = \int_t^\infty e^{-r(s-t)} rpc_s e^{-\nu(s-t)} ds$$

Here, the rental price of capital ($rpc$) is defined as the amount that a firm pays for use of one unit of capital, $r$ is the discount rate (rate of return on capital), $s$ denotes the period in which the capital services are supplied, and $t$ denotes the period in which the capital goods are purchased. Differentiation of this equation with respect to time ($t$) gives the following equation for the rental price of capital:

$$rpc_t = PK_t(r_t + q)$$

The rental price of capital ($rpc$) is defined on a per-unit basis, and $(r_t + q)$ is the cost of capital, which is defined for a dollar's worth of capital. In the simplest case where there is no tax, inflation, or depreciation, the cost of capital is equal to the rate of return.

To capture changes in the nominal price of the capital good, the inflation rate ($\pi_t$) is incorporated in the equation for the rental price of capital:
Finally, if tax variables are incorporated, then the rental price of capital is:

\[ r_{pc_t} = PK_t[r_t^{-\pi_t}+(1+\pi_t)\theta] \]

Here, \( k_q \) is the rate of investment tax credit on corporate assets, \( t_q \) is the corporate income tax rates, \( z_q \) is the present value of capital consumption allowances on new assets, and \( t_p^q \) is the property tax rate on corporate assets.

C. Measurement of Welfare Change

1. Benefit-cost Analysis

Benefit-cost analysis is a widely-used method for evaluating projects and policies. An important concept in benefit-cost analysis is potential Pareto improvement (PPI). A potential Pareto improvement can be defined to be a change that could make at least one person better off without making any person worse off, assuming that compensation is given to losers. In other words, a change is a PPI if aggregate gains from a project are greater than aggregate losses (Randall, 1987). This benefit-cost criterion is basically the same concept as the maximum value of social product (MVSP) criterion in which losses are allowed as long as the sum of gains exceeds the sum of losses, and gains and
losses are measured as compensating variation (Randall, 1987).

In a partial equilibrium framework, all inputs employed in a marginal project are treated as coming from unemployed resources. However, to capture the welfare effects of a project in markets which are interlinked with each other so that all the prices and quantities of outputs and factors are allowed to vary, a general equilibrium framework is needed in evaluating the benefits and costs of the project.

Benefit-cost analysis commonly assumes full employment of most primary factors of production, perfect resource mobility, and absence of scale economies (Howe and Easter, 1971; Margolis, 1957). It is recommended by the Treasury Board of Canada that "as a general practice, the project analyst should adopt the assumption that resources are fully employed in evaluating the allocative effects of public projects" (Treasury Board, 1976). With these assumptions, the net benefits (impacts minus opportunity costs) will be zero since the increase in value added from the implementation of a project will be exactly offset by the opportunity cost of the inputs.

However, the reality is that there is a certain level of unemployment or underemployment of some resources that persist in many regions because of barriers to resource mobility. In this case, the net benefits will be higher
than under the full-employment assumption since the otherwise unemployed inputs will have lower opportunity costs. Haveman and Krutilla (1968) argued that where there is unemployment, underemployment, or idle capacity, the opportunity cost of a project should be subtracted from the value added generated by the project. They also suggested that the money costs of project construction be adjusted so as to more accurately reflect the foregone economic opportunities.

To overcome the difficulty in dealing with Keynesian macroeconomic issues that arose because of the lack of a satisfactory link between microeconomics and macroeconomics, Johansson (1982) used a general disequilibrium model to generate project evaluation rules to be used in the case where markets do not clear through price adjustments. For example, in one section of his paper, he presented the case of fixed wage rates that result in effective excess supply of labor (unemployment) while all the other markets clear through price adjustments. He used this model to derive a monetary measure of welfare change following the implementation of a project.

2. Measurement of Welfare Change in the Present Study

In calculating welfare changes from an economic policy or project, there arises the issue of whose welfare should be included when labor is assumed to be mobile across
regions. There are two extreme positions--to include all or to include none of the incomes of in-migrants (Hamilton et al., 1991). The first position is appropriate if policy-makers wish to maximize per capita income of all residents including original residents who remain in the region and in-migrants. On the other hand, the second position is appropriate if policy-makers wish to maximize the per-capita income of the existing population. This study takes the first position. The first position accords closely with the apparent goal of many regional policymakers of maximizing the value of land in their jurisdictions. Thus, welfare change will be measured as the change in per capita real expenditure of Ohio residents, the number of which is updated in each period.

The following describes the method of measuring welfare change in the present model. The aggregate representative consumer is assumed to have a constant elasticity of substitution (CES) utility function. I use equivalent variation for measuring welfare change in this dissertation. This measure of welfare change is easy to calculate since, in the continuous benchmark, prices remain constant in the model. Using the CES utility function, equivalent variation (EV) is calculated for the consumer in each period:
(8) \[ EV_t = e_{t,t}(p^0,U_1) - e_{0,t}(p^0,U^0) \]

where \( e(p,U) \) is the expenditure function, \( p \) is a price vector, \( U \) is utility, \( t \) denotes time, and 0 and 1 denote benchmark equilibrium and counterfactual equilibrium. Per capita expenditure in the \( t \)th period is given by

(9) \[ PCEX_t = \frac{e_t(p^0,U^z)}{POP_t/POPB} \]

where \( POP_t \) and \( POPB \) are population in the \( t \)th period and in the base year, respectively, and \( z \) is either 0 (benchmark) or 1 (counterfactual). Using the welfare measurement adopted by Ballard et al. (1985), I calculate the present value of the per capita expenditure using the formula

(10) \[ PVEX = \sum_t \frac{PCEX_t}{(1+d)^t} \]

where \( d \) is the discount rate. If it is assumed that the economy is close to the new steady-state growth path of the economy at time \( T \) (the terminal period), the present value of the welfare change from a policy is approximated by

(11) \[ PVWG = PVEX^1 - PVEX^0 \]

\[ + \frac{PCEX_T^1}{d(1+d)^T} - \frac{PCEX_T^0}{d(1+d)^T} \]

where the third and fourth terms approximate changes in welfare beyond the terminal period, as explained below. The
percentage change in welfare as compared to its base-year value is given by

\[(12) \frac{PVWG}{PCEXB}\]

where PCEXB denotes per capita expenditure in the base year.

Figure 2.1 shows the time path of household expenditure \([e(p^0, U^1)]\) used to calculate welfare changes. The straight line labeled "continuous benchmark" represents a steady-state growth path which the economy is assumed to follow if no policy is implemented. Suppose at time \(T^0\) the state government lowers corporate income tax rates. Then the economy follows a sharply increasing path, labeled as the "transition path", in the initial periods after the policy implementation until the state government restores (raises) the tax rates to the pre-policy levels at time \(T_1\). At time \(T_1\), household expenditure goes up because households, as capital owners, now have more disposable income since less retained earnings are held by firms and more corporate earnings are distributed to households. Soon after \(T_1\), the economy grows at a slower rate because the tax rates are raised to their pre-policy levels. The economy eventually approaches asymptotically a new steady-state path labeled "actual new steady-state path".

To approximate the change in welfare, the terminal period is set at \(T_2\). The welfare gain generated up to time
Figure 2.1 Transition Path and Welfare Approximation
$T_2$ is represented by the area ABCD in Figure 2.1. The discounted value of this area is calculated as the first two terms on the right hand side of equation (11) above. The welfare gain accruing after $T_2$ is approximated by the area below the path labeled "approximate steady-state path for welfare calculation" but above the continuous benchmark. The discounted value of this area is calculated as the last two terms on the right hand side of equation (11) above. When welfare gain is calculated in this way, over-estimating the true welfare gain by the amount represented by the shaded area in the figure, is unavoidable. As the number of solution periods increases, the degree of this over-estimation diminishes. Sensitivity analysis can be performed to determine an appropriate terminal period to minimize the degree of over-estimation of welfare change.
CHAPTER III
MODEL EQUATIONS AND ASSUMPTIONS

The model specification in this chapter draws on previous work by Kraybill and Pai (1995), de Melo and Tarr (1992), Lee and Schreiner (1993), Jorgenson and Yun (1991), and Adelman et al. (1979).

A. Import Demand

Economic agents in Ohio, including households, producers, and governments, minimize the cost of a composite of imports and locally produced goods. This implies that the variants of each traded good produced in different places are imperfect substitutes and that consumer prices for the same type of good vary across regions (Armington, 1969). The optimization problem of commodity users is to minimize

\[(13) \quad P_Q_i Q_i = P M_i M_i + P D_i D_i\]

subject to

\[(14) \quad \frac{Q_i}{P_i} = A_i^C [\delta_i M_i^{-P_i} + (1-\delta_i) D_i^{-P_i}] \frac{1}{P_i}\]

where \(PQ_i\) is the price of the composite good \(i\), \(Q_i\) is its
quantity, $PM_i$ is the exogenously given price of the imported good $i$, $PD_i$ is the price of the locally produced good $i$, $M_i$ and $D_i$ are quantities of imported and locally produced good $i$, respectively, $A_i^c$ and $\delta_i$ are constants, and $\nu_i = 1/(1+\rho_i)$ is the elasticity of substitution between imports and locally produced goods. This yields:

$$\frac{M_i}{D_i} = \left(\frac{PD_i}{PM_i}\right)^{\nu_i} \left(\frac{\delta_i}{1-\delta_i}\right)^{\nu_i}$$

Thus, the allocation of locally produced goods and imports in consumption depends on the price ratio, $(PD_i/PM_i)$. The price of the composite good $i$ is calculated as:

$$PQ_i = \frac{(PD_iD_i + PM_iM_i)}{D_i + M_i}$$

This equation says that the price of composite good $i$ is the weighted average of the price of the domestic version of good $i$ and the price of the imported version of good $i$.

B. Production

The model in this dissertation has 2 goods and 2 industries: a tradable good (industry) and a nontradable good (industry). Under the assumption of constant returns to scale, industry behavior is identical to firm behavior. The industries in the model are therefore treated as optimizing firms. Firms optimize with respect to two
factors of production—capital and labor. There is one homogeneous labor input.

This study employs a two-level production function. In the first level, a Cobb-Douglas (CD) function is used to determine the components of value-added:

\[ VAF_i^p = \phi_i L_i^a K_i^k \]

where \( VAF_i \) is the value added for sector \( i \), \( \phi_i \) is a scale parameter, \( L_i \) denotes labor, \( K_i \) is sector-specific capital, and \( a \) and \( k \) are share parameters that sum to one. In the second level, intermediate inputs are combined in fixed ratios:

\[ X_i = \min\left[ \frac{VAF_i}{a_v}, \frac{X_{i1}}{a_{i1}}, \frac{X_{i2}}{a_{i2}}, \ldots, \frac{X_{in}}{a_{in}} \right] \]

where \( X_i \) is the output level in sector \( i \), \( a_v \) is the share of the value-added in one unit of output, \( X_{ij} \) is sector \( i \)'s use of intermediate good \( j \), and \( a_{ji} \) is an input-output coefficient that represents the amount of the \( j \)th good needed to produce one unit of the \( i \)th product.

The "net price" of a unit of value-added in sector \( i \) is defined as

\[ PV_i = PX_i - \sum_j P_{ij} a_{ji} - IT_i \]

where \( PX_i \) is output price, \( IT_i \) is indirect tax payment per unit of output. The indirect tax payment per unit of output is given by:
(20) \( IT_i = i tr_i PX_i \)

where \( i tr_i \) is the indirect tax rate in sector \( i \).

Under perfect competition, the first order condition for labor use is

(21) \( P V_i \frac{\partial X_i}{\partial L_i} = W \)

where \( W \) is the nominal wage rate common to all sectors in the economy. In other words, the wage rate is equal to the value of the marginal product of labor in each sector.

Intermediate demand for material inputs is given by:

(22) \( INTD_i = \sum_j a_{ij} X_j \)

C. Export Supply

Each of the goods is exported out of Ohio. Exports of a good are determined by revenue maximization behavior of firms, given the profit-maximizing production level for the good. Therefore, exports depend on the ratio of the domestic price of the good (\( PD_i \)) and the export price of the good (\( PE_i \)). \( PE_i \) is assumed to be exogenously given. This study uses a constant elasticity of transformation (CET) function to allocate output (\( X_i \)) of the \( i \)th good to the domestic market (\( D_i \)) and the export market (\( E_i \)): 
(23) \[ X_i = A_i^f \left[ \psi_i E_i^0 + (1 - \psi_i) D_i^0 \right]^{1 / \theta_i} \]

where \( X_i \) is output of the ith good produced in Ohio, \( A_i^f \) and \( \psi_i \) are constants, and \( \theta_i \) is a substitution parameter. For the optimal level of output, the firm maximizes revenue,

(24) \[ PX_i X_i = PD_i D_i + PE_i E_i \]

subject to the transformation function shown in equation (23). Here, \( PX_i \) is the producer price of good \( i \) and is a weighted average of \( PD_i \) and \( PE_i \). The supply choice between domestic sales and exports is determined as follows:

(25) \[ \frac{E_i}{D_i} = \frac{PE_i}{PD_i} A_i \left( \frac{1 - \psi_i}{\psi_i} \right)^{A_i} \]

where \( D_i = X_i - E_i \), and \( A_i = 1/(1 - \theta_i) \) is the elasticity of transformation.

D. Consumption

An aggregate representative consumer maximizes a constant elasticity of substitution utility function (Shoven and Whalley, 1992) subject to a budget constraint. The consumer is assumed to consume both locally produced goods and imported goods from outside of Ohio. The utility function for the aggregate representative consumer is:
where $U$ denotes utility, $\beta_i$ is expenditure share for good $i$, $\gamma$ is the elasticity of substitution, and $C_i$ is units of good $i$. Utility maximization for the representative consumer subject to the budget constraint yields the demand function (Shoven and Whalley, 1992) for each good:

\begin{equation}
C_i = \frac{\beta_i \text{HEXP}}{PQ_i \gamma \sum_j \beta_j PQ_j^{1-\gamma}}
\end{equation}

where HEXP is household expenditure.

E. Public Goods

1. A Brief Overview

For some simulation experiments in the current study, public goods are incorporated in household consumption and/or in firms' production technology. Therefore, this section will discuss the role of public goods in household consumption and private industries' production.

There are two kinds of policy instruments that policymakers can use at the state-local level. The first instrument is tax policy (revenue side), and the second is government expenditure policy (expenditure side).

Regional government in general plays three roles in the regional economy (Nijkamp et al., 1986): (i) the regional government plays the role of redistributing income
across households and firms through taxes and transfers; (ii) the regional government provides infrastructure which increases productivity of firms and welfare of households; (iii) the regional government provides households with personal services such as education and health care. For (ii) and (iii) above, the regional government acts as a component of final demand for private goods produced in the economy. All of the above roles are considered in the current study.

The present study has two different concepts regarding public goods: first, public goods as a flow as is implied in (iii) above; and second, public goods as a stock as implied in (ii) above. The flow is defined as the combined state and local government spending on commodities and is considered as a composite good consumed by households. The stock is defined as public capital stock which is accumulated, depreciated, and updated every period, and is treated as an unpaid input in production. Figure 3.1 describes the relationship among tax policy, public expenditures, and factor supplies in the present model.

2. Public Good in Production

Public goods have an important role in production. An econometric study by Aschauer (1989) reports that nonmilitary public capital 'stock' is more effective in increasing productivity than the 'flow' of nonmilitary
Figure 3.1 The Relationship among Tax Policy, Public Expenditure, and Factor Supplies
public expenditure. Many econometric studies have provided estimates of the effects of public capital stock on regional growth. Munnell (1990), for example, estimated a public capital elasticity of output of 0.15 at the state level in a study of the effects of nonmilitary, nonresident public capital. Costa, Ellson, and Martin (1987) obtained an elasticity of similar magnitude (0.20) for the same type of public capital. Garcia-Milà and McGuire (1992) obtained a public capital elasticity of output of 0.045 for highways and streets. Eberts (1991) reports a positive relationship between public investment and regional employment. Most recently, using a data set of 85 West German cities, Seitz (1995) examined the impact of infrastructure services on production cost of private industries, and derived an optimal local infrastructure supply rule and an optimal rate of corporate capital tax. Seitz and Licht (1995) report a significant cost reducing effects of public capital and a strong relationship between private investment and public capital formation.

For incorporating public goods into production, the value-added function specified in equation (17) can be modified:

\[(28) \quad VAF_i = \phi_i G K^{\varepsilon_i} L_i^{\xi_i} K_i^{\xi_i} \]

where GK is public capital and \( \varepsilon_i \) is the public capital elasticity of output. With public capital in the value-
added function as an unpaid factor of production, if public investment increases, the rate of return on private capital will go up, leading to an increase in private investment and an increase in output in the private sector (Aschauer, 1987).

In a study by Glomm and Ravikumar (1994) dealing with the role of public investment in infrastructure, the authors assume production technology is represented by constant returns to scale with respect to private inputs but increasing returns to scale with respect to total inputs, including public capital. In an econometric study, Aschauer (1989) found that constant returns to scale technology cannot be rejected for total inputs inclusive of public nonmilitary capital. In the present study, it is assumed that private production technology is constant returns to scale with respect to total inputs including public capital.

3. Public Good in Household Consumption

In response to Samuelson's (1954) theory regarding the provision of public goods, Tiebout (1956) asserted that households reveal their preferences for local public goods through their choice of residential location. For some of the simulations in the present study, a public good is included in the household utility function. With a public good in the household utility function, it is assumed that
people in(out)-migrate in response to interregional differentials in per capita utility.

There are three approaches in modeling public goods in household consumption. In the first two approaches, the level of provision of the public good is determined by the government and exogenously given to households. The only difference in the two approaches lies in whether or not the price of the public good is explicitly incorporated in the household utility maximization problem. The first approach is to treat the public good as a rationed good with its price explicitly charged to households (e.g., Neary and Roberts, 1980; Goodspeed and Schwab, 1993). The second approach is to treat the public good as an unpriced good in the household utility maximization problem (e.g., Johansson, 1987, chapter 6). In the second approach, the price of the public good is charged in the form of a reduction of household (gross) income by the amount of tax payment. Thus, in both approaches, the public good is priced in some way. In the third approach, the level of the public good is determined endogenously by the median voter or a representative consumer by maximizing his/her utility function.

The present study follows the second approach. The price of the public good is assumed to be exogenously given in each period by the tax rules of the combined state and local government, although the price is not explicitly
considered in the present study. The quantity of the public good is exogenously given in each period by:

\[ G = \sum_i [CSG_i + CLG_i] \]

where \( CSG_i \) and \( CLG_i \) are state government demand and local government demand for good \( i \), respectively. The expenditure rule of the combined state and local government is such that the base-year ratio of the combined state and local government expenditure to its revenue is maintained in each period.

When a public good is incorporated in household consumption in one of the simulation experiments below, the public good enters a CES utility function:

\[ U = \left[ \beta_g \frac{1}{G} \gamma^{-1} + \sum_i \beta_i \frac{1}{C_i} \gamma^{-1} \right] \gamma^{-1} \]

where \( \beta_g \) is share parameter for the public good and \( G \) its quantity. Using this function, equation (8) is modified to incorporate the public good in the equivalent variation for the consumer in each period:

\[ EV_t = e_{1,t}(p^o, G^o, U^o) - e_{o,t}(p^o, G^o, U^o) \]

where \( G^o \) denotes levels of the public good provision on the continuous benchmark path.
F. Budgets of Households

Household income is composed of after-tax-returns to labor and capital earnings plus federal, state, and local government transfers. Capital earnings are composed of dividends and interest payment. Since corporate capital in Ohio is assumed to be nationally owned, Ohio households receive a fixed share of the capital earnings generated in Ohio and the rest is treated as a leakage of income from the region. The budget of the representative consumer is given by:

\[
HEXP = DYH - HSAV
\]

where \(DYH\) and \(HSAV\) are the disposable income and the household savings of the consumer, respectively. \(DYH\) is given by:

\[
DYH = (LABY + CAPY) (1 - LTX - STX - FTX) + LTR + STR + FTR
\]

Here, \(LABY\) is labor earnings of the consumer net of social security tax payment; \(CAPY\) is capital earnings; \(LTX, STX,\) and \(FTX\) are local, state, and federal income tax rates, respectively; and \(LTR, STR,\) and \(FTR\) are local, state, and federal government transfers to households, respectively. Labor earnings are calculated as
(34) \[ \text{LABY} = (1-W\text{LEAKR})(1-s\text{str})W\sum L_i \]

where \( W\text{LEAKR} \) is the labor income leakage rate, and \( s\text{str} \) is social security tax rate and \( L_i \) is labor employed in sector \( i \). Capital earnings are given by:

(35) \[ \text{CAPY} = (1-R\text{LEAKR})\sum (\text{INTT}_i + \text{DV}_i - \text{NS}_i) \]

where \( R\text{LEAKR} \) is the capital income leakage rate; \( \text{INTT}_i \) is the interest payment to capital owners in sector \( i \); \( \text{DV}_i \) is the dividend payment by sector \( i \); and \( \text{NS}_i \) is new share issues. A more detailed explanation of how capital earnings are determined will be given in section J in this chapter.

G. Budgets of State and Local Governments

The state and local governments in the present study collect taxes from households and corporate firms. From corporate firms, the governments collect corporate income taxes, property taxes, and indirect taxes. From households, the governments collect personal income taxes, the tax base of which is labor earnings plus capital earnings. The state and local governments receive federal government transfers. Thus, state government revenue is

(36) \[ \text{SGREV} = STX(\text{LABY} + \text{CAPY}) \]
where \( CITS_i \) is corporate income taxes collected by state government in sector \( i \); \( PROPS_i \) is tax on corporate property (there is no property tax levied by state government in Ohio, therefore, \( PROPS_i \) is set to zero in the model); \( ITS_i \) is an indirect tax payment to state government; \( TRAFLS \) is federal government transfers to the state government; and \( TRALs \) is transfers from local government to state government. The local government revenue is

\[
LREV = LTX(LABY + CAPY) + \sum [CITL_i + PROPL_i] + \sum ITL_i + TRAFL + TRASL
\]

where \( CITL_i \) is corporate income taxes collected by local government in sector \( i \); \( PROPL_i \) is local taxes on corporate property; \( ITL_i \) is an indirect tax payment to local government; \( TRAFL \) is federal government transfers to the local government; and \( TRASL \) is state transfers to local government.

Tax revenues are spent on the state-local public good which is composed of private goods from all sectors. It is assumed that state government expenditure on the public good is proportional to the level of its revenue. The state government also provides transfers to households in the
region, transfers to local government, and investment tax credit to firms. Total state government expenditure is:

\[ SGEXP = \sum_i PQ_i CSG_i + TRASH + TRASL + CREDITS \]

where \( CSG_i \) is state government demand for private good \( i \); \( TRASH \) is state government transfers to households in Ohio; \( TRASL \) is state government transfers to local government; and \( CREDITS \) is state government tax credit given to firms in Ohio. \( TRASH \) and \( TRASL \) are given by fixed shares of state government revenue in each period. Total local government expenditure is:

\[ LGEXP = \sum_i PQ_i CLG_i + TRALH + TRALS \]

where \( CLG_i \) is local government demand for private good \( i \); \( TRALH \) is local government transfers to households in Ohio; and \( TRALS \) is local government transfers to state government. \( TRALH \) and \( TRALS \) are given by fixed shares of local government revenue in each period.

H. Federal Government

The equation for federal government revenue is similar to that of state government except that the federal government collects social security taxes. On the expenditure side, the federal government purchases goods produced in Ohio and provides transfers to households and to
state and local governments. Thus, federal government expenditure is

(40) \[ FGEXP = \sum \text{P}_{i} \text{CFG}_{i} + \text{TRAFH} + \text{TRAFS} + \text{TRAFL} \]

where CFG\textsubscript{i} is federal government demand for good i, and TRAFH, TRAFS, and TRAFL are federal government transfers to households, state government, and local government, respectively.

I. Labor Market and Labor Mobility

Labor demand is determined by equation (21) in the production section. In the present study, the change in labor supply is composed of two sources: (i) change in net in-migration and (ii) natural increase in the existing population. Also, a constant ratio of labor force to population (i.e., labor force participation rate) is assumed. The unemployment rate is set exogenously. This assumption is due to the fact that regional economists have not been very successful in explaining regional unemployment.

As Plaut (1981) points out, a potential migrant to a region compares two kinds of costs. The first kind of cost is incurred by not migrating, i.e., foregone income that can be obtained from the region that the individual contemplates moving to and foregone happiness from environmental goods in the alternative region. The second kind of cost includes
the physical cost of moving, opportunity cost of foregone income from the region where he/she resides, and psychological cost. Thus, according to the author, the individual migrates in response to the difference between these two kinds of costs.

Jones and Whalley (1989) point out the inappropriateness of the extreme assumption of perfect mobility or perfect immobility of labor across regions. First, if labor is assumed to be perfectly mobile, it is hard to identify the effects of a policy on regions of interest because this assumption implies that all regions, with wage rates equalized, constitute a single homogeneous region. Second, if labor is assumed to be completely immobile across regions, the policy effect on regions of interest will be easily identified. However, with this assumption, efficiency issues arising from the interregional movement of labor are ignored.

In the present model, it is assumed that labor is partially mobile across regions. It is also assumed that labor is perfectly mobile across sectors within regions. The partial adjustment assumption for interregional labor mobility allows some wage rate differentials across regions and is consistent with the dynamic structure of the present model discussed below in the section on dynamics. The net in-migration of labor into Ohio is determined as follows:
\[ \text{LMIG} = (LME) (LSTK) \log \frac{WAFTL_{OH}}{WAFTL_{ROW}} \]

where LMIG denotes the net in-migration of labor; LME is the migration elasticity; LSTK is the aggregate stock of labor given at the beginning of each period; WAFTL\textsubscript{OH} and WAFTL\textsubscript{ROW} are the after-tax wage rates in Ohio and in ROW, respectively.

If public goods are included in the household utility function as in one of the simulation experiments below, then labor-consumers (voters) are assumed to respond not only to wage differentials across regions but also to differentials in levels of public goods provision across regions (Tiebout, 1956), as mentioned in section E above. In this case, some modifications are made to the labor migration equation:

\[ \text{LMIG} = (LME) (LSTK) \log \frac{U_{OH}}{U_{ROW}} \]

where \( U_{OH} \) and \( U_{ROW} \) are per capita utility levels in Ohio and in ROW, respectively. Equilibrium resulting from equation (42) is such that utility rather than after-tax wage rates is equalized across regions. Thus, the approach taken regarding migration specified in equation (42) is similar to that presented in Graves and Linneman (1979), in which in equilibrium, the interregional difference in wages reflects compensation for differing climate and amenities.
The labor market clears when the demand for labor is equal to the supply of labor:

\[ LTOT = (1 - ur)LSTK \]  

Here, LTOT denotes aggregate labor demand in the economy, which is the sum of labor demand across sectors, and ur is the assumed natural rate of unemployment. In the present study, the natural increase in population has a constant annual growth rate. LSTK is updated each period by

\[ LSTK_t = LSTK_{t-1}(1 + POPG) + LMIG_{t-1} \]

where \( t \) denotes time, and POPG, the rate of natural increase in the population.

J. Capital Income and Capital Mobility

In this study, a unit of physical capital is a composite good composed of private goods produced in the two sectors of the economy. Therefore, the price of a unit of sector i’s capital is a linear combination of the prices of ordinary goods:

\[ PK_i = \sum_j PQ_j h_{ji} \]

where \( PQ_j \) is the price of the good produced in sector j, and \( h_{ji} \) is the share of good j in one unit of sector i’s capital stock.

Equation (35) shows that the major components of capital income are dividends and interest payments. The
equation also implies that there are two major sources of financing investment: debt financing and equity financing. Firms pay capital owners interest for debt financing, and dividends for equity financing.

First, interest payments are given by:

\[(46) \quad INTT_i = i \beta q PK_i K_i\]

where \(i\) is the interest rate which is determined in financial markets and given to this model exogenously, \(\beta_q\) is a fixed ratio of debt to the total value of corporate assets, and \(PK_i\) is the acquisition price of a unit of sector-specific capital in sector \(i\).

Second, for dividend payments \((DV_i)\), there are two specifications in the literature on investment. These specifications are based on differing views of corporate taxation (Jorgenson and Yun, 1991). The first view is the "traditional view" adopted, for example, by Poterba and Summers (1983). According to this view, the marginal source of funds for the equity portion of net investment is new shares of equity. The second view is that new shares of equity are fixed and retained earnings are the marginal source of funds for the equity portion of net investment (e.g., Boadway, Bruce, and Mintz, 1984). In this study, following the second view, it is assumed that firms retain enough funds to finance the equity portion of net investment before they distribute corporate income as dividends to equity holders.
Retained earnings \((RET_i)\) are determined by

\[(47) \quad RET_i = (1-\beta^i) PK_i NI_i\]

where \(NI_i\) denotes net investment. New share issues are set at zero, and dividends are given by:

\[(48) \quad DV_i = TB_i - CIT_i - DEPR_i - RET_i\]

Here, \(TB_i\) is the tax base for the corporate income tax which is equal to cash flow \((PV_i X_i - W_i L_i)\) less interest payment \((INTTi)\) and property tax payment \((PROP_i)\), and \(DEPR_i\) is depreciation allowances. \(CIT_i\) is corporate income tax paid by sector \(i\) and is given by:

\[(49) \quad CIT_i = t_q TB_i\]

where \(t_q\) is a combined federal, state, and local government corporate income tax rate.

In this dissertation, installed capital is sectorally immobile and sector-specific. Although physical capital itself is not mobile across sectors, the investible funds for financing new physical capital are perfectly mobile across sectors and regions. The next section explains the interregional flow of investible funds.

K. Investment

1. Total Savings as a Residual

In many national-level CGE models, the volume of total savings in the national economy determines total investment. Investment in these models is said to be
"savings-driven". In the present model, investment is determined by an investment function that is independent of domestic (i.e., regional) savings. The level of regional investment is driven by rates of return in the region relative to the rest of the nation. Since regions are highly open economies and investment funds appear to be geographically mobile in the United States, it seems appropriate to treat the inflow of external savings as a residual that responds to the level of investment in the region.

2. Determination of Investment

A tax policy change in any sector changes the desired level of capital stock through a change in the rental price of capital in the sector. The rental price of capital, defined in equation (7) in Chapter II, is

\[ r_{PC_t} = \frac{(1-k_q-t_q z_q)PK_t[x_t-\pi_t+(1+\pi_t)q]}{(1-t_q)} + t_p q PK_t \]

where \( k_q \) is the investment tax credit rate on new corporate assets; \( t_q \) is the combined state-local and federal corporate tax rate; \( z_q \) is the present value of capital consumption allowances on a new asset; \( t_p q \) is the property tax rate on corporate assets; \( r_t \) is the rate of return on corporate capital; \( \pi_t \) is the inflation rate for the capital good; and \( q \) is the depreciation rate.
Generally, the rental price of capital in each industry differs because capital is sector-specific, which implies that each sector may have differential depreciation rates, differential inflation rates for sector-specific capital, and differential tax rates. In the present study, tax rates and the depreciation rates are assumed to be the same across sectors, but inflation rates for capital goods differ among sectors.

From the general equilibrium solution in period $t$ solved with a given level of capital in period $t$, the net price, the output level, and the rental price of capital for sector $i$ are computed. By substituting these values into the demand function for capital, the desired level of capital, $KD_{t,i}$ is computed each period using the first-order condition for the profit-maximizing level of capital demand:

$$ (50) \quad KD_{t,i} = \frac{k_i PV_i X_i}{IDC_i} $$

Net investment in each sector is given by:

$$ (51) \quad NI_{t,i} = \lambda_i (KD_{t,i} - K_{t-1,i}) $$

where $\lambda_i$ is the speed of stock adjustment. Here, $K_{t-1,i}$ is actual level of capital stock given at the beginning of period $t$, and updated in each period by

$$ (52) \quad K_{t,i} = K_{t-1,i} + NI_{t,i} $$

The value of the speed of adjustment depends on two kinds of cost: (i) foregone profits and (ii) cost of changes in the
actual level of capital (Griliches, 1967; Plaut, 1981). It is assumed in the present model that $\lambda_i$ is the same across all sectors. This specification of the net investment function does not explicitly consider the lag structure of investment.

Equation (51) says that net investment is determined by the speed of adjustment times the disparity between the desired level of capital and its actual level. A positive amount of net investment observed in the base year reflects the fact that the desired level of capital is greater than its actual level in the year. This implies that the value of the marginal product of capital is greater than its rental price in the base year. Therefore, firms, as profit maximizers, will increase investment and production. Now, suppose the state government reduces corporate income tax rates. Then, the reduction in the corporate income tax rate, through a decrease in the rental price of capital (equation 7), increases the desired level of capital (equation 50). This widens the gap between the desired level of capital and its actual level. This will result in a higher level of net investment (equation 51).

As Hayashi (1982) points out, in the original neoclassical investment theory (Jorgenson, 1963), the optimal stock of capital, and, hence, the optimal rate of investment, is calculated under the assumption that production is subject to a constant returns to scale
technology and that the level of output is exogenously given. But because the assumption of perfect competition does not allow the output of a firm to be fixed, the original version of the theory needs a capital adjustment mechanism to determine the optimal level of capital stock. Incorporation of an adjustment mechanism in the determination of net investment implies that changes in the level of capital stock impose adjustment costs.

Lucas (1967) and others (e.g., Treadway, 1969) improved the original version of neoclassical investment theory by explicitly incorporating adjustment costs into producers' optimization problem. The present study basically follows the original version of theory of investment with adjustment costs, which is implicitly represented by $\lambda_i<1$ in this study.

Net investment is one component of total investment in a sector. The other component is replacement investment, which is given by:

\[ R\bar{I}_i = \varpi_i K_i \]

where $\varpi_i$ denotes the depreciation rate for sector $i$'s capital.

3. Financing Investment

The capital goods required to fulfill net investment (NI) in each sector are financed by new equity ($N^{eq}$) and new debt ($N^{db}$) in fixed proportions of the total value of
the capital stock in each sector. The total value of net investment is given by:

\[ VNI_i = VNI_i^{eq} + VNI_i^{db} = PK_iNI_i \]

where \( VNI_i^{eq} \) is the value of equity-financed net investment, and \( VNI_i^{db} \) is the value of debt-financed net investment.

Following the second view on corporate taxation mentioned in section J in this chapter, the equity-financed new investment is assumed to be financed by retained earnings (\( RET_i \)) only; i.e.,

\[ VNI_i^{eq} = RET_i \]

In addition to retained earnings, net investment is financed by components of total savings other than retained earnings. These components will be explained in section L in this chapter. Replacement investment is financed by a depreciation allowance for capital, which is given by:

\[ DEPR_i = \varphi_i PK_i K_i \]

Figure 3.2 shows the financing structure of total investment in this study.

4. Investment as a Component of Final Demand

Sector j's use of good i for net investment is given by:
Figure 3.2   Financing of Total Investment
(57) \[ CNI_{i,j} = h_{ij} NI_j \]

where \( h_{ij} \) is the fraction of good \( i \) in sector \( j \)'s capital stock. Total demand for good \( i \) for net investment in the economy is given by:

(58) \[ TCNI_i = \sum_j CNI_{i,j} \]

Sector \( j \)'s use of good \( i \) for replacement investment is given by:

(59) \[ CRI_{i,j} = h_{ij} g_{ij} K_j \]

Total demand for good \( i \) for replacement investment in the economy is given by:

(60) \[ TCRI_i = \sum_j CRI_{i,j} \]

Thus, total investment demand for good \( i \) is given by:

(61) \[ TCTI_i = TCNI_i + TCRI_i \]

L. Savings

Total savings in Ohio consists of household savings, retained earnings summed over all industries, depreciation allowances summed over all industries, external savings, and savings from state and local governments. External savings consists of net inflows of savings from the national and international economies. Total savings is given by:
(62) \[ TSAV = HSAV + \sum_i RET_i + \sum_i DEPR_i + FSAV + GSSL \]

where FSAV is external savings, and GSSL is combined state and local government savings. Here, external savings is given by:

(63) \[ FSAV = \sum_i PM_i M_i - \sum_i PE_i E_i + YX + GSF - CAPIN \]

where \( PM_i \) is the price of imported good \( i \); \( M_i \) is its quantity; \( PE_i \) is the price of exported good \( i \); \( E_i \) is its quantity; \( YX \) is income leakage from Ohio to ROW; \( GSF \) is the excess of federal receipts over federal spending in the region; and \( CAPIN \) is a savings inflow that adjusts as a residual to ensure that the level of total savings in the region is sufficient to accommodate the level of investment.

M. Market Equilibrium Conditions

1. Commodity Market

The market equilibrium condition for good \( i \) is:

(64) \[ C_i + INTD_i + TCTI_i + DST_i + TCRG_i = Q_i \]

where \( INTD_i \) denotes intermediate demand for good \( i \), \( DST_i \) denotes inventory investment in sector \( i \), and \( TCRG_i \) denotes combined federal, state, and local demand for good \( i \). This condition says that aggregate demand for good \( i \) in the economy, which is the sum of consumer demand, intermediate demand, investment demand, inventory, and government demand for the good, must equal total supply of good \( i \).
2. Factor Markets

The labor market equilibrium condition represented by equation (43) above is:

\[ LTOT = (1-ur)LSTK \]

This condition says that total demand for labor summed over all industries equals the labor supply. Since sectoral capital stocks (and hence the aggregate stock of capital in the economy) are fixed in each period, there is no capital market equilibrium condition.

3. Savings and Investment

\[ TSAV = \sum_i VNI_i + \sum_i DEPR_i + \sum_i PX_i DST_i \]

This equilibrium condition says that total savings must be equal to total investment in the economy.

N. Dynamics

1. Dynamic CGE Models

In the literature, there are two categories of dynamic CGE models. In the first category of models, a static equilibrium is solved for during the present period with stock variables (e.g., capital and labor) given exogenously by the solution results of the previous period. Either during or after each period, these stock variables are updated, and given to the next period as exogenous variables. In these models, economic agents have "myopic"
expectations about future events in the sense that when they make decisions in the current period, they expect that future events (prices) will remain stable, and agents do not incorporate the future events into current decisions. Examples of models in this category include Adelman et al. (1979) and Ballard et al. (1985).

In the second category, dynamic CGE models are characterized by economic agents considering not only past solution results but also expected future events such as the expected time-paths of prices, wages, and rates of return. In these models, the assumption of "perfect foresight" is typically employed by the modelers. Examples of models in the second category include Goulder and Summers (1989), Pereira (1991), and Pereira (1993).

2. Dynamics in the Model for the Present Study

The model in this dissertation belongs to the first category. The structure of the model is similar to that of Adelman et al. (1979), a description of which is found in Robinson (1976). Concerning the requirements for an ideal long-run model, Robinson (1976) points out that there are two kinds of adjustment behavior to be considered. First, in goods markets, the adjustments of prices and quantities occur in a short period, reducing excess demand to zero. The equilibria attained in these markets are Walrasian in nature. Second, in factor markets, adjustment takes
multiple periods because of lagged responses of factor supplies, represented, for example, by labor migration elasticities and the adjustment coefficient in the investment function in the present model.

To deal with these two kinds of adjustment behavior, the author proposes two different stages of modeling: stage 1 for modeling the instantaneous adjustment of prices and quantities in product markets and stage 2 for modeling lagged adjustment in factor markets. The structure of the present model is similar to the model presented in Robinson (1976), and is schematically depicted in Table 3.1.

In this dissertation, static equilibria are sequenced through time to reflect changes in the economy's capital stock due to investment. The equilibria in any sequence are connected to each other through capital accumulation, labor migration, and population change. Each single period equilibrium calculation begins with an initial capital stock in each sector and labor endowment in the economy. It is assumed that the economy in the base year is on a steady-state path on which capital and labor grow at the same rate, and prices, including wage rates and rate of return, are stable on the path (Shoven and Whalley, 1992).

The introduction of a government policy such as a tax cut sets the economy on a transition path, which approaches a new steady state asymptotically over time. The magnitude and source of the policy shock determine (i) the position of
<table>
<thead>
<tr>
<th>Endowments</th>
<th>Stage 1</th>
<th>Result of stage 1</th>
<th>Stage 2</th>
<th>Period (t+1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor stock</td>
<td>Calculation of static CGE</td>
<td>After-tax real wage</td>
<td>Labor migration</td>
<td>Updated labor stock</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Natural increase in population</td>
<td>Increase in population</td>
<td></td>
</tr>
<tr>
<td>Capital stock</td>
<td>Prices of goods</td>
<td>Net investment</td>
<td>Updated capital stock</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Output level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rental price of capital</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
the new steady state path, (ii) the shape and slope of the transition path, and (iii) the time required to reach the new steady state path. If the policy shock is very small, then the transition path will reach the new steady state in a relatively short time.

The financing of private investment may come at the cost of reduced household consumption in the initial periods after the implementation of the tax abatement policy. This is because retained earnings must increase to finance a higher level of investment. However, because the rental price is cheaper because of the tax cut, the policy will induce (i) a substitution effect in the employment of capital and labor and (ii) an output effect (i.e., shifting outward of the supply curves for goods), leading to lower prices (Harberger, 1962; Mieszkowski, 1967).
CHAPTER IV
DATA AND PARAMETERS

This study uses a microconsistent data set that satisfies the equilibrium conditions of the model in the base year. A Social Accounting Matrix (SAM) for Ohio is constructed. Calibration is performed to determine the values of selected parameters required to numerically replicate the base-year data set. All tables referred to in this chapter are in the Appendices.

A. Data

1. Social Accounting Matrix (SAM)

Data used in a CGE model are assembled in a Social Accounting Matrix (SAM). A SAM is a matrix of balanced expenditure and income accounts, and provides a tabular snapshot of the economy at one point in time. Construction of a SAM begins with input-output accounts consisting of detailed industry, commodity, factor, and final demand transactions that are balanced to reflect market-level equilibrium, as well as the aggregate income-expenditure equilibrium. A detailed discussion of the SAM data framework is provided by Pyatt and Round (1985).
The structure of the SAM is shown in Table A.1 (see Appendix A). Numerical values of the Ohio SAM are given for the base year (1990) in Table A.2 (see Appendix A). There are 8 accounts: activity, commodity, labor, capital, household, government, investment-savings, and rest-of-the-world accounts.

2. Data Sources
(a) IMPLAN

IMPLAN (IMpact Analysis for PLANning) is used to create an Ohio input-output table, including interindustry transactions, value-added, and final demands. This table is based upon various U.S. census: Manufactures, Agriculture, Retail, Governments, and County Business Patterns (Alward et al, 1992). Next, the input-output table is placed within an Ohio SAM, developed by Minnesota IMPLAN Group, Incorporated.

The use matrix, final demands (household consumption demand, investment demand, government demand, and exports), and imports are obtained from IMPLAN. IMPLAN permits construction of regional input-output accounts for up to 528 sectors for any county or state in the U.S.

In constructing the regional data base, it is assumed that production technology in each sector is homogeneous across all U.S. regions. In estimating interregional commodity flow, IMPLAN uses a regional purchase coefficient (RPC) for each industry. The RPCs were estimated
econometrically by using the Multiregional Input-Output accounts (MRIO) data. By using RPCs, IMPLAN can provide detailed regional data on imports and domestic demands.

(b) Sectoral Aggregation and Adjustment of Accounts

The 528 sectors in the Ohio SAM are aggregated into the two sectors in the present study: a traded-product sector and a nontraded-product sector. Table A.3 (see Appendix A) shows how the 528 sectors are aggregated. Details are found in Kraybill and Pai (1995).

3. Other Data Sources

In addition to the SAM data, the model requires data on employment, unemployment, and government purchases and transfers in the base year. The employment and unemployment data are obtained from the Ohio Bureau of Employment Services (OBES), and government purchase and transfer data are obtained from the U.S. Census Government Finances (UCGF) series. UCGF data are used to disaggregate IMPLAN's combined state-local government purchases into separate state and local components. Details are found in Kraybill and Pai (1995).

B. Parameter Calibration

Calculation of the effects of policy changes in a CGE model requires specific values of parameters in the
equations of the model. Some parameters are estimated econometrically. Other parameter values are calibrated so that the model replicates the base-year equilibrium (Mansur and Whalley, 1984). Because calibration usually involves only a single observation of model variables, the unknown parameters cannot be solved for deterministically. Some parameters such as elasticities of substitution and elasticities of transformation are specified on the basis of econometric research. The remaining parameters such as share parameters are then determined by solving the model equations with the base-year observations for model variables and the exogenous parameters substituted in the model (Shoven and Whalley, 1992). Since most of the calibration procedures are detailed in Kraybill and Pai (1995), this section deals only with the calibration methods which are unique to the present study. Table B.1 (see Appendix B) presents the values of all the calibrated and exogenously given parameters for this study.

1. Tax Rates

For tax rates on capital income, this study uses corporate income tax rates \( t_q \), investment tax credit rates \( k_q \), property tax rates \( t_q^p \), and present value of capital consumption allowances \( z_q \) calculated under the 1986 Tax Act by Jorgenson and Yun (1991). Specific values of these capital tax rates are found in Table B.1 in Appendix B.
other tax rates, including household income tax rates, are
detailed in Kraybill and Pai (1995) and are reported also in
Table B.1.

2. Capital and Investment

The nominal interest rate is fixed at 6 percent
throughout all periods. The rate of return is set equal to
the interest rate in the base year. The price of capital
\((PK_i)\) is set to be unity in the base year. The inflation
rate of the price of the capital is set to be zero in the
base year. Sectoral depreciation rates \((\xi_i)\) are set at 0.04
for all sectors. The sectoral rental price of capital is
calculated for the base year by using equation (7).

As is mentioned in Section N in Chapter III, it is
assumed that the economy in the base year is on a balanced
growth path. To satisfy this assumption, as a first step,
the following eight equations are solved simultaneously
based on an intial value of adjustment coefficient \((\lambda_i)\):

\[
(66) \quad NI_i = (grk)K_i \\
(67) \quad RI_i = \xi_iK_i \\
(68) \quad KDU_i = \frac{CAPINCOME_i}{\rho PC_i} \\
(69) \quad DK_i = \xi_iK_i + (grk)K_i
\]
\begin{align*}
70) \quad K_i &= KU_i - NI_i \\
71) \quad NIU_i &= (g_{rk}) KU_i \\
72) \quad KU_i &= KDU_i - \frac{NIU_i}{\lambda_i} \\
73) \quad KD_i &= \frac{NI_i}{\lambda_i} + K_i
\end{align*}

for the following eight variables:

(i) \(DK_i\) : investment by sector of destination in the base year,
(ii) \(NI_i\) : net investment in the base year,
(iii) \(RI_i\) : replacement investment in the base year,
(iv) \(K_i\) : actual level of capital stock in the base year,
(v) \(KD_i\) : desired level of capital stock in the base year,
(vi) \(KU_i\) : actual level of capital stock in the next year,
(vii) \(KDU_i\) : desired level of capital stock in the next year, and
(viii) \(NIU_i\) : net investment in the next year.
The parameters in the above equations are defined as:

(i) \( g_{rk} \) is the exogenous growth rate of the actual level of capital, which is set equal to the rate of natural increase in population;

(ii) \( \varphi_i \) is the exogenous sectoral capital depreciation rate

(iii) \( \text{CAPINCOME}_i \) is sectoral capital income, exogenous in this calibration system of equations, though not in the model; and

(iv) \( r_{pc_i} \) is exogenously given by equation (7).

The second step is to revise the base-year value of \( DK_i \) solved for by the above equation system as follows:

\[
(74) \quad DKR_i = \frac{DK_i}{\sum_j DK_j} \sum_j TCTI_j
\]

where \( DKR_i \) is a revised value of \( DK_i \), and \( TCTI_j \) is total investment demand for good \( j \) in the economy. The third step is to use the RAS (row-and-column sum) technique of matrix balancing to calibrate a capital composition matrix, whose elements are \( b_{ij} \), such that the following conditions are satisfied:

\[
(75) \quad \sum_j b_{ij} = 1 \quad \text{and} \quad TCTI_i = \sum_j b_{ij} DKR_j
\]

The final step is (i) to substitute this revised value (\( DKR_i \)) of sectoral investment by destination for \( DK_i \) in the above equation system, and (ii) to solve the equation system again for the final base-year values of the
variables, with \( \lambda_i \) now treated as an unknown variable. The adjustment coefficient (\( \lambda_i \)) calibrated in this manner is 0.302 for all sectors.

3. Public Capital

To calculate the base-year level of public capital (\( GK \)), total private capital stock (\( KTOT \)) is multiplied by the ratio of the combined state and local government demand for all private goods (\( CSG_i + CLG_i \)) to total net investment (\( \Sigma NI_i \)):

\[
GK = \frac{\sum [CSG_i + CLG_i]}{\sum NI_i KTOT}
\]

An assumption underlying the derivation of the base-year level of public capital stock is that the public capital stock growth rate is the same as the private capital growth rate on the continuous benchmark path. In an experiment where public capital is included as an input in production, the shift parameter in the production function in Chapter III must be re-calibrated as follows:

\[
AV_i^g = \frac{X_i}{GK^{\epsilon_i L_i^{(1-\epsilon_i)}} K_i^{(1-\epsilon_i)} (1-\epsilon_i)}
\]

where \( \epsilon_i \) denotes the public capital elasticity of output. Here, \( \epsilon_i \) is set to be 0.2 for all sectors. The depreciation rate for public capital (\( \rho_g \)) is set to be 0.04, equal to the rate of depreciation of private capital.
4. Consumer Demand Function

The elasticity of substitution ($\gamma$) in equations (26) and (27) is set to be 1.1. The share parameters in these equations are calculated as:

\[ \beta_i = \frac{PQ_iC_i}{HEXP} \]  

The calculated values of the share parameters are 0.257 (sector 1) and 0.743 (sector 2), respectively. To calculate the share parameter for the public good ($\beta_g$) in equation (30), the following two equations are solved simultaneously for the virtual price (VPG) of the public good and its share parameter ($\beta_g$):

\[ G = \frac{\beta_g[HEXP + (VPG)G]}{VPG\sum (1-\beta_g)(\beta_i)PQ_i^{1-\gamma}} \]  

\[ \beta_g = \frac{(VPG)G}{HEXP + (VPG)G} \]  

Here, the virtual price of the public good (VPG) is defined to be the price of the public good at which the aggregate representative consumer would have demanded the given level of the rationed public good ($G$). Equation (79) is the demand function for the public good. Equation (80) defines the share parameter of the public good. Solving equations (79) and (80) gives a value of $\beta_g$ of 0.149.
5. Other Parameters

Other parameters that are specific to the present study are the debt-asset ratio \( (\beta_q) \), the discount rate \( (d) \), the labor force participation rate \( (LPR) \), and the natural rate of increase of population \( (POPG) \). The values of these parameters are: \( \beta_q = 0.23 \) (Jorgenson and Yun, 1991), \( d = 0.05 \), \( LPR = 0.6 \), and \( POPG = 0.027 \).
A. Equal Yield

For evaluating tax policies, it is useful to employ the concept of equal-yield equilibria. Using this concept, we can compare an existing tax scheme with an alternative tax scheme that would result in the same level of tax revenue (Ballard et al., 1985). This applies not only to static models but also to dynamic models. There are two forms of yield equality that can be applied to dynamic models: a strong form and a weak form. The strong form of yield equality requires that the level of revenue generated in a given period by a particular tax policy be equal to the revenue level generated in the same period by an alternative tax policy. The weak form of yield equality requires that the present value of the sum of the stream of revenues obtained over all periods from a particular tax policy be equal to the value resulting from an alternative tax policy (Ballard et al., 1985). Also, as Pereira (1993) points out, the concept of yield equality needs to be refined to deal with government deficits. Specifically, the author
distinguishes between revenue neutrality and deficit neutrality.

The present study employs Pereira’s (1993) concept of deficit neutrality of a strong form. Specifically, the tax replacement scheme for each of the experiments below is a lump sum labor tax. Thus, when the state government has a deficit due to a tax cut, the amount of the deficit in the current period is levied on labor as a lump sum tax in the next period.

B. Experiments

In evaluating policy effects and calculating welfare changes for this study, the terminal period must be set. Because the transition path approaches a new steady state path only asymptotically (see Figure 2.1 in Chapter II), never reaching the new steady state path, the modeler must choose a terminal period. Depending on where the terminal period is set, the magnitude of welfare change will differ. Ballard et al. (1985, chapter 7) set the terminal period at the fiftieth year after the policy shock to measure approximate aggregate welfare gains of tax policy changes. In the present study, the terminal period is set at the fortieth period.

Policy changes are evaluated in a dynamic CGE framework by comparing continuous benchmark equilibria and continuous counterfactual equilibria. Policy effects on
variables in the present model are expressed in terms of aggregate percent change over time as compared to the continuous benchmark, i.e.,

\[
POLICY\ EFFECT = \frac{\sum_{t}^{T} [VAR_t^1 - VAR_t^0]}{\sum_{t}^{T} VAR_t}
\]

where \(VAR\) denotes a variable of interest, \(T\) denotes the terminal period, "1" denotes continuous counterfactual, and "0" denotes continuous benchmark. For welfare change, this study uses the measure of welfare change represented by equation (12) in Chapter II.

The tax rate is cut by thirty percent in each of the experiments below. It is assumed that the state government cuts the corporate income tax rates in the base year, maintains the lower tax rates for ten periods (years), and restores the tax rates to the pre-policy levels in period 11.

1. Derivation of a Balanced Growth Path for the Continuous Benchmark

The assumption that the economy is on a balanced growth path in the base year is crucial in dynamic CGE modeling. It is assumed that on the continuous benchmark path capital in each sector grows at the same steady-state rate as the rate at which labor (population) grows. Model
results based on this assumption show (i) that output, household consumption, investment, government expenditure, and real gross regional product grows at the same rate, (ii) that commodity prices stay at the base-year levels throughout forty periods, and (iii) that the after-tax wage rate, which is the determinant of labor migration in experiments 1 and 2 below, also stays at the base-year level. This indicates that on the continuous benchmark path, aggregate demand and aggregate supply grow at the same rate so that all prices stay at their base-year levels.

2. Experiment 1: Thirty Percent Reduction in Corporate Income Tax in Both Sectors

In this experiment, the corporate income tax rates are lowered by thirty percent in both industries. The lowered tax rates are maintained for ten periods. In the eleventh period, the state government is assumed to re-impose the pre-policy corporate income tax rates. The results are shown in Table 5.1 and Figures 5.1, 5.2, and 5.3.

As Figure 5.1 shows, on the continuous counterfactual path, net investment in sector 1 is larger than that on the continuous benchmark path for the first ten periods after the policy shock. From period 11 to period 22, net investment on the continuous counterfactual path is smaller than on the continuous benchmark path since in period 11,
Table 5.1  Effects of Corporate Tax Cut (in percentages)

<table>
<thead>
<tr>
<th>Net Investment (NI)</th>
<th>Labor In-migration (LMIG)</th>
<th>Employment (LTOT)</th>
<th>Real Gross Regional Product (RGRP)</th>
<th>Present Value of Welfare Gain (PVWG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.83</td>
<td>1.61</td>
<td>1.47</td>
<td>1.83</td>
<td>8.65</td>
</tr>
</tbody>
</table>

* The figure for LMIG in this table is the ratio of the number of in-migrants to base-year population in the region.
* The figure for PVWG in this table is the ratio of present value of welfare gain to base-year per capita expenditure.
Figure 5.1  Net Investment in Sector 1 (Experiment 1)
Figure 5.2    Real Gross Regional Product (Experiment 1)
Figure 5.3  Change in Real Gross Regional Product
(counterfactual minus Benchmark)
(Experiment 1)
the pre-policy corporate tax rates are re-imposed. From period 22 to the terminal period, the net investment on the continuous counterfactual path is larger than on the continuous benchmark path. This is because, after period 22, the accelerator effect (i.e., the change in investment due to the change in output) of the tax cut during the first ten years dominates the dampening of net investment that occurs when the pre-policy tax rate is restored in period 11. Although not reported in this study, similar results are observed for the effect of the tax cut on net investment in sector 2.

Figure 5.2 presents time-paths of real gross regional product for the continuous benchmark and counterfactual equilibria. Figure 5.3 shows the difference between real gross regional product in each period on the continuous counterfactual and continuous benchmark paths. The time path in Figure 5.3 goes up in the first 10 periods after the policy shock, decreases by a small amount in period 11, and begins to rise again at period 13. Table 5.1 summarizes the aggregate effects of the tax cut on the major economic variables over forty years. Aggregate net investment increases by 2.83 percent when compared to the continuous benchmark; aggregate net migration is 1.61 percent of base-year domestic population; real gross regional product increases by 1.83 percent; and the present value of welfare
gain is 8.65 percent of base-year per capita expenditure.

3. Experiment 2: Corporate Income Tax Cut with Public Capital in Production

I now use a version of the model in which the public good enters as an unpaid input (i.e., as public capital) in the production functions of the two industries. Production is assumed to exhibit constant returns to scale with respect to all inputs, including public capital. Results are shown in Table 5.2 and Figures 5.4, 5.5, 5.6, and 5.7.

Comparing Table 5.1 (from experiment 1) and Table 5.2 (from the present experiment), it is observed that the tax cut stimulates the state economy less if public capital affects the productivity of firms, as compared to the previous experiment in which public capital does not affect the productivity of firms. The tax cut with public capital in production causes net investment to decrease by 0.11 percent as compared to continuous benchmark. This is because the state government lowers its expenditure when revenues drop following the tax cut. The reduced expenditure lowers the level of public capital, lowering output, productivity of private capital, and thus, desired level of private capital. This diminishes the effect of the tax cut on net investment, and therefore, on the stock of private capital.
Table 5.2  Effects of Corporate Tax Cut with Public Capital in Production in Private Sectors (in percentages)

<table>
<thead>
<tr>
<th></th>
<th>Net Investment (ND)</th>
<th>Labor In-migration (LMIG)</th>
<th>Employment (LTOT)</th>
<th>Real Gross Regional Product (RGRP)</th>
<th>Present Value of Welfare Gain (PVWG)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.11</td>
<td>-0.18</td>
<td>0.14</td>
<td>0.14</td>
<td>3.29</td>
</tr>
</tbody>
</table>

* The figure for LMIG in this table is the ratio of the number of in-migrants to base-year population in the region.
* The figure for PVWG in this table is the ratio of present value of welfare gain to base-year per capita expenditure.
Figure 5.4 Net Investment in Sector 1 (Experiment 2)
Figure 5.5 Real Gross Regional Product (Experiment 2)
Figure 5.6  Change in Real Gross Regional Product  
(Counterfactual minus Benchmark)  
(Experiment 2)
Figure 5.7 Change in Public Capital Stock (Counterfactual minus Benchmark) (Experiment 2)
These results are shown by examining Figure 5.7 and by comparing Figure 5.1 (from experiment 1) with Figure 5.4 (from the present experiment). Figure 5.7 shows the difference between the public capital stock in each period on the continuous counterfactual and the continuous benchmark paths. According to Figure 5.7, the reduced government expenditure due to tax cut lowers the level of public capital in the first ten periods. As the pre-policy tax rates are restored in period 11, the level of public capital stock goes up again in the following periods. Comparing Figure 5.1 (from experiment 1) with Figure 5.4 (from the present experiment), the tax cut with public capital has less effect on net investment than that without public capital.

Figure 5.5 presents time-paths of real gross regional product for the continuous benchmark and continuous counterfactual equilibria. The comparison of Figure 5.6 (from the present experiment) with Figure 5.3 (from experiment 1) shows that the effect of tax cut on real gross regional product is reduced with public capital in production. In experiment 1, the biggest difference between real gross regional product on the continuous counterfactual and the continuous benchmark paths is about 8.5 billion dollars (see Figure 5.3) recorded in period 11 while the biggest difference in the present experiment is only about 2.9 billion dollars in the same period (see Figure 5.6). In
comparing these two figures, from period 11 on, while the difference goes up steadily in Figure 5.3 (experiment 1), the difference goes down and drops below zero in period 25 in Figure 5.6 (the present experiment). This indicates that real gross regional product on the continuous counterfactual path in the present experiment is lower from period 25 onward compared to the continuous benchmark path (see Figure 5.5).

In summary, in the present experiment, the tax cut in effect during the first ten years induces two opposing effects: (i) a decrease in public capital (shown in Figure 5.7) and (ii) an increase in aggregate private capital stock. These two effects are offsetting so that the tax cut policy with public capital in private production has relatively little net effect on the key variables in the model. The results of this experiment imply that to evaluate tax policy accurately, it is necessary to correctly analyze (i) the magnitude of the contribution of public capital to changes in the productivity of private inputs, and (ii) the relationship among tax policy, the government spending rule, and changes in the level of public capital.
4. Experiment 3: *Corporate Income Tax Cut with a Public Good in Household Consumption*

I now use a version of the model in which a public good enters the household utility function. In this version, labor migration is determined by per capita utility differentials between regions. Therefore, the changes in the level of the public goods influence migration flows. Results are shown in Table 5.3 and Figures 5.8, 5.9, 5.10, 5.11, and 5.12.

Comparison of Tables 5.1 and 5.3 shows that the tax cut is less effective if migration decisions are influenced by the level of public goods. The tax cut now causes net investment to increase by 1.46 percent as compared to the continuous benchmark (see Table 5.3).

The tax cut induces labor to out-migrate in the initial periods after the new tax rate is implemented (see Figure 5.11). The tax cut lowers state government revenue which, in turn, lowers the quantity of the public good (see Figure 5.12). Households obtain lower utility from residing in the state as compared to the continuous benchmark path. As time goes on, however, the positive effect of the tax cut (i.e., the increase in net investment, output, and per capita disposable income) starts to outweigh the negative effect of the reduction in the public good. From period 6 onward, there is a net inflow of migrants (see Figure 5.11).
Table 5.3 Effects of Corporate Tax Cut with Public Good in Household Consumption (in percentages)

<table>
<thead>
<tr>
<th>Net Investment (NI)</th>
<th>Labor In-migration (LMIG)</th>
<th>Employment (LTOT)</th>
<th>Real Gross Regional Product (RGRP)</th>
<th>Present Value of Welfare Gain (PVWG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.46</td>
<td>0.99</td>
<td>0.63</td>
<td>1.02</td>
<td>4.96</td>
</tr>
</tbody>
</table>

* The figure for LMIG in this table is the ratio of the number of in-migrants to base-year population in the region.
* The figure for PVWG in this table is the ratio of present value of welfare gain to base-year per capita expenditure.
Figure 5.8 Net Investment in Sector 1 (Experiment 3)
Figure 5.9  Real Gross Regional Product (Experiment 3)
Figure 5.10 Change in Real Gross Regional Product (Counterfactual minus Benchmark) (Experiment 3)
Figure 5.11  Labor Migration (Experiment 3)
Figure 5.12 Change in Public Good Flow (Counterfactual minus Benchmark) (Experiment 3)
In period 11, when the state government restores the tax rates to pre-policy levels, labor in-migration rises because the increased state government revenue during this period implies an increased public good provision (see Figure 5.12). From period 12 onward, the rate of labor in-migration decreases, ultimately converging to zero as time goes on. Labor in-migration over 40 years amounts to 0.99 percent of base-year population (see Table 5.3), an amount that is smaller than that in experiment 1 (see Table 5.1).

As Figure 5.11 shows, household response to the policy shock is quite strong. This is because the present study assumes a lag of only one period in labor migration function to illustrate clearly how households respond to the policy shock. Multiple lags can be introduced in a future study. The model results for net investment in sector 1 and real gross regional product are shown in Figures 5.8, 5.9, and 5.10.

C. Sensitivity Analysis

Model results depend upon the number of solution periods beyond the base year because the policy-induced transition path approaches the new steady state only asymptotically (Ballard et al., 1985). In the experiments above, the terminal period is set at the fortieth period (year) after policy implementation. Because the choice of the terminal period is arbitrary, there is no guarantee that
the welfare changes calculated using equation (12) and the policy effects calculated using equation (81) are complete. Even at the terminal period, the economy may still be on the sharply increasing portion of transition path. Therefore, the model results will vary depending on where the terminal period is set. Thus, it is appropriate to examine how sensitive the model results are to the number of solution periods.

This section analyzes the sensitivity of the welfare gain to the number of solution periods. Table 5.4 represents the present value of welfare gain for the aggregate representative consumer calculated for alternative terminal periods. The table shows that as the number of solution periods is increased, the approximated value of the welfare gain decreases and converges to a certain value (13,578 million dollars in period 50). Thus, if we set the terminal period at, for example, period 15, then the welfare gain (17,796 million dollars in period 15) overestimates the true welfare gain (13,578 million dollars in period 50) by a large amount (31.07 percent). The table shows that after period 40 the present value of the welfare gain changes very little. It is concluded, therefore, that the welfare gain calculated for the experiments above do not overestimate the true welfare gain generated by the policy.
Table 5.4 Present Value of Welfare Gain (PVWG)

<table>
<thead>
<tr>
<th>Terminal Period</th>
<th>PVWG (in $ millions)</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>17,796</td>
<td>11.33</td>
</tr>
<tr>
<td>20</td>
<td>14,595</td>
<td>9.29</td>
</tr>
<tr>
<td>25</td>
<td>13,821</td>
<td>8.80</td>
</tr>
<tr>
<td>30</td>
<td>13,635</td>
<td>8.68</td>
</tr>
<tr>
<td>35</td>
<td>13,591</td>
<td>8.65</td>
</tr>
<tr>
<td>40</td>
<td>13,581</td>
<td>8.65</td>
</tr>
<tr>
<td>45</td>
<td>13,578</td>
<td>8.64</td>
</tr>
<tr>
<td>50</td>
<td>13,578</td>
<td>8.64</td>
</tr>
</tbody>
</table>

* The percentage change is calculated as ratio of PVWG to base-year aggregate household expenditure.
A. Summary and Conclusions

One of the economic development policies that state and local governments use is to provide tax incentives to firms. In this dissertation, a dynamic CGE model is employed to analyze the effect of a corporate tax abatement on a regional economy. The dynamics in the model are relatively simple, yet they serve to illustrate how capital and labor accumulation can be influenced by regional policies. Policy effects are evaluated from a dynamic perspective.

The main objective of this dissertation was to build a multi-period, multisectoral model for assisting state and local policy-makers in understanding how tax reduction influences major economic variables and, thereby, in implementing economic development policies. Innovative features of this study, which distinguish this study from other CGE models, are (i) use of the concept of cost of capital, (ii) detailed specification of net investment, (iii) dynamic adjustment mechanisms in factor markets, and
(iv) incorporation of public goods in household consumption and/or firms' production.

When multiple factors influencing growth are taken into account, regional policies may be less effective than policymakers expect. Analysis of the model results suggests that the stimulatory effects of tax abatements for economic development are muted when the effects of public expenditures on the productivity of private capital and the migration of households are taken into account.

Effects of a tax cut depend much on whether or not public capital is incorporated as an unpaid input in production. Effects of a tax cut are smaller with public capital in production than without it because the tax cut lowers the level of public investment in each period as compared to continuous benchmark, reducing the public capital stock as an unpaid input in private industries, and reducing the productivity of private capital.

The inclusion of a public good in household utility and migration functions results in smaller effects of a tax cut than without the public good. This is because the lower level of public goods provision due to tax cut induces some people to out-migrate in the initial several periods after the policy shock.

While these results are not surprising, regional economists have lacked an empirical general equilibrium
framework that allows examination of the growth impacts of both taxation and public expenditures.

A sensitivity test for the number of solution periods shows that the present value of welfare gains calculated for this study is close enough to the value implied by a new actual steady-state path. This implies that the welfare gains approximated in this study do not overestimate much the true welfare gains.

Finally, a caveat is in order. The "accounting stance" in this study is regional rather than interregional. This study ignores interregional spillovers that arise in a federalist system when policies in one region affect households in another region. For example, this study ignores the fact that migration into Ohio represents a loss of productive labor and hence a potential reduction in growth in other regions of the country. This simplification may be justified in considering policies from the standpoint of state policymakers, but for national-level evaluation of state policies, a multiregional framework should be developed.

B. Future Research Initiatives

This study employs simple dynamics to illustrate key channels through which tax cuts affect regional growth. As a consequence of this simplicity, policy changes in the present model induce shifts in net investment and migration
that are probably unrealistically rapid. A future study can introduce lags into the net investment and migration functions in the present model. By making net investment a function of the gap between desired and actual capital over several previous periods, it is anticipated that investment changes will be less sudden and less extreme. Similarly, making migration a function of lagged interregional utility differences will smooth the flow of migration and avoid the rapid, discontinuous changes shown in Figure 14 in Chapter V.

This study examines the effects of public expenditures on firms in one model version (Experiment 2) and the effects on households in another version (Experiment 3). A future study can develop a model version in which both firms and households are influenced by public expenditures. Theory and observation suggest that public expenditures affect the location of firms and households jointly.

This study examines the sensitivity of the present model's welfare measure to changes in the terminal period. Future research can explore more fully the sensitivity of the model results to change in major parameters.
REFERENCES


Industrial Development and Site Selection Handbook 154 (Jan.-Feb. 1985): pp. 52-54


### APPENDICES

#### A. Social Accounting Matrix and Sectoral Aggregation

**Table A.1 Social Accounting Matrix for OCGE**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Activity</td>
<td>Gross Output</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Commodity</td>
<td>Intermed iate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Labor</td>
<td>Labor Factor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Capital</td>
<td>Capital Factor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Household</td>
<td>Resident L.</td>
<td>Resident K.</td>
<td></td>
<td>Transfer to HH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Gov't</td>
<td>Indirect Corp.</td>
<td></td>
<td>Personal</td>
<td></td>
<td>Transfer to Gov.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Savings-Investment</td>
<td>Depreciation</td>
<td></td>
<td>Household</td>
<td></td>
<td>SL Gov</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. ROW</td>
<td>Imports</td>
<td>Leak.(L)</td>
<td>Leak.(K)</td>
<td></td>
<td>Fed Gov</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Kraybill and Pai (1995)
Table A.2  Social Accounting Matrix for Ohio, 1990 (in millions of 1990 $U.S.)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Activity</td>
<td>417709</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>197567</td>
<td>417709</td>
</tr>
<tr>
<td>2. Commodity</td>
<td>180819</td>
<td></td>
<td></td>
<td></td>
<td>157082</td>
<td>41812</td>
<td>35292.49</td>
<td></td>
<td>612573</td>
</tr>
<tr>
<td>3. Labor</td>
<td>149109</td>
<td></td>
<td></td>
<td></td>
<td>44885</td>
<td>34048</td>
<td></td>
<td></td>
<td>74137</td>
</tr>
<tr>
<td>4. Capital</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>43382</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Household</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Gov't</td>
<td>15923</td>
<td></td>
<td></td>
<td></td>
<td>4662</td>
<td>10170</td>
<td></td>
<td></td>
<td>74137</td>
</tr>
<tr>
<td>7. Savings-Investment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17323</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Rest-of-the U.S.</td>
<td>194865</td>
<td>7455</td>
<td>4987</td>
<td></td>
<td>220586</td>
<td>10170</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Total</td>
<td>417709</td>
<td>612573</td>
<td>149109</td>
<td>71857</td>
<td>220586</td>
<td>74137</td>
<td></td>
<td></td>
<td>195767</td>
</tr>
</tbody>
</table>

Source: Kraybill and Pai (1995)
Table A.3  Mapping of IMPLAN 528 sectors into 2 sectors

<table>
<thead>
<tr>
<th>Sectors in Implan SAM</th>
<th>Mapped into</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sector 001-432, Sector 516 and Sector 524</td>
<td>Goods-Producing</td>
</tr>
<tr>
<td>Sector 433-515, Sector 517-523, and Sector 525-528</td>
<td>Service-Producing</td>
</tr>
</tbody>
</table>

Source: Kraybill and Pai (1995)
### B. Parameter Values

#### Table B.1 Parameter Values

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A_i )</td>
<td>Armington function shift parameter</td>
<td>1.986 (sector 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.950 (sector 2)</td>
</tr>
<tr>
<td>( \delta_i )</td>
<td>Armington function share parameter</td>
<td>0.532 (sector 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.420 (sector 2)</td>
</tr>
<tr>
<td>( \rho_i )</td>
<td>Armington function exponent</td>
<td>-0.718 (sector 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.500 (sector 2)</td>
</tr>
<tr>
<td>( v_i )</td>
<td>Elasticity of substitution between imports and local goods</td>
<td>3.546 (sector 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.000 (sector 2)</td>
</tr>
</tbody>
</table>

#### Import Demand

| \( \phi_i \) | Production function shift parameter                      | 0.133 (sector 1)       |
|              |                                                          | 0.060 (sector 2)       |
| \( \alpha_i \) | Labor share                                               | 0.624 (sector 1)       |
|                |                                                          | 0.707 (sector 2)       |
| \( \kappa_i \) | Capital share                                             | 0.376 (sector 1)       |
|                |                                                          | 0.293 (sector 2)       |
| \( \nu_i \) | Indirect tax rates                                        | 0.012 (sector 1)       |
|                |                                                          | 0.066 (sector 2)       |

#### Production

#### Export Supply

| \( A_i \) | CET function shift parameter                             | 2.030 (sector 1)       |
|            |                                                          | 2.274 (sector 2)       |
| \( \psi_i \) | CET function share parameter                            | 0.450 (sector 1)       |
|             |                                                          | 0.776 (sector 2)       |
| \( \theta_i \) | CET function exponent                                    | 1.345 (sector 1)       |
|            |                                                          | 2.429 (sector 2)       |
| \( \Lambda_i \) | Elasticity of transformation                            | 2.899 (sector 1)       |
|            |                                                          | 0.700 (sector 2)       |
(Table B.1 continued)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Consumption</strong></td>
<td></td>
</tr>
<tr>
<td>$\beta_i$</td>
<td>Expenditure share</td>
<td>0.257 (sector 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.743 (sector 2)</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Elasticity of substitution</td>
<td>1.100</td>
</tr>
<tr>
<td></td>
<td><strong>Public Good</strong></td>
<td></td>
</tr>
<tr>
<td>$\epsilon_i$</td>
<td>Public capital elasticity of output</td>
<td>0.200 (sector 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.200 (sector 2)</td>
</tr>
<tr>
<td>$\phi_i^z$</td>
<td>Production function shift parameter (with public capital)</td>
<td>0.176 (sector 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.091 (sector 2)</td>
</tr>
<tr>
<td>$\beta^z$</td>
<td>Share parameter for the public good</td>
<td>0.149</td>
</tr>
<tr>
<td>$\beta_i^g$</td>
<td>Expenditure share for good $i$ (with public good)</td>
<td>0.218 (sector 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.633 (sector 2)</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Depreciation rate for public capital</td>
<td>0.040</td>
</tr>
<tr>
<td></td>
<td><strong>Budget of Household</strong></td>
<td></td>
</tr>
<tr>
<td>LTX</td>
<td>Local income tax rate</td>
<td>0.001</td>
</tr>
<tr>
<td>STX</td>
<td>State income tax rate</td>
<td>0.032</td>
</tr>
<tr>
<td>FTX</td>
<td>Federal income tax rate</td>
<td>0.108</td>
</tr>
<tr>
<td>WLEAKR</td>
<td>Labor income leakage rate</td>
<td>0.050</td>
</tr>
<tr>
<td>RLEAKR</td>
<td>Capital income leakage rate</td>
<td>0.100</td>
</tr>
<tr>
<td>sstr</td>
<td>Social security tax rate</td>
<td>0.130</td>
</tr>
<tr>
<td></td>
<td><strong>Budgets of State and Local Governments</strong></td>
<td></td>
</tr>
<tr>
<td>LOCIBT</td>
<td>Local gov’t indirect business tax share</td>
<td>0.000</td>
</tr>
<tr>
<td>STIBT</td>
<td>State gov’t indirect business tax share</td>
<td>0.847</td>
</tr>
<tr>
<td>LOCFLAGS</td>
<td>Local gov’t demand sectoral share</td>
<td>0.290 (sector 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.710 (sector 2)</td>
</tr>
</tbody>
</table>
### Table B.1 continued

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>STGLES</td>
<td>State gov't demand sectoral share</td>
<td>0.290 (sector 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.710 (sector 2)</td>
</tr>
<tr>
<td>LOCTDRT</td>
<td>Ratio of local gov't expenditure on private goods to its revenue</td>
<td>0.587</td>
</tr>
<tr>
<td>STTDRT</td>
<td>Ratio of state gov't expenditure on private goods to its revenue</td>
<td>0.567</td>
</tr>
<tr>
<td>LSRAT</td>
<td>Ratio of local transfer to state gov't to its expenditure</td>
<td>0.010</td>
</tr>
<tr>
<td>SLRAT</td>
<td>Ratio of state transfer to local gov't to its expenditure</td>
<td>0.147</td>
</tr>
</tbody>
</table>

Federal Government

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEDIBT</td>
<td>Federal gov't indirect business tax share</td>
<td>0.153</td>
</tr>
<tr>
<td>FEDGLES</td>
<td>Federal gov't demand sectoral share</td>
<td>0.566 (sector 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.434 (sector 2)</td>
</tr>
<tr>
<td>FEDTDRT</td>
<td>Ratio of federal gov't expenditure on private goods to its revenue</td>
<td>0.319</td>
</tr>
<tr>
<td>FSRAT</td>
<td>Ratio of federal transfer to state gov't to its expenditure</td>
<td>0.078</td>
</tr>
<tr>
<td>FLRAT</td>
<td>Ratio of federal transfer to local gov't to its expenditure</td>
<td>0.043</td>
</tr>
<tr>
<td>Symbol</td>
<td>Parameter description</td>
<td>Value</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>LME</td>
<td>Labor migration elasticity</td>
<td>0.105</td>
</tr>
<tr>
<td>ur</td>
<td>Natural rate of unemployment</td>
<td>0.057</td>
</tr>
<tr>
<td>POPG</td>
<td>Natural rate of growth of the population</td>
<td>0.027</td>
</tr>
<tr>
<td>i</td>
<td>Interest rate</td>
<td>0.060</td>
</tr>
<tr>
<td>β_q</td>
<td>Debt-asset ratio</td>
<td>0.230</td>
</tr>
<tr>
<td>t_q</td>
<td>Combined federal, state, and local government corporate income tax rate</td>
<td>0.380</td>
</tr>
<tr>
<td>k_q</td>
<td>Investment tax credit rates</td>
<td>0.000</td>
</tr>
<tr>
<td>z_q</td>
<td>Present value of capital consumption allowances on a new asset</td>
<td>0.460</td>
</tr>
<tr>
<td>t_pq</td>
<td>Property tax rate on corporate assets</td>
<td>0.010</td>
</tr>
<tr>
<td>r</td>
<td>Rate of return on corporate capital</td>
<td>0.060</td>
</tr>
<tr>
<td>q</td>
<td>Depreciation rate</td>
<td>0.040</td>
</tr>
<tr>
<td>λ_1</td>
<td>Speed of stock adjustment</td>
<td>0.302</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.302</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>Discount rate</td>
<td>0.050</td>
</tr>
<tr>
<td>LPR</td>
<td>Labor force participation rate</td>
<td>0.060</td>
</tr>
</tbody>
</table>

Source: Kraybill and Pai (1995)

* Tax rates on capital are from Jorgenson and Yun (1991, p. 90, p. 95, and p. 103)
### C. List of Variables

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi_i$</td>
<td>Inflation rate of sector i's capital good</td>
</tr>
<tr>
<td>CAPIN</td>
<td>Capital inflow</td>
</tr>
<tr>
<td>CAPY</td>
<td>Household capital earnings net of all firm-level taxes</td>
</tr>
<tr>
<td>CFG$_i$</td>
<td>Federal government demand for good i</td>
</tr>
<tr>
<td>C$_i$</td>
<td>Representative consumer’s demand for good i</td>
</tr>
<tr>
<td>CITF$_i$</td>
<td>Corporate income taxes collected by federal gov’t</td>
</tr>
<tr>
<td>CIT$_i$</td>
<td>Total corporate income taxes paid by sector i</td>
</tr>
<tr>
<td>CITL$_i$</td>
<td>Corporate income taxes collected by local gov’t</td>
</tr>
<tr>
<td>CITS$_i$</td>
<td>Corporate income taxes collected by state gov’t</td>
</tr>
<tr>
<td>CLG$_i$</td>
<td>Local government purchase of good i</td>
</tr>
<tr>
<td>CNI$_{i,j}$</td>
<td>Quantity of sector j’s use of good i for net investment</td>
</tr>
<tr>
<td>CREDITS</td>
<td>State government tax credit given to firms in Ohio</td>
</tr>
<tr>
<td>CRI$_{i,j}$</td>
<td>Quantity of sector j’s use of good i for replacement investment</td>
</tr>
<tr>
<td>CSG$_i$</td>
<td>State government demand for good i</td>
</tr>
<tr>
<td>DEPR$_i$</td>
<td>Depreciation allowance in sector i</td>
</tr>
<tr>
<td>DEPRT</td>
<td>Total depreciation allowance in the economy</td>
</tr>
<tr>
<td>D$_i$</td>
<td>Quantity of locally produced and consumed good i</td>
</tr>
<tr>
<td>DK$_i$</td>
<td>Volume of investment by sector of destination</td>
</tr>
<tr>
<td>DST$_i$</td>
<td>Inventory investment in sector i</td>
</tr>
<tr>
<td>DV$_i$</td>
<td>Dividend payment in sector i</td>
</tr>
<tr>
<td>DYH</td>
<td>Disposable income</td>
</tr>
</tbody>
</table>
e  Expenditure function
E_i  Quantity of exported good i
ER  Exchange rate
EV  Equivalent variation
FEDGDTOT  Federal government expenditure on commodities
FGEXP  Total federal government expenditure
FGREV  Federal government revenue
FSAV  External savings
FTR  Federal government transfers to households
G  Level of public good provision
GK  Level of public capital stock
GKU  Level of public capital stock in the next period
GRP  Gross regional product at market prices
GSF  Federal government savings
GSL  Local government savings
GSS  State government savings
GSSL  Combined state and local government savings
HEXP  Household expenditure
HSAV  Household savings
INTDi  Intermediate demand for good i
INTTi  Interest payment to capital owners in sector i
ITFi  Indirect tax payment to federal government
ITi  Indirect tax payment per unit of output
ITLi  Indirect tax payment to local government
ITOT  Total value of investment
ITSi  Indirect tax payment to state government
\( KD_i \quad \text{Desired level of capital} \\
KD_{U_i} \quad \text{Desired level of capital in the next period} \\
K_i \quad \text{Actual level of capital} \\
KTOT \quad \text{Total capital stock in the economy} \\
KU_i \quad \text{Actual level of capital in the next period} \\
LABY \quad \text{Household labor earnings net of leakage and social security taxes} \\
LGEXP \quad \text{Total local government expenditures} \\
LGREV \quad \text{Local government revenue} \\
L_i \quad \text{Labor employment in sector i} \\
LMIG \quad \text{Net labor in-migration} \\
LOCGDTOT \quad \text{Local government expenditures on commodities} \\
LS \quad \text{Labor supply} \\
LSU \quad \text{Labor supply in the next period} \\
LSUMT \quad \text{Lump sum tax or subsidy} \\
LTOT \quad \text{Aggregate labor demand in the economy} \\
LTR \quad \text{Local government transfers to households} \\
M_i \quad \text{Quantity of imported good i} \\
ND_{i,j} \quad \text{Quantity of sector j's use of intermediate good i} \\
NI^{db} \quad \text{Debt portion of net investment} \\
NI^{eq} \quad \text{Equity portion of net investment} \\
NI_i \quad \text{Net investment} \\
NS_i \quad \text{New share issues in sector i} \\
PCEX \quad \text{Per capita expenditure} \\
PD_i \quad \text{Price of locally produced and consumed good i} \\
PE_i \quad \text{Price of exported good i} \)
PK_i: Price of a unit of sector-specific capital
PKP_i: Price of capital good in the previous period
PM_i: Price of imported good i
POP: Population
PQ_i: Price of composite good i
PROPI: Total property tax payment by sector i
PROPL_i: Property tax payment by sector i (local gov’t)
PROPS_i: Property tax payment by sector i (state gov’t)
PVEX: Present value of per capita expenditure
PV_i: Net price of a unit of value-added in sector i
PVWG: Present value of welfare gain
PWE_i: World price of exported good i
PWM_i: World price of imported good i
PX_i: Output price of good i
PZ_i: Price of domestic commodity output
Q_i: Quantity of composite good i
r: Average Rate of return
RET_i: Retained earnings
RGRP: Real gross regional product
RI_i: Replacement investment
rpc_i: Rental price of capital
SGEXP: Total state government expenditures
SGREV: State government revenue
STGDTOT: State government expenditures on commodities
STR: State government transfers to households
TB_i: Tax base for corporate income tax
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCNI&lt;sub&gt;i&lt;/sub&gt;</td>
<td>Aggregate demand for good i for net investment</td>
</tr>
<tr>
<td>TCRG&lt;sub&gt;i&lt;/sub&gt;</td>
<td>Combined federal, state, and local gov’t demand for good i</td>
</tr>
<tr>
<td>TCRI&lt;sub&gt;i&lt;/sub&gt;</td>
<td>Aggregate demand for good i for replacement investment</td>
</tr>
<tr>
<td>TCTI&lt;sub&gt;i&lt;/sub&gt;</td>
<td>Aggregate investment demand for good i</td>
</tr>
<tr>
<td>TIME</td>
<td>Time variable</td>
</tr>
<tr>
<td>TRAFL</td>
<td>Federal transfers to local government</td>
</tr>
<tr>
<td>TRAFS</td>
<td>Federal transfers to state government</td>
</tr>
<tr>
<td>TRALS</td>
<td>Local transfers to state government</td>
</tr>
<tr>
<td>TRASL</td>
<td>State transfers to local government</td>
</tr>
<tr>
<td>TRET</td>
<td>Total retained earnings</td>
</tr>
<tr>
<td>TSAV</td>
<td>Total savings</td>
</tr>
<tr>
<td>U</td>
<td>Utility</td>
</tr>
<tr>
<td>VNI&lt;sub&gt;i&lt;/sub&gt;</td>
<td>Total value of net investment</td>
</tr>
<tr>
<td>VNI&lt;sub&gt;i&lt;/sub&gt;&lt;sup&gt;db&lt;/sup&gt;</td>
<td>Value of debt-financed net investment</td>
</tr>
<tr>
<td>VNI&lt;sub&gt;i&lt;/sub&gt;&lt;sup&gt;eq&lt;/sup&gt;</td>
<td>Value of equity-financed net investment</td>
</tr>
<tr>
<td>W</td>
<td>Wage rate</td>
</tr>
<tr>
<td>WAFTL</td>
<td>After-tax wage rates</td>
</tr>
<tr>
<td>X&lt;sub&gt;i&lt;/sub&gt;</td>
<td>Industry output in sector i</td>
</tr>
<tr>
<td>YCAP&lt;sub&gt;i&lt;/sub&gt;</td>
<td>Gross capital income</td>
</tr>
<tr>
<td>YX</td>
<td>Income leakage from Ohio to ROW</td>
</tr>
<tr>
<td>Z&lt;sub&gt;i&lt;/sub&gt;</td>
<td>Commodity output</td>
</tr>
</tbody>
</table>
D. List of Equations

**PRICES**

Definition of domestic import prices

\[ PM_i = P_{WM_iER} \]  \hspace{1cm} (1)

Definition of domestic export prices

\[ PE_i = P_{WE_iER} \]  \hspace{1cm} (2)

Definition of composite good prices

\[ PQ_iQ_i = PD_iD_i + PM_iM_i \]  \hspace{1cm} (3)

Definition of domestic sales prices

\[ PD_iD_i = PZ_iZ_i - PE_iE_i \]  \hspace{1cm} (4)

Definition of domestic industry prices

\[ PX_i = \sum_j \Delta_{i,j}PZ_j \]  \hspace{1cm} (5)

(Here, \( \Delta_{i,j} \) denotes row-sum normalized make matrix.)

Definition of activity prices

\[ PV_i = PX_i - \sum_j a_{j,i}PQ_j - itr_iPX_i \]  \hspace{1cm} (6)

(Here, \( a_{j,i} \) denotes technical coefficients.)

Definition of capital goods prices

\[ PK_i = \sum_j PQ_jh_{j,i} \]  \hspace{1cm} (7)

(Here, \( h_{j,i} \) denotes capital composition matrix.)
Inflation rate of capital goods prices

$$\pi_i = \frac{PK_i - PKP_i}{PKP_i}$$

\[ (8) \]

INPUT DEMAND AND PRODUCTION

Labor demand function

$$L_d = \frac{a_i PV_i X_i}{W}$$

\[ (9) \]

Rental price of capital

$$r_{PC_i} = \frac{(1-k_q-t_q z_q) PK_i [r_i - \pi_i + (1+\pi_i) q] + t_p q_{PK_i}}{(1-t_q)}$$

\[ (10) \]

Desired level of capital

$$KD_i = \frac{k_i PV_i X_i}{r_{PC_i}}$$

\[ (11) \]

Intermediate demand of sector \( j \) for good \( i \)

$$ND_{i,j} = a_{i,j} X_j$$

\[ (12) \]

Definition of domestic commodity output

$$Z_d = \sum_j A_{j,i} X_j$$

\[ (13) \]

CET function

$$Z_d = A_i ^T [\psi_i E_i^{0_i} + (1-\psi_i) D_i^{0_i}]$$

\[ (14) \]
Production function

\[ X_i = \phi_i L_i^x K_i^y \]  \hspace{1cm} (15)

**HOUSEHOLD DEMAND FOR COMMODITIES**

Household consumption demand

\[ C_i = \frac{\beta_i HEXP}{P_{Q_i}} \sum_j \beta_j P_{Q_j}^{1-y} \]  \hspace{1cm} (16)

**INCOME BLOCK**

Gross capital income

\[ YCAP_i = P_{V_i} L_i^x - WL_i \]  \hspace{1cm} (17)

After-leakage labor income

\[ YL = (1-wleakr)(W)LTOT - LSUMT \]  \hspace{1cm} (18)

Interest income

\[ INTT_i = \delta_p (1-k_p-t_pz_p) P_{K_i} K_i \]  \hspace{1cm} (19)

Dividend income

\[ DV_i = TB_i - CIT_i - DEPR_i - RET_i \]  \hspace{1cm} (20)

Labor income net of leakage and social security tax

\[ LABY = YL(1-sstr) \]  \hspace{1cm} (21)

After-leakage capital income

\[ CAPY = (1\text{-rlleakr}) \sum_i [DV_i + INTT_i] \]  \hspace{1cm} (22)
Household disposable income

\[ DYH = (1 - TINCTR) [LABY + CAPY] + FTR + STR + LTR \]  

(23)

Household expenditure

\[ HEXP = DYH - HSAV \]  

(24)

Federal transfers to households

\[ FTR = (TRAFHPC) POP \]  

(25)

State transfers to households

\[ STR = (TRASHPC) POP \]  

(26)

Local transfers to households

\[ LTR = (TRALHPC) POP \]  

(27)

CORPORATE TAXES

Property tax

\[ PROP_i = t_p q(PK_i) K_i \]  

(28)

Tax base for corporate income tax

\[ TB_i = YCAP_i - INTT_i - PROP_i \]  

(29)

Corporate income tax

\[ CIT_i = t_q TB_i \]  

(30)
FEDERAL, STATE, AND LOCAL GOVERNMENTS

Federal government revenue

\[ FGREV = \text{FEDIBT} \sum_i \text{itr}_i \text{PX}_i \text{X}_i + \sum_t \text{t}_q \text{TB}_i \]  

\[ + \text{FTX(LABY + CAPY) + (sstr)_YL} \]  

(31)

Federal government expenditure

\[ FGEXP = \text{FEDGDTOT} + \text{TRAFS} + \text{TRAF} + \text{FTR} + \text{CREDITF} \]  

(32)

Federal government expenditure on commodities

\[ FEDGDTOT = (\text{FEDTDRT})FGREV \]  

(33)

Federal government demand for commodities

\[ PQCGI = \text{FEDGLES}_I FEDGDTOT \]  

(34)

State government revenue

\[ SGREV = \text{STIBT} \sum_i \text{itr}_i \text{PX}_i \text{X}_i + \sum_t \text{t}_q \text{TB}_i \]  

\[ + \text{STX(LABY + CAPY) + TRAF} + \text{TRALS + LSUMT} \]  

(35)

State government expenditure

\[ SGEXP = \text{STGDTOT} + \text{TRASL} + \text{STR} + \text{CREDITS} \]  

(36)

State government expenditure on commodities

\[ STGDTOT = (\text{STTDRT})SGREV \]  

(37)

State government demand for commodities

\[ PQCSGI = \text{STGLES}_I STGDTOT \]  

(38)
Local government revenue

\[
LGREV = LOCIBT \sum_i itr_i PX_i X_i + \sum_i t_q^i TB_i
\]  
\[+ LTX (LABY + CAPY) + t_p \sum_i PKP_i K_i + TRAFL + TRASL \tag{39}\]

Local government expenditure

\[
LGEXP = LOCGD Tot + TRALS + LTR \tag{40}\]

Local government expenditure on commodities

\[
LOCGD Tot = (LOCĐT) \cdot LGREV \tag{41}\]

Local government demand for commodities

\[
PQ_i CLG_i = LOCGLS_i \cdot LOCGD Tot \tag{42}\]

State government investment credit to firms

\[
CREDITS = \sum_i (k_q^e + t_q^e z_q) PK_i DK_i \tag{43}\]

Federal government investment credit to firms

\[
CREDITF = \sum_i (k_q^f + t_q^f z_q) PK_i DK_i \tag{44}\]

Federal transfers to state government

\[
TRAFS = (FSRAT) \cdot FGEXP \tag{45}\]

Local transfers to state government

\[
TRALS = (LSRAT) \cdot LGEXP \tag{46}\]
State transfers to local government

\[ TRASL = (SLRAT) SGEXP \]  \hspace{1cm} (47)

Federal transfers to local government

\[ TRAFL = (FLRAT) FGEXP \]  \hspace{1cm} (48)

**SAVINGS**

Household savings

\[ HSAV = (MPS) DYH \]  \hspace{1cm} (49)

Retained earnings

\[ RET_i = (1-\beta_g) (1-k_q-t_q z_q) PK_i N_i - \beta_g (1-k_q-t_q z_q) (PK_i - PK_i) K_i \]  \hspace{1cm} (50)

Total retained earnings

\[ TRET = \sum_i RET_i \]  \hspace{1cm} (51)

Depreciation allowance

\[ DEPR_i = q_i (1-k_q-t_q z_q) PK_i K_i \]  \hspace{1cm} (52)

Total depreciation in the economy

\[ DEPRT = \sum_i DEPR_i \]  \hspace{1cm} (53)

Federal government savings

\[ GSF = FGREV - FGEXP \]  \hspace{1cm} (54)
State government savings
\[ GSS = SGREV - SGEXP \]  (55)

Local government savings
\[ GSL = LGREV - LGEXP \]  (56)

Foreign savings
\[ FSAV = \sum_I PM_I M_I - \sum_I PE_I E_I + YX + GSF - CAPIN \]  (57)

Total savings
\[ TSAV = HSAV + TRET + DEPRT + GSS + GSL + (ER) FSAV \]  (58)

**INVESTMENT**

Replacement investment
\[ RI_I = \theta_I K_I \]  (59)

Investment by sector of destination
\[ DK_I = NI_I + RI_I \]  (60)

Investment by sector of origin
\[ TCTI_I = \sum_j h_{i,j} DK_j \]  (61)

Inventory
\[ DST_I = (dstrate) X_I \]  (62)

Value of total investment
\[ ITOT = \sum_I [PQ_I DST_I + PQ_I TCTI_I] \]  (63)
Value of firms' total investment expenditure

\[ ITOTF = ITOT - CREDITS - CREDITF \] (64)

**EXPORTS AND IMPORTS**

Export supply function

\[ E_i = \left( \frac{P E_i}{P D_i} \right)^{\Lambda_i} \left( \frac{1 - \Psi_i}{\Psi_i} \right)^{\Lambda_i} D_i \] (65)

CES function

\[ Q_i = A_i \left[ \delta_i M_i^{-\rho_i} + (1 - \delta_i) D_i^{-\rho_i} \right]^{\frac{1}{\rho_i}} \] (66)

Cost minimization function

\[ M_i = \left( \frac{P D_i}{P M_i} \right)^{\nu_i} \left( \frac{\delta_i}{1 - \delta_i} \right)^{\nu_i} D_i \] (67)

**LABOR MARKET AND POPULATION**

Per capita after-tax labor income

\[ WAFTL = \frac{(1 - TINCTR) LABY}{LTOT} \] (68)

Net labor in-migration

\[ LMIG = (LME) (LS) \log \left( \frac{WAFTL}{WAFTLW} \right) \] (69)

Updated level of labor supply

\[ LSU = LS(1 + POPG) + LMIG \] (70)
Population

\[ \text{POP} = \frac{LS}{LPR} \]  \hspace{1cm} (71)

**EQUILIBRIUM CONDITIONS**

Goods market equilibrium

\[ Q_i = C_i + \sum_j ND_{i,j} + TCTI_i + DST_i + CGF_i + CGS_i + CGL_i \]  \hspace{1cm} (72)

Total labor demand

\[ LTOT = \sum_i L_i \]  \hspace{1cm} (73)

Labor market equilibrium

\[ LTOT = (1-UR)LS + (1-UR)LMIG \]  \hspace{1cm} (74)

Savings-investment equilibrium

\[ TSAV = ITOTF \]  \hspace{1cm} (75)

**GROSS REGIONAL PRODUCT**

Gross regional product at market prices

\[ GRP = \sum_i [PV_iX_i + iTR_iPX_iX_i] \]  \hspace{1cm} (76)

Real gross regional product

\[ RGRP = \sum_i \left[ C_i + TCTI_i + DST_i + CGL_i + CGS_i + CGF_i + E_i - M_i \right] \]  \hspace{1cm} (77)
E. GAMS Code for the Dynamic Ohio CGE Model

This appendix presents GAMS code for the continuous benchmark in Experiment One. GAMS code for the counterfactual in Experiment One, the continuous benchmark and the counterfactual in Experiment Two, and the continuous benchmark and counterfactual in Experiment Three are available from the author or from Professor David Kraybill in the Department of Agricultural Economics, Ohio State University.

* ----------- OHIO DYNAMIC CGE MODEL ---------------
* MODEL 1: CONTINUOUS BENCHMARK
* NO PUBLIC GOOD

* TWO-SECTOR DYNAMIC REGIONAL CGE MODEL USING IMPLAN SAM DATA PLUS OTHER DATA
* ADAPTED FROM STATIC REGIONAL CGE MODEL BY KRAYBILL AND PAI, 1995

SET I INDUSTRIES /1
433
ALIAS(I,J);

SET H HOUSEHOLD /LOW
MED
HIGH
ALIAS(H,F);

SET ZC CONSUMPTION /LOW
MED
HIGH
FED
SL
ALIAS(I,J);
ALIAS(H,F);

SET ZI INVEST & TRD. /INVENT
CAPFORM
EXPORT
TIO
ALIAS(I,J);
ALIAS(H,F);

SET ZF FACTORS /EMPCOMP
IBT
PROPIHC
OPINC
EMPL
ALIAS(I,J);
ALIAS(H,F);

SET ZT TRADE /IMPORT
ALIAS(I,J);
ALIAS(H,F);

* OH90SAM DATA ***********************

TABLE T401(I,J) make matrix
1  213461.37  2893.51
433  19.45  201334.22

TABLE T402(I,J) industry transactions
1  88929.12  17757.43
433  38829.70  35303.18

TABLE T403A(I,ZC) regional consumption demand
LOW
MED
HIGH
FED
SL
1  5327.28  12699.43  22301.67  8121.36  7962.39
TABLE T403B(I,ZI) regional investment and trade demand

<table>
<thead>
<tr>
<th></th>
<th>INVENT</th>
<th>CAPFORM</th>
<th>EXPORT</th>
<th>TIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1094.48</td>
<td>31743.13</td>
<td>137189.87</td>
<td>213480.80</td>
</tr>
<tr>
<td>433</td>
<td>1047.05</td>
<td>1407.83</td>
<td>60378.69</td>
<td>204227.73</td>
</tr>
</tbody>
</table>

TABLE T404A(ZF,I) final payments (factor)

<table>
<thead>
<tr>
<th></th>
<th>EMPCOMP</th>
<th>PROPIHC</th>
<th>IBT</th>
<th>OPINC</th>
<th>EMPL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53689.98</td>
<td>4008.28</td>
<td>2576.30</td>
<td>28321.37</td>
<td>95419.16</td>
</tr>
<tr>
<td>433</td>
<td>95419.16</td>
<td>9489.78</td>
<td>13346.43</td>
<td>30037.72</td>
<td>95419.16</td>
</tr>
</tbody>
</table>

TABLE T404B(I,ZT) imports

<table>
<thead>
<tr>
<th></th>
<th>IMPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>119644.40</td>
</tr>
<tr>
<td>433</td>
<td>75220.14</td>
</tr>
</tbody>
</table>

* ASSIGN ECONOMIC LABELS TO OH90SAM FLOWS *

PARAMETERS

MAKERNORM(I,J) row-sum normalized make matrix

INDOUTPUT(I) total industry output

INTERMED(I,J) interindustry transactions

LABOR(I) sectoral employment

LABINCOME(I) wages

CAPINCOME(I) rents

ITAX(I) indirect tax payments

COMOUTPUT(I) total commodity output

CONSUME(I,H) consumption

FEDDEMAND(I) federal government purchases

SLDEMAND(I) state-local government purchases

INVENTORY(I) inventory investment

INVEST(I) investment

EXPORTS(I) exports

IMPORTS(I) imports

INTERMED(I,J) = T402(I,J);

LABINCOME(I) = T404A("EMPCOMP",I);

CAPINCOME(I) = T404A("PROPIHC",I) + T404A("OPINC",I);

LABOR(I) = T404A("EMPL",I);

ITAX(I) = T404A("ITB",I);

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do(I)</td>
<td>demand for domestic goods</td>
</tr>
<tr>
<td>DCRT</td>
<td>discount rate</td>
</tr>
<tr>
<td>DEFTA(I)</td>
<td>Armington fn share parameter</td>
</tr>
<tr>
<td>DEPR(I)</td>
<td>depreciation rate</td>
</tr>
<tr>
<td>DEPHIO(I)</td>
<td>depreciation in sector I in dollars</td>
</tr>
<tr>
<td>DPRTCH(I)</td>
<td>aggregate depreciation in the economy</td>
</tr>
<tr>
<td>DXo(I)</td>
<td>base-year volume of investment by sector of destination</td>
</tr>
<tr>
<td>DSTo(I)</td>
<td>base-year inventory</td>
</tr>
<tr>
<td>DIVo(I)</td>
<td>ratio of inventory investment to gross output</td>
</tr>
<tr>
<td>DVo(I)</td>
<td>disposable income</td>
</tr>
<tr>
<td>E(I)</td>
<td>base-year exports</td>
</tr>
<tr>
<td>ELASUB</td>
<td>elasticity of substitution in consumption of private goods</td>
</tr>
<tr>
<td>ERo</td>
<td>base-year exchange rate</td>
</tr>
<tr>
<td>EYNo</td>
<td>per capita expenditure</td>
</tr>
<tr>
<td>EYDo</td>
<td>per capita discounted expenditure</td>
</tr>
<tr>
<td>FEDGO(I)</td>
<td>base-year federal government purchases</td>
</tr>
<tr>
<td>FEDGTDo</td>
<td>federal government total demand</td>
</tr>
<tr>
<td>FEDGEPo</td>
<td>federal government expenditure</td>
</tr>
<tr>
<td>FEDGLES(I)</td>
<td>federal government demand sectoral share</td>
</tr>
<tr>
<td>FEDGEPo</td>
<td>federal government revenue</td>
</tr>
<tr>
<td>FEDIBT</td>
<td>indirect business tax share for federal gov’t</td>
</tr>
<tr>
<td>FEDDRT</td>
<td>ratio of total federal govt demand to its revenue</td>
</tr>
<tr>
<td>FINCR</td>
<td>tax rate on household incomes fed. gov’t</td>
</tr>
<tr>
<td>FSAT</td>
<td>ratio of fed. transfers to loc. gov’t to fed. gov’t exp.</td>
</tr>
<tr>
<td>FSRo</td>
<td>ratio of fed. transfers to st. gov’t to fed. gov’t exp.</td>
</tr>
<tr>
<td>GAMMA(I)</td>
<td>CET function parameter</td>
</tr>
<tr>
<td>GNCAP(I)</td>
<td>growth rate of capital in the base year</td>
</tr>
<tr>
<td>GRPo</td>
<td>nominal gross regional product</td>
</tr>
<tr>
<td>HEXPo</td>
<td>household expenditure</td>
</tr>
<tr>
<td>HHTFED(H)</td>
<td>tax rate on income of household H : fed. gov’t</td>
</tr>
<tr>
<td>HHTRLOC(H)</td>
<td>tax rate on income of household H : loc. gov’t</td>
</tr>
<tr>
<td>HHTRST(H)</td>
<td>tax rate on income of household H : st. gov’t</td>
</tr>
<tr>
<td>HHTR(H)</td>
<td>aggregate tax rate on income of household H</td>
</tr>
<tr>
<td>IDo(I)</td>
<td>base-year private investment</td>
</tr>
<tr>
<td>IGDSCHEK</td>
<td>sum of capital good composition shares</td>
</tr>
<tr>
<td>INCREDT(FED(I))</td>
<td>investment tax credit rate: fed. gov’t</td>
</tr>
<tr>
<td>INCREDT(ST(I))</td>
<td>investment tax credit rate: st. gov’t</td>
</tr>
<tr>
<td>INCREDT(LOC(I))</td>
<td>investment tax credit rate: loc. gov’t</td>
</tr>
<tr>
<td>INCREDT(I)</td>
<td>aggregate investment tax credit rate</td>
</tr>
<tr>
<td>INTO(I)</td>
<td>interest income</td>
</tr>
<tr>
<td>INFRo(I)</td>
<td>inflation rate of capital goods</td>
</tr>
<tr>
<td>ITIR</td>
<td>interest rate</td>
</tr>
<tr>
<td>ITAXR(I)</td>
<td>indirect tax rate</td>
</tr>
<tr>
<td>ITOTo</td>
<td>value of base-year total investment</td>
</tr>
<tr>
<td>ITOTDo</td>
<td>firms’ expenditure on total investment</td>
</tr>
<tr>
<td>KDo(I)</td>
<td>desired level of capital</td>
</tr>
<tr>
<td>KDUPo(I)</td>
<td>desired level of capital in the next period</td>
</tr>
<tr>
<td>KGDo(I)</td>
<td>capital stock in the current period</td>
</tr>
<tr>
<td>KGUC(I)</td>
<td>capital stock in the next period</td>
</tr>
<tr>
<td>KSHARE(I)</td>
<td>production function capital share coefficient</td>
</tr>
<tr>
<td>KSHR(I)</td>
<td>base-year share of investment by sector of destination</td>
</tr>
<tr>
<td>KSTO</td>
<td>total capital stock</td>
</tr>
<tr>
<td>LDo(I)</td>
<td>base-year sectoral labor demand</td>
</tr>
<tr>
<td>LINCR</td>
<td>tax rate on household income: loc. gov’t</td>
</tr>
<tr>
<td>LME</td>
<td>labor migration elasticity</td>
</tr>
<tr>
<td>LMO</td>
<td>labor in-migration</td>
</tr>
<tr>
<td>LOCBD(I)</td>
<td>base-year local government purchases</td>
</tr>
<tr>
<td>LOCCEXPO</td>
<td>local government total purchases</td>
</tr>
<tr>
<td>LOCCEPO</td>
<td>local government expenditure</td>
</tr>
<tr>
<td>LOCLES(I)</td>
<td>local government demand sectoral share</td>
</tr>
<tr>
<td>LOCGREPo</td>
<td>local government revenue</td>
</tr>
<tr>
<td>LOCIBT</td>
<td>indirect business tax share for local gov’t</td>
</tr>
<tr>
<td>LOCXRT</td>
<td>ratio of total local govt demand to its revenue</td>
</tr>
<tr>
<td>LPR</td>
<td>labor force participation rate</td>
</tr>
<tr>
<td>LSo</td>
<td>labor supply</td>
</tr>
<tr>
<td>LSHARE(I)</td>
<td>production function labor share coefficient</td>
</tr>
<tr>
<td>LSAT</td>
<td>ratio of loc. transfers to st. gov’t to loc. gov’t exp.</td>
</tr>
<tr>
<td>LSUMTo</td>
<td>lump sum tax or subsidy</td>
</tr>
<tr>
<td>LTOTo</td>
<td>regional labor demand</td>
</tr>
<tr>
<td>Mo(I)</td>
<td>imports</td>
</tr>
<tr>
<td>MPS</td>
<td>marginal propensity to consume</td>
</tr>
<tr>
<td>NDo(I,J)</td>
<td>intermediate demand</td>
</tr>
<tr>
<td>NFINo</td>
<td>net financial inflow</td>
</tr>
<tr>
<td>NILo(I)</td>
<td>net investment in units of capital good</td>
</tr>
<tr>
<td>NILo(I)</td>
<td>net investment in period 1</td>
</tr>
<tr>
<td>PQo(I)</td>
<td>composite price index</td>
</tr>
<tr>
<td>PDo(I)</td>
<td>price of domestic goods</td>
</tr>
</tbody>
</table>
# ASSIGN SHORT LABELS

\[ X_o(I) = IHDOUTPUT(I); \]
\[
Zo(I) = \sum J, \text{MAKERNORM}(J, I) \cdot Xo(J); \\
Lo(I) = \text{LABOR}(I); \\
NDo(I,J) = \text{INTERMED}(I,J); \\
Co(I) = \sum H, \text{CONSUME}(I,H); \\
DSTO(I) = \text{INVENTORY}(I); \\
IDo(I) = \text{INVEST}(I); \\
Mo(I) = \text{IMPORTS}(I); \\
FKGDo(I) = \text{FEDDEMAND}(I); \\
LOCDo(I) = 0.334 \cdot \text{SLDEMAND}(I); \\
STGDo(I) = \text{SLDEMAND}(I) - \text{LOCDo}(I);
\]

*CALIBRATION, ASSIGNMENT OF NUMBERS TO COEFFICIENTS, AND CALCULATION OF BASE-YEAR VALUES OF VARIABLES*

*CALCULATE PRODUCTION COST SHARES*
\[
A(I,J) = \text{INTERMBD}(I,J) / Xo(J); \\
ITAXR(J) = \text{ITAX}(J) / Xo(J); \\
PKP(I) = 1.0; \\
PKPo(I) = 1.0; \\
INFRO(I) = (PKo(I) - PKPo(I)) / PKPo(I); \\
ERo = 1.0; \\
PVo(I) = PXo(I) \cdot (1 - ITAXR(I)) - \sum J, A(J, I) \cdot PZo(J); \\
PWE(I) = PKo(I) / ERo; \\
PWM(I) = PMo(I) / ERo; \\
PWE(I) = PEo(I) / ERo;
\]

*BASE-YEAR TOTAL LABOR DEMAND AND WAGE RATE*
\[
LTOTo = \sum I, Lo(I); \\
WAGEo = 0.01;
\]

*TAX RATES ON CAPITAL INCOME AND RENTAL PRICE OF CAPITAL*
\[
BQ = 0.23; \\
CITRFED("1") = 0.15; \\
CITRFED("433") = 0.15; \\
CITRSTo("1") = 0.15; \\
CITRSTo("433") = 0.15; \\
CITRLOC("1") = 0.08; \\
CITRLOC("433") = 0.08; \\
CITRLF(I) = CITRFED(I) + CITRLOC(I); \\
INTR = 0.06; \\
INCRDSTFED(I) = 0.00; \\
INCRDSTST(I) = 0.00; \\
INCRDSTLOC(I) = 0.00; \\
INCRDST(I) = INCRDSTFED(I) + INCRDSTST(I) + INCRDSTLOC(I); \\
PVCCA(I) = 0.46; \\
DEPR(I) = 0.04; \\
PPTRLOC = 0.01; \\
RAR(I) = 0.05; \\
RPo(I) = (1 - INCRDST(I) - (CITRSTo(I) + CITRLF(I)) \cdot PVCCA(I)) \cdot (PKo(I) \cdot (RAR(I) \cdot DEPR(I) \cdot (1 - INFRO(I)))/(1 - CITRSTo(I)) - CITRST(I)) + PPTRLOC \cdot PKPo(I); \\
\]

*REGIONALLY PRODUCED OR IMPORTED GOODS*
\[
Bo(I) = Zo(I) + Mo(I) - \sum J, NDm(I,J) - Co(I) - LOCDo(I) - \text{STGDo}(I) - Do(I) - DSTO(I); \\
Do(I) = Zo(I) - Bo(I); \\
NDo(I) = Do(I) + Mo(I);
\]

*SET TRADE ELASTICITIES AND CALIBRATE*
\[
\text{RHO}(*1") = 1 + (1/2.9); \\
\text{RHO}(*433") = 1 + (1/0.7); \\
\text{GAMMA}(I) = 1/(1 + FDp(I)/PDo(I) \cdot (Bo(I)/Do(I))) \cdot (1/(1 + RHOC(I) - 1)); \\
\text{AT}(I) = Zo(I) / (GAMMA(I) \cdot Bo(I) \cdot RHOC(I) - (1 - GAMMA(I)) \cdot Do(I) \cdot RHOC(I)); \\
\text{RHO}(*1") = 1 + (1/3.5); \\
\text{RHO}(*433") = 1 + (1/2.0); \\
\text{DELTA}(I) = (PDo(I)/PDo(I)) \cdot (Mo(I)/Do(I)) \cdot (1 - RHOC(I)); \\
\text{DELTA}(*1") = \text{DELTA}(I) / (1 + \text{DELTA}(I)); \\
\text{TAU}(I) = Qo(I) / (\text{DELTA}(I) \cdot Mo(I) \cdot (1 - RHOC(I)) + (1 - \text{DELTA}(I)) *
Do(I)**((-RHOC(I))**(-1/RHOC(I)));  

* ********** ADJUSTMENT OF CAPITAL COMPOSITION MATRIX

SET  
RAS row-and-column sum elements /1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17, 
18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40 /;  

TABLE IMAT(RAS,I,J) capital composition matrix  
1 433  
1.1 0.7 0.7  
1.433 0.3 0.3  

KSHR(I) = Xo(I) / SUM(J,Xo(J));  
* DKo(I) = KSHR(I)*SUM(J,IDo(J));  
DKo("l") = 14915.172;  
DKo("433") = 18235.788;  

* DKo(I) calculated from the formula, DKo(I) = KSHR(I)*SUM(J,IDo(J)),  
* are 17170.757 and 15980.203 for sector 1 and sector 2, respectively.

PARAMETER HOLD1(RAS,I)  
PARAMETER HOLD2(RAS,J)  
PARAMETER TEMP(RAS,I,J)  
PARAMETER B(I,J) adjusted IMAT

LOOP(RAS,  
8(1,J) = IMAT(RAS,I,J);  
HOLD1(RAS,I) = SUH(J,IMAT(RAS,I,J)*DKo(J));  
TEMP(RAS,I,J) = IHAT(RAS,I,J)*IDo(I)/HOLD1(RAS,I);  
HOLD2(RAS,J) = SUH(I,TEMP(RAS,I,J));  
IMAT(RAS+1,I,J) = TEMP(RAS,I,J)/HOLD2(RAS,J);  

PARAMETER DIFFCOL(I)  
PARAMETER DIFFROW(J);  

DIFFCOL(I) = SUM(J,B(I,J)*DKo(J))-IDO(I);  
DIFFROW(J) = SUM(I,B(I,J))-1;  
DISPLAY DIFFCOL,DIFFROW;  

* ********** FACTOR SHARE IN PRODUCTION  
LSHARE(I) = Lo(I)*WAGEo/(PVo(I)*Xo(I));  
KSHARE(I) = 1 - LSHARE(I);  

* ********** CAPITAL AND INVESTMENT  
IDO(I) = SUM(J,B(I,J)*DKo(J));  
IToTo = SUM(I,IDo(I) + DSTo(I));  
GRCAP(I) = 0.027;  
KGuO(I) = KGo(I) + HIo(I);  
NIo(I) = GRCAP(I)*KGuO(I);  
KDo(I) = NIo(I)/ADJCOEF(I) + KGo(I);  
NiTo = SUM(I,KDo(I));  
Ro(I) = DEPR(I)*KDo(I);  

* ********** CALIBRATE PRODUCTION FUNCTION SHIFT PARAMETER  
AV(I) = Xo(I)/(Lo(I)**LSHARE(I))*(KGo(I)**KSHARE(I));  

* ********** INVESTMENT TAX CREDIT AND FIRMS' INVESTMENT EXPENDITURE  
CREDITSLo = SUM(I,(INCREDIST(I)+INCREDLOC(I)+(CITRSTG(I)+CTIRLOC(I))*PWCCA(I)*PKo(I)*DKo(I)));  
CREDITFo = SUM(I,(INCRDFTFED(I)+CITRSTFed(I)*PKo(I)*DKo(I)));  
IToTfo = IToTo - CREDITSLo - CREDITFo;  

* ********** TAX RATES ON HOUSEHOLD INCOME  
SSTR = (10795+8595)/149109;  
HHTRFed("LOW") = 0.075;  
HHTRFed("HED") = 0.072;  
HHTRFed("HIGH") = 0.124;  
HHTRSt("LOW") = 0.023;
*Using the income tax rates for each type of households, I calculated the tax rate for the aggregate representative household for each level of governments.*

```
*{{#### GOVERNMENT TRANSFERS TO HOUSEHOLDS}}
TRAFEDHHo("LOW") = 11526;
TRAFEDHHo("MED") = 6647;
TRAFEDHHo("HIGH") = 3952;
TRFHo = SUM(H,TRAFEDHHo(H));
TRASTHHo("LOW") = 2699*(1-0.354);
TRASTHHo("MED") = 5411*(1-0.354);
TRASTHHo("HIGH") = 3823*(1-0.354);
TRSHo = SUM(H,TRASTHHo(H));
TRALOCHHo("LOW") = 2699*0.354;
TRALOCHHo("MED") = 5411*0.354;
TRALOCHHo("HIGH") = 3823*0.354;
TRLHo = SUM(H,TRALOCHHo(H));

*{{#### INCOME LEAKAGE RATES}}
WLEAKR = 0.05;
RLEAKR = 0.1;

*{{#### LABOR INCOME, CAPITAL INCOME, AND SAVINGS}}
LSUMTo = 537.31;
YLo = (1-WLEAKR)*SUM(I, WAGEo*Lo(I)) - LSUMTo;
YCAPo(I) = PQo(I)*Xo(I) - Lo(I)*WAGEo;
INTo(I) = BQ*INTR*(1-INCRDT(I)-(CITRSTo(I)+CITRLF(I))*(PVCCA(I))*(PKo(I))*KGo(I);
PROPo(I) = PPTLOC*(PKo(I))*KGo(I);
TPo(I) = YCAPo(I)-INTo(I)-PROPo(I);
CITo(I) = (CITRSTo(I)+CITRLF(I))*TPo(I);
DEPRho(I) = DEPR(I)*(1-INCRDT(I)-(CITRSTo(I)+CITRLF(I))*(PVCCA(I))*(PKo(I))*KGo(I);
RETo(I) = (1-BQ)*(1-INCRDT(I)-(CITRSTo(I)+CITRLF(I))*(PVCCA(I))*(PKo(I))*KGo(I) - BQ*(1-INCRDT(I) - (CITRSTo(I)+CITRLF(I))*(PVCCA(I))*(PKo(I))*KGo(I)) - (1-TPo(I))*(PKo(I))*(PKo(I)-PKPo(I))*KGo(I);
DVo(I) = YHo*(1-LETRho(I)-INTo(I)));
DEPRBTo = SUM(I,DEPRho(I));
TRETo = SUM(I,RETo(I));
YHo = YTo*(1-LSR); 
YHo = (1-WLEAKR)*SUM(I,DVo(I)+INTo(I));
DYHo = (1-TINCTR)*(YHo+YHKo) + TRFHo + TRSHo + TRLHo;
DYPo = SUM(I,PQo(I)*Co(I));
SHo = DYHo - HEXPo;
MPS = SHo/DYHo;

*{{#### LABOR SUPPLY}}
UR = 0.057;
LSo = LToTo/(1-UR);

*{{#### CONSUMPTION DEMAND COEFFICIENT}}
ELASUB = 1.1;
ALPHA("1") = (-PQo("433")**((1-ELASUB))/((PQo("433")**((1-ELASUB))) - PQo("433")**((1-ELASUB))) - {HEXPo/Co("1")}*PQo("1")**ELASUB));
ALPHA("433") = 1-ALPHA("1") ;

*{{#### POPULATION}}
LPR = 0.6;
POPo = LSo/LPR;
POPS = POPo;

*{{#### PER CAPITA GOV'T TRANSFERS}}
TRAFHPC = TRFHo/POPo;
```
**Discount Rate and Time Variable**

\[ \text{DCNT} = 0.05 \]

\[ \text{TTIMO} = 0.0 \]

**Government Expenditure and Revenue**

\[ \text{FEDIBT} = \frac{2442}{(2442+13481)} \]

\[ \text{STIBT} = \frac{13481}{(2442+13481)} \]

\[ \text{LOCIBT} = 0 \]

\[ \text{TrafEdSTo} = 5346 \times (1 - 0.354) \]

\[ \text{TrafEdLocO} = 5346 \times 0.354 \]

\[ \text{TralOCSTo} = \left(\frac{195615}{12605147}\right) \times \sum(I, \text{LocGDo}(I)) \]

\[ \text{TralSTLocO} = \left(\frac{6048914}{22975018}\right) \times \sum(I, \text{StGDo}(I)) \]

\[ \text{LocGDTOTo} = \sum(I, \text{LocGDo}(I)) \]

\[ \text{LocGRevO} = \text{LocIBT} \times \sum(I, \text{ITAXR}(I) \times \text{PXo}(I) \times \text{Xo}(I)) + \sum(I, \text{CITRLOC}(I) \times \text{TBo}(I)) + \sum(I, \text{FINCTR}(\text{YHo}+\text{YHKo}) + \text{TrafEdLocSTo} + \text{TralOCSTo} + 0.5 \times \text{CREDITSLO} \]

\[ \text{LocGDTRO} = \text{LocGDTOTo} / \text{LocGRevO} \]

\[ \text{StGDTOTo} = \sum(I, \text{StGDo}(I)) \]

\[ \text{StGLES}(I) = \frac{\text{StGDo}(I)}{\text{StGDTOTo}} \]

\[ \text{StGRevO} = \text{StIBT} \times \sum(I, \text{ITAXR}(I) \times \text{PXo}(I) \times \text{Xo}(I)) + \sum(I, \text{CITRFED}(I) \times \text{TBo}(I)) + \sum(I, \text{FINCTR}(\text{YHo}+\text{YHKo}) + 0.5 \times \text{CREDITSLO} \]

\[ \text{StGDTRO} = \text{StGDTOTo} / \text{StGRevO} \]

\[ \text{FedGDTOTo} = \sum(I, \text{FedGDo}(I)) \]

\[ \text{FedGLES}(I) = \frac{\text{FedGDo}(I)}{\text{FedGDTOTo}} \]

\[ \text{FedGRevO} = \text{FedIBT} \times \sum(I, \text{ITAXR}(I) \times \text{PXo}(I) \times \text{Xo}(I)) + \sum(I, \text{CITRFED}(I) \times \text{TBo}(I)) + \sum(I, \text{FINCTR}(\text{YHo}+\text{YHKo}) + 0.5 \times \text{CREDITSLO} \]

\[ \text{FedGDTRO} = \text{FedGDTOTo} / \text{FedGRevO} \]

\[ \text{SGLES}(I) = \text{FedGDo}(I) / \text{FedGDTOTo} \]

**After-Tax Labor Income**

\[ \text{WAFTo} = (1 - \text{TINCTR}) \times \text{YHo} / \text{LTTo} \]

\[ \text{WAFTLW} = \text{WAFTo} \]

**Net Labor In-Migration**

\[ \text{LMe} = 0.1049 \]

\[ \text{C1} = 1.0 \]

\[ \text{C2} = 1.0 \]

\[ \text{LMIGo} = \text{C2} \times \text{LMe} \times \log(\text{WAFTo} / \text{WAFTLW}) \]

**Total Savings**

\[ \text{YKo} = \text{REALkB} \times \sum(I, \text{DV}(I) + \text{INT}(I)) + \text{REALkB} \times \sum(I, \text{WAGRo} \times \text{Lo}(I)) \]

\[ \text{NFINo} = \text{YKo} \]

\[ \text{SFG} = \sum(I, \text{Xo}(I)) - \sum(I, \text{EC}(I)) + \text{SGEDo} + \text{NFINo} \]

\[ \text{STOTo} = \text{SHo} + \text{DEPRTo} + \text{TRET} + \text{SGLOC} + \text{SGTo} + \text{ERSp} + \text{SFo} \]

**Gross Regional Product**

\[ \text{GRPo} = \sum(I, \text{PV}(I) \times \text{Xo}(I)) + \text{ITAXR}(I) \times \text{PXo}(I) \times \text{Xo}(I)) \]

\[ \text{HRGPr} = \sum(I, \text{Co}(I) + \text{Do}(I) + \text{STo}(I) + \text{LocGDo}(I) + \text{StGDo}(I) + \text{FedGDo}(I) + \text{LocEdDo}(I) - \text{Mo}(I)) \]

**Welfare Measurement**

\[ \text{PR} = 1.0 \]

\[ \text{PRS} = 1.0 \]

\[ \text{SE} = 1.0 \]

\[ \text{UtilO} = \left(\sum(I, \text{ALPHA}(I)^{\times}(1/\text{ELASUB}) \times \text{Co}(I)^{\times}(1/\text{ELASUB}))\right) \]

\[ \text{ExFNo} = \left(\text{UtilO} \times \text{PR} \times \text{ALPHA}^{\times}(1/\text{ELASUB}) + \text{ALPHA}^{\times}(433) \times \text{ALPHA}^{\times}(1/\text{ELASUB}) \times \text{Co}(I)^{\times}(1/\text{ELASUB})\right) \]
143

\[ \text{EXPDo} = \text{EXFNo} / ((1 + \text{DCNT})^{\text{TIMEO}}) ; \]

* VERIFY THAT PRODUCTION COST SHARES SUM TO ONE

\[ \text{PSHARCHEK}(I) = \sum(J, A(J, I)) + \text{PVo}(I) + \text{ITAXR}(T) - \text{OPTION} \]

As

f

LSHAREse,

RAR:

ADJCOEFsG,

TRASHPC:6,

HHTRFEDsG,

SLRAT:6,

DKo:

EXFNo:6,

EXPDo:6,

DISPLAY

PWM,

LSHARE,

POPG,

CITRFED,

HHTRFED,

LOCIBT,

STGLES,

DISPLAY

KSHARE,

KSHR,

GAMMA,

RHO,

TAU,

DELTA,

POMS,

EQ,

INTER,

ILER,

WIZAR,

SSR,

DEPR,

CITRFED,

CITRSTG,

CITRLOC,

CITRFL,

INCRED,

FTPLOC,

PVCQA,

HHTRFED,

HHTRSTG,

HHTRFL,

TRAFHPC,

TRASHPC,

HHTRLOC,

HHTRST,

A,

KSHR,

INTR,

CITRLOC,

HHTRLOC,

B,

GAMMA,

RLEAKR,

CITRFL,

HHTRFL,

TRAFEDLOCo,

TRASHLOCo,

FEDGLES, DSTRATE,

ITAXR,

RHOT,

WLEAKR,

INCRDT,

TRAFHPC,

TRALOCSTo,

FEDIBT,

PSHARCHEK,

FEDTDRT,

LOCTDRT :

RAR, CREDITSLo, CREDITFo, PKPo, INFRo, RPCo, ALPHA,

KDo, Do, Ro, NDo, LSo, Co, Nio,

RIO, YHRO, YLO, THO, HEXPO, LOGGREVo, LOGGEXPo,

LOCEDTOo, LOCEDTo, DEFRTNO, DEFRTNTo, INFO, PROPo,

RETo, TB0, TRET0, YCAPO, STGREVo, STGEXPo, STGDSTo,

STGDto, FEDGREVo, FEDGEXPo, FEDGDTXo, FEDGDoo, SGFLo,

SGFLo, DSTo, DETo, DEo, IDo, Mo, LMSGo, LSTOo,

WAGOo, GRPho, NGRPho, Xko, SPFo, STOTo, Zo,

YTOTo, YCAPo, YHRO, SHo, ADJCOEF, YTOTo, POPo,

TRALOCHHo, TRASHLWo, POoB, TRPHo, TSHo, TRMHo,

FSRAT, LSRA, SLRAT, FLRAT, LSUTo, Nio, Nio,

KGo, KGDo, KDo, KDUo, WAPTo, WAPTLm, UTILo,

EXPDo, EXPDo ;

**********************************************************************

VARIABLES

**********************************************************************

C(I) household consumption

CITRST(I) tax rate on corporate incomes state gov't

CIT(I) corporate income tax

CREDITSLo combined state and local gov't investment credit

CREDIF federal gov't investment credit

DI(i) domestic goods

DEPRTH(I) depreciation

DEFRTNT total depreciation in the economy

DK(I) volume of investment by sector of origin

DST(I) inventory

DYN disposable income

DV(I) dividend income

N(I) exports

ER exchange rate

EXFN per capita expenditure

EXPD per capita discounted expenditure

FEDGD(I) federal gov't demand

FEDGDTXo federal gov't total demand

FEDGEXP federal gov't expenditure

FEDGREV federal gov't revenue

GRP gross regional product at market prices

HEXP household expenditure

ID(i) volume of investment by sector of origin

INFR(I) inflation rate of capital goods

INT(I) interest income

ITOT value of total investment

ITOTF firms' expenditure on total investment

KD(I) desired level of capital stock

KDU(I) desired level of capital stock in the next period

KG(I) capital stock in the current period

KDU(I) capital stock in the next period
**VARIABLE INITIALIZATION**

* USE INITIAL VALUES OF VARIABLES *

```plaintext
ERR.L = 0.0;
PQ.L(I) = PQo(I);
PZ.L(I) = PZO(I);
PD.L(I) = PDo(I);
PE.L(I) = PEo(I);
PM.L(I) = PMo(I);
WAGE.L = WAGEo;
X.L(I) = Xo(I);
E.L(I) = Eo(I);
TRAPEST.L = TRAFEDSTo;
TRAPELOC.L = TRAFEDLOC;
```
* COMPUTE INITIAL VALUES FOR OTHER VARIABLES

* PRICES

\[
\begin{align*}
PX.L(I) & = \text{SUM}(J, \text{MAKERDOM}(I, J) \cdot PQ.L(J)); \\
PV.L(I) & = PX.L(I) - \text{SUM}(J, A(J, I) \cdot PQ.L(J)) - ITAXR(I) \cdot PX.L(I); \\
PK.L(I) & = \text{SUM}(J, PQ.L(J) \cdot B(J, I)); \\
INFR.L(I) & = PX.L(I) - PE.P.L(I) / PE.P.L(I); \\
RPC.L(I) & = (1 - INCRTST(I) - CTRST.L(I) + CITRLF(I)) \cdot PVCCA(I) \cdot (PK.L(I)) \cdot (RAR(I) + DEPR(I) \cdot (1 + INFRT.L(I))) / (1 - CTRST.L(I) - CITRLF(I)) + FPTRLOC \cdot FP.L(I); \\
\end{align*}
\]

* INPUTS DEMAND AND PRODUCTION

\[
\begin{align*}
L.L(I) & = PV.L(I) \cdot (\text{SHARE}(I) \cdot X.L(I) / WAGE.L); \\
YCAP.L(I) & = PV.L(I) \cdot X.L(I) - L.L(I) \cdot WAGE.L; \\
X.L(I) & = AV(I) \cdot (L.L(I) \cdot \text{SHARE}(I) \cdot (KG.L(I) \cdot \text{SHARE}(I)); \\
Z.L(I) & = \text{SUM}(J, \text{MAKERDOM}(I, J) \cdot X.L(J)); \\
KH.L(I) & = SHARE(I) \cdot PV.L(I) \cdot X.L(I) / RPC.L(I); \\
KD.L(I) & = X(L(I)); \\
R.L(I) & = \text{ADJCOF}(I) \cdot (KD.L(I) - KG.L(I)); \\
DKL.L(I) & = R.L(I) + R.L(I); \\
KGU.L(I) & = KG.L(I) + MG.L(I); \\
LTOF.L & = \text{SUM}(I, X.L(I)); \\
KZOT.L & = \text{SUM}(I, KG.L(I)); \\
D.L(I) & = (PK.L(I) \cdot Z.L(I) - PE.P.L(I) \cdot R.L(I)) / PZ.L(J); \\
* D.L(I) & = Z.L(I) \cdot X.L(I); \\
LDN.L(I, J) & = A(I, J) \cdot L.L(J); \\
\end{align*}
\]

* CAPITAL INCOME AND CORPORATE TAX

\[
\begin{align*}
INT.L(I) & = BO \cdot \text{INSTR} \cdot (1 - INCRT(I) - (CITRST.L(I) + CITRLF(I)) \cdot PVCCA(I)) \cdot (PEP.L(I)) \cdot KG.L(I); \\
PROP.L(I) & = PPTPLCM \cdot (PEP.L(I)) \cdot KG.L(I); \\
TB.L(I) & = YCAP.L(I) \cdot INT.L(I) - PROP.L(I); \\
CIT.L(I) & = \text{SUM}(I, \text{CITRST}(I) \cdot CITRLF(I) \cdot TB.L(I); \\
DEPR.L(I) & = \text{DEPR}(I) \cdot (1 - INCRT(I) - (CITRST.L(I) + CITRLF(I)) \cdot PVCCA(I)) \cdot PK.L(I) \cdot KG.L(I); \\
DFTN.L & = \text{SUM}(I, DEPR.L(I)); \\
DEFT.L & = (1 - BO) \cdot \text{DEPR}(I) \cdot (1 - INCRT(I) - (CITRST.L(I) + CITRLF(I)) \cdot PVCCA(I)) \cdot PK.L(I) \cdot KG.L(I); \\
DV.L(I) & = TB.L(I) \cdot CIT.L(I) - DEPR.L(I) - RET.L(I); \\
TRWL.L & = \text{SUM}(I, RET.L(I)); \\
\end{align*}
\]

* HOUSEHOLD INCOME

\[
\begin{align*}
YHK.L & = (1 - RLEAKR) \cdot \text{SUM}(I, DV.L(I) + INT.L(I)); \\
LSUMT.L & = YHK.L; \\
YL.L & = (1 - \text{WZAKR}) \cdot \text{WAGE.L} \cdot LTOT.L - LSUMT.L; \\
YH.L & = YL.L \cdot (1 - SSZ); \\
YX.L & = \text{WLEAKR} \cdot \text{SUM}(I, DV.L(I) + INT.L(I)) + \text{WLEAKR} \cdot \text{WAGE.L} \cdot LTOT.L; \\
POP.L & = LS.L \cdot LPR; \\
TRFH.L & = TRAFHPC \cdot POP.L; \\
TRSH.L & = TRASHPC \cdot POP.L; \\
TRAL.L & = TRALHCPC \cdot POP.L; \\
DYH.L & = (1 - TINCTR) \cdot (YH.L + YHK.L) + TRFH.L + TRSH.L + TRAL.L; \\
SH.L & = NPSL; \\
HEXP.L & = DYH.L - SH.L; \\
\end{align*}
\]

* CONSUMPTION DEMAND

\[
\begin{align*}
C.L(I) & = \text{ALPHA}(I) \cdot \text{HEXP.L} \cdot ((PQ.L(I) \ast \text{ELASUB}) \ast \text{SUM}(J, \text{ALPHA}(J) \ast \text{PQ.L}(J) \ast (1 - \text{ELASUB}))) \\
\end{align*}
\]

* GOVERNMENT

\[
\begin{align*}
\text{CRDDTSL.L} & = \text{SUM}(I, \text{INCRDST}(I) \cdot (\text{INCRTLOC}(I) + (\text{CTRST.L(I) + CITRLOC}(I) \cdot FP.L(I) \cdot D.L(I))); \\
\text{CRDDTF.L} & = \text{SUM}(I, \text{INCRTFD}(I) \cdot (\text{CTRPFED}(I) \cdot PVCCA(I)) \cdot PK.L(I) \cdot DK.L(I)); \\
\text{LOGCREV.L} & = \text{LOCRST} \cdot \text{SUM}(I, ITAXR(I) \cdot PX.L(I) \cdot X.L(I) + PPTRLOC \cdot SUM(I, CITRLOC(I) \cdot TB.L(I)) + LINCTR \cdot (YH.L + YHK.L) + TRAFLOC.L + TRSTLOC.L; \\
\text{LOGCD.TOT.L} & = \text{LOCTRT} \ast \text{LOGCREV.L}; \\
\text{LOGCD.B.L(I)} & = \text{LOGCDLGIN} \ast \text{LOGCDTOT.L} / PQ.L(I); \\
\end{align*}
\]
null
<table>
<thead>
<tr>
<th>Definition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIMPORT(I)</td>
<td>Definition of domestic import prices</td>
</tr>
<tr>
<td>PXPORT(I)</td>
<td>Definition of domestic export prices</td>
</tr>
<tr>
<td>PSALES(I)</td>
<td>Definition of domestic sales prices</td>
</tr>
<tr>
<td>PCOMPOSITE(I)</td>
<td>Definition of composite good prices</td>
</tr>
<tr>
<td>PXREQ(I)</td>
<td>Definition of domestic industry prices</td>
</tr>
<tr>
<td>PACTIVITY(I)</td>
<td>Definition of activity prices</td>
</tr>
<tr>
<td>PCAPITAL(I)</td>
<td>Definition of capital goods prices</td>
</tr>
<tr>
<td>INFRATE(I)</td>
<td>Inflation rate of capital goods</td>
</tr>
<tr>
<td>RPCAP(I)</td>
<td>Rental price of capital</td>
</tr>
<tr>
<td>ACTIVITY(I)</td>
<td>Production function</td>
</tr>
<tr>
<td>LABDEMAND(I)</td>
<td>Labor demand function - first order condition</td>
</tr>
<tr>
<td>KDESIRED(I)</td>
<td>Desired level of capital</td>
</tr>
<tr>
<td>XGSUPPLY(I)</td>
<td>Definition of domestic commodity output</td>
</tr>
<tr>
<td>CET(I)</td>
<td>CET function</td>
</tr>
<tr>
<td>ESUPPLY(I)</td>
<td>Export supply function</td>
</tr>
<tr>
<td>CES(I)</td>
<td>CES function</td>
</tr>
<tr>
<td>COST(I)</td>
<td>Cost minimization function</td>
</tr>
<tr>
<td>INTDEMAND(I,J)</td>
<td>Intermediate demand function</td>
</tr>
<tr>
<td>CONSUME(I)</td>
<td>Household consumption demand</td>
</tr>
<tr>
<td>CAPYEQ(I)</td>
<td>Gross capital income</td>
</tr>
<tr>
<td>LASYEQ</td>
<td>After-leakage labor income</td>
</tr>
<tr>
<td>TAXBASE(I)</td>
<td>Tax base for corporate income tax</td>
</tr>
<tr>
<td>INTEREST(I)</td>
<td>Interest income</td>
</tr>
<tr>
<td>PROFITAX(I)</td>
<td>Property tax</td>
</tr>
<tr>
<td>CORPYTX(I)</td>
<td>Corporate income tax</td>
</tr>
<tr>
<td>DIVIDENDS(I)</td>
<td>Dividend income</td>
</tr>
<tr>
<td>HIINCIAS</td>
<td>Labor income net of leakage and ss. tax</td>
</tr>
<tr>
<td>CAPYDOM</td>
<td>After-leakage capital income</td>
</tr>
<tr>
<td>DRESEQ</td>
<td>Disposable income</td>
</tr>
<tr>
<td>HSAVE</td>
<td>Household savings</td>
</tr>
<tr>
<td>HEXPEQ</td>
<td>Household expenditure</td>
</tr>
<tr>
<td>TFRHEQ</td>
<td>Federal government transfers to households</td>
</tr>
<tr>
<td>TENSHEQ</td>
<td>State government transfers to households</td>
</tr>
<tr>
<td>TSREQE</td>
<td>Local government transfers to households</td>
</tr>
<tr>
<td>CREDTSEQQL</td>
<td>Combined state and local government investment credit</td>
</tr>
<tr>
<td>CREDTSEQF</td>
<td>Federal government investment credit</td>
</tr>
<tr>
<td>LOCGREVEQ</td>
<td>Local government revenue</td>
</tr>
<tr>
<td>LOCGKPEQ</td>
<td>Local government expenditure</td>
</tr>
<tr>
<td>LOCDEQ(I)</td>
<td>Local government total demand</td>
</tr>
<tr>
<td>STGREVEQ</td>
<td>State government revenue</td>
</tr>
<tr>
<td>STGKPEQ</td>
<td>State government expenditure</td>
</tr>
<tr>
<td>STGRBDQ(I)</td>
<td>State government total demand</td>
</tr>
<tr>
<td>STTEQ</td>
<td>State government total demand</td>
</tr>
<tr>
<td>FEDGREVQ</td>
<td>Federal government revenue</td>
</tr>
<tr>
<td>FEDKPEQ</td>
<td>Federal government expenditure</td>
</tr>
<tr>
<td>FEDDEQ(I)</td>
<td>Federal government total demand</td>
</tr>
<tr>
<td>FREDSEQ</td>
<td>Federal government total demand</td>
</tr>
<tr>
<td>TGREQ</td>
<td>Federal government transfers to state government</td>
</tr>
<tr>
<td>TGLSEQ</td>
<td>Local government transfers to state government</td>
</tr>
<tr>
<td>TSLSEQ</td>
<td>State government transfers to local government</td>
</tr>
<tr>
<td>TFLSEQ</td>
<td>Federal government transfers to local government</td>
</tr>
<tr>
<td>RETAINED(I)</td>
<td>Retained earnings</td>
</tr>
<tr>
<td>RETAINT</td>
<td>Total retained earnings</td>
</tr>
<tr>
<td>DEPRECIATION(I)</td>
<td>Depreciation</td>
</tr>
<tr>
<td>TDEPR</td>
<td>Total depreciation</td>
</tr>
<tr>
<td>TSAVE</td>
<td>Total savings</td>
</tr>
<tr>
<td>FEDGBUDGET</td>
<td>Federal government budget</td>
</tr>
<tr>
<td>LOCGBUDGET</td>
<td>Local government budget</td>
</tr>
<tr>
<td>STGBUDGET</td>
<td>State government budget</td>
</tr>
<tr>
<td>CURRACCT</td>
<td>Current account balance</td>
</tr>
<tr>
<td>DSTEQ(I)</td>
<td>Inventory</td>
</tr>
<tr>
<td>RBPINV(I)</td>
<td>Replacement investment</td>
</tr>
<tr>
<td>IDEST(I)</td>
<td>Investment by sector of destination</td>
</tr>
<tr>
<td>IDEMAND(I)</td>
<td>Investment by sector of origin</td>
</tr>
<tr>
<td>TOINV</td>
<td>Value of total investment</td>
</tr>
<tr>
<td>TOINVF</td>
<td>Firms' expenditure on total investment</td>
</tr>
<tr>
<td>PPOFQ</td>
<td>Population</td>
</tr>
<tr>
<td>QDMSKZ(I)</td>
<td>Goods market equilibrium condition</td>
</tr>
<tr>
<td>LMGIEQ</td>
<td>Labor in-migration</td>
</tr>
<tr>
<td>LTOEQ</td>
<td>Total labor demand</td>
</tr>
<tr>
<td>LAHMT</td>
<td>Labor market equilibrium condition</td>
</tr>
<tr>
<td>WAFTLEQ</td>
<td>After-tax wage rate</td>
</tr>
<tr>
<td>SI</td>
<td>Savings-investment equilibrium condition</td>
</tr>
<tr>
<td>GRPY</td>
<td>Gross regional product at market prices</td>
</tr>
<tr>
<td>RGRPY</td>
<td>Real gross regional product</td>
</tr>
</tbody>
</table>
# MODEL EQUATIONS

**# PRICES**

\[
P_{\text{IMPORT}}(I) = P_{\text{M}}(I) ER \]

\[
P_{\text{EXPORT}}(I) = P_{\text{E}}(I) ER \]

\[
P_{\text{COMPOSITE}}(I) = P_{\text{Q}}(I) Q(I) \]

\[
P_{\text{SALES}}(I) = P_{\text{D}}(I) D(I) \]

\[
P_{\text{EQ}}(I) = P_{\text{X}}(I) \]

\[
P_{\text{ACTIVITY}}(I) = P_{\text{V}}(I) \]

\[
P_{\text{INFRATE}}(I) = P_{\text{R}}(I) \]

\[
P_{\text{INFRA}}(I) = (P_{\text{K}}(I) - P_{\text{K}}(I)) ER \]

**# INPUTS DEMAND AND PRODUCTION**

\[
L_{\text{DEMAND}}(I) = L(I) = P_{\text{V}}(I) LSHARE(I) X(I)/WAGE \]

\[
R_{\text{CAP}}(I) = R_{\text{C}}(I) = (1-LDEPKRT(I)) WAGE/LEVE-LSUMT \]

\[
K_{\text{DESIRED}}(I) = K_{\text{D}}(I) = KSHARE(I) PV(I) X(I)/RPC(I) \]

\[
I_{\text{SUPPLY}}(I) = Z(I) = SUM(J, TERMS(J,I) X(J)) \]

\[
C_{\text{ACTIVITY}}(I) = X(I) = AV(I) LSHARE(I) KG(I) \]

**# HOUSEHOLD DEMAND FOR COMMODITIES**

\[
C_{\text{CONSUME}}(I) = C(I) = ALPHA(I) XELASP/(P_{\text{Q}}(I) ELASUB) SUM(J, ALPHA(J) P_{\text{Q}}(J)) \]

\[
C_{\text{SUPPLY}}(I) = Y_{\text{CAP}}(I) = PV(I) X(I) - L(I) WAGE \]

**# INCOME**

\[
C_{\text{INCOME}}(I) = Y_{\text{L}} = WARE\times(I) \]

\[
C_{\text{INTEREST}}(I) = I_{\text{INT}} = BQ I_{\text{INT}} (1-ICRRT(I)) \]

**# CORPORATE TAX**

\[
C_{\text{PROPTAX}}(I) = P_{\text{PROP}}(I) = PPTBL(P_{\text{Q}}(I) KG(I)) \]

**# STATE, LOCAL AND FEDERAL GOVERNMENT**

\[
C_{\text{LOC}} = L\text{OCREV} = \text{SUM}(I, ITAXR(I)*PX(I)*X(I)) + \]

\[
C_{\text{STTEQ}} = STTDTB\text{SUM}(I, ITAXR(I)*PX(I)*X(I)) + \]

\[
C_{\text{FEDTEQ}} = FEDTDRT\text{SUM}(I, ITAXR(I)*PX(I)*X(I)) + \]

\[
C_{\text{CREDTEQF}} = CREDITF = SUM(I, ICRED(TFED(I)) + CREDITF) \]

**# STATE, LOCAL AND FEDERAL GOVERNMENT**

\[
C_{\text{FSRAT} = FSRTAXP} \]

\[
C_{\text{SLRAT} = SLRTACEN} \]

\[
C_{\text{SLRAT} = SLRTACEN} \]
### SAVINGS

HSAVE..  SH  =E=  MPS+DYH;
RETAINT(I)  .  RET(I)  =E=  [1-BQ]*(1-INCROI(I)-(CITRST(I)+CITRLF(I))*(PVCCA(I))*PR(I)*RI(I)-
EQ*(1-INCROI(I)-(CITRST(I)+CITRLF(I))*(PVCCA(I))*PR(I)*CE(I)) /
RKP(I)*KG(I);  
DEPRCATh(I)  .  DEPR(I)  =E=  DEPR(I)*[1-INCROI(I)-(CITRST(I)+CITRLF(I))*(PVCCA(I))*PR(I)*KG(I)];
DEPR(I)  =E=  DEPR(I)*[1-INCROI(I)-(CITRST(I)+CITRLF(I))*(PVCCA(I))*PR(I)*KG(I)];
FEDBUDGET..  SGFED  =E=  FEDGREV-FEDGEXP;
LOCBUDGET..  SGLOC  =E=  LOCGREV-LOCGEXP;
STOBRUGED..  SGST  =E=  STOBRGREV-SGEXP;
CURRACCT..  SF  =E=  SUM(I,PW(I)*M(I)) + SUM(I,PW(I)*R(I)) + SFGED + NFIN;
TSAVE..  STOT  =E=  SH + DEPRINT+STRET+SGLOC+SGST+ER*SF ;

### INVESTMENT

REPVNV(I)  .  RI(I)  =E=  DEPR(I)*EG(I);
IDEST(I)  .  DK(I)  =E=  NI(I) + RI(I);
IDIBAND(I)  .  ID(I)  =E=  SUM(J,B(I,J)*DK(J));
DSTOQ(I)  .  DST(I)  =E=  DSTRATE(I)*I(I);
TINV(I)  .  ITOT  =E=  SUM(I,PQ(I)*DST(I)+PQ(I)*ID(I));
TINVF(I)  .  ITOTF  =E=  ITOT - CREDITSL - CREDIIT ;

### EXPORTS AND IMPORTS

ESUPPLY(I)  .  E(I)  =E=  ((PF(I)/PDI(I)*(1-GAMMA(I))/GAHANN(A))**
(1/(BROZ(I)-1)))*Q(I);
CES(I)  .  Q(I)  =E=  TAW(I)*DELTA(I) + H(I)**(-1)*RHO(I)**(1-DELTA(I))**(-1/RHOC(I))**(-1/RHOC(I));
COST(I)  .  M(I)  =E=  (1/(1-RHOC(I)))*D(I);

### LABOR MARKET AND POPULATION

WFLAQE..  WAFTL  =E=  (1-TINCTR)*YH/LTOT ;
LMIQEO..  LMIG  =E=  C2*IUME*LS*LOG(WAFTL/WAFLM);  
POPO90..  POP  =E=  LS/PLR ;

### EQUILIBRIUM CONDITIONS

GDSREL(I)  .  Q(I)  =E=  SUM(J,HD(I,J)+C1+LOGCDG(I)+STGD(I)+
PEQV(I)*ID(I)+DST(I));
LTQEQ..  LTOT  =E=  SUM(I,L(I));
LABQEQ..  LTOT  =E=  (1-UR)*LS + C1*(1-UR)*LMIG;
SI..  ITOTF  =E=  STOT ;

### GROSS REGIONAL PRODUCT

GROPE..  GRP  =E=  SUM(I,PF(I)*X(I)+ITAXR(I)*PX(I)*X(I));
GRGPE..  RGPE  =E=  SUM(I,C(I)+ID(I)+DST(I)+LOGCDG(I)+STGD(I)+
FEDGEXP*E(I)-M(I));

### VARIABLE BOUNDS

* These are included to improve algorithm performance.

PQ.LO(I)  =  0.00001;  PX.LO(I)  =  0.00001;  PM.LO(I)  =  0.00001;
PE.LO(I)  =  0.00001;  PD.LO(I)  =  0.00001;  PV.LO(I)  =  0.00001;
PR.LO(I)  =  0.00001;  A.X(LO)  =  0.0;  KG.LO(I)  =  0.0 ;
LX.LO(I)  =  0.0;  D.LO(I)  =  0.0;  S.LO(I)  =  0.0;
ND.LO(I,J)  =  0.0;  LS.LO  =  0.0;  CI.LO(I)  =  0.0;
YH.LO  =  0.0;  YH.LO  =  0.0;  
HEX.LO  =  0.0;  TVTOT.LO  =  0.0;  WAFTL.W  =  0.00001;
LOCBEXV.LO  =  0.0;  LOGCREXP.LO  =  0.0;  LOGCDG.LO(I)  =  0.0;
STGCREV.LO  =  0.0;  STGEXP.LO  =  0.0;  STGD.LO(I)  =  0.0;
FEDGREV.LO  =  0.0;  FEDGEXP.LO  =  0.0;  FEDG.DLO(I)  =  0.0;
STOT.LO  =  0.0;  M.LO(I)  =  0.0;  LTOT.LO  =  0.0;
WAGE.LO  =  0.00001;  V2.LO(I)  =  0.00001;
FCP.LO(I)  =  0.00001;  RPC.LO(I)  =  0.00001;  RL.LO(I)  =  0.0;
YCAP.LO(I)  =  0.0;  INT.LO(I)  =  0.0;  RET.LO(I)  =  0.0;
KD.LO(I)  =  0.0;  DEPRN.LO(I)  =  0.0;  DEPRTNL.LO  =  0.0;
CIT.LO(I)  =  0.0;  CIRTRST.LO(I)  =  0.0;  TRST.LO  =  0.0;
KDU.LO(I)  =  0.0;  CREDITS.LO  =  0.0;  CREDITL.LO  =  0.0;
CIT.LO(I)  =  0.0;  PROP.LO(I)  =  0.0;  TRPH.LO  =  0.0;
TRSH.LO  =  0.0;  TRNL.LO  =  0.0;  DYN.LO  =  0.0;
POP.LO  =  0.0;  LUO.LO  =  0.0;  LLO.LO(I)  =  0.0;
FEDGTOLO  =  0.0;  STUGTOLO  =  0.0;  LOGCDGTOLO  =  0.0;
DV.LO(I)  =  0.0;  M.LO(I)  =  0.0;
* *** MODEL CLOSURE 0-1 ***

* ---------- BASE-YEAR REPLICATION

* ### CURRENT ACCOUNT CLOSURE
ER.FX = ER.L;

* ### TIME VARIABLE
TIME.FX = 0.0;

* ### FACTOR MARKET CLOSURE
KG.FX(I) = KG.L(I);
KD.FX(I) = KD.L(I);
PKP.FX(I) = PKP.L(I);
LS.FX = LS.L;
C1 = 1.0;
C2 = 1.0;
N1.FX(I) = ADJCOEF(I)*(KD.L(I)-KG.L(I));

* ### GOVERNMENT
CITRST.FX(I) = CITRST.L(I);
LSUMP.FX = LSUMP.L;

* ******** END OF MODEL ********

OPTIONS ITERLIM=1000, LIMROW=0, LIMCOL=0, SOLPRINT=OFF;
MODEL OHIOCGE /ALL/;
SOLVE OHIOCGE MAXIMIZING RGRP USING NLP;

* ### VARIABLES DETERMINED AFTER SOLUTION OF THE EQUATION SYSTEM
KGU.L(I) = KG.L(I)+NI.L(I);
KTOT.L = SUM(I,KG.L(I));
LSU.L = LS.L*(1+POP0PG) + LMIG.L;
YX.L = RLEAKR*SUM(I,DV.L(I)+IKT.L(I))+WLEAKR*WAGE.L*LTOT.L;

* ### WELFARE MEASUREMENT
UTIL.L = (SUM(I,(ALPHA(I)**(1/ELASUB))**(ELASUB-1))/ELASUB))**(ELASUB/(ELASUB-1));
EXFN.L = (UTIL.L*(PRF*(ALPHA("1")**(1/ELASUB) + ALPHA("433")**(1/ELASUB)))**((1-ELASUB)/ELASUB))**(ELASUB/(1-ELASUB))/POP.L;
EXPD.L = EXFN.L/((1+DCNT)**TIME.L);

* ******** RESULTS ********

DISPLAY

* *** MODEL CLOSURE 0-2 ***

* -------- POLICY IMPLEMENTATION IN BASE YEAR

* ### CURRENT ACCOUNT CLOSURE
ER.FX = ER.L;

* ### TIME VARIABLE
TIME.FX = 0.0;

* ### FACTOR MARKET CLOSURE
KG.FX(I) = KG.L(I);
KD.FX(I) = KD.L(I);
PKP.FX(I) = PKP.L(I);
LS.FX = LS.L;
C1 = 0.0;
C2 = 0.0;
N1.FX(I) = ADJCOEF(I)*(KD.L(I)-KG.L(I));

* ### GOVERNMENT
CITRST.FX(I) = CITRST.L(I);
CITRST.FX(I) = 0.70*CITRST.L(I);
By setting \( C_1 = 0.0 \), we assume that net labor in-migration occurring in the current period is not added to labor supply in the current period.

Instead, by the equation below,

\[
LSU.L = LS.L \ast (1 + POPG) + LMIG.L,
\]

we assume that the labor inflow is added to the labor supply in the next period.

Since this simulation is for deriving the continuous benchmark path, we set \( C_2 = 0.0 \), which means that there is no net in-migration on the continuous benchmark path. However, for deriving a continuous counterfactual path, \( C_2 \) must be set to be 1.

For a continuous counterfactual, we set, for example,

\[
CITRST.FX(I) = 0.7 \ast CITRST.L(I)
\]

instead of

\[
CITRST.FX(I) = CITRST.L(I)
\]

SOLVE OHIOCGE MAXIMIZING RGRP USING NLP;

### VARIABLES DETERMINED AFTER SOLUTION OF THE EQUATION SYSTEM

\[
KGU.L(I) = KG.L(I) + NI.L(I);
\]

\[
KTOT.L = SUH(I, KG.L(D));
\]

\[
LSU.L = LS.L \ast (1 + POPG) + LMIG.L;
\]

\[
YX.L = RLEAKR \ast \text{SUM(I,DV.L(I) + INT.L(I) + WLEAKR \ast WAGE.L \ast LTOT.L)};
\]

### WELFARE MEASUREMENT

\[
\text{UTIL.L} = \frac{\left(\text{SUH} \ast \left(\frac{\text{ALPHA} \ast \left(1 - \frac{1}{\text{ELASUB}}\right)}{\text{ELASUB}}\right)^{\left(1 - \frac{\text{ELASUB}}{\text{ELASUB}}}\right)\right)^{\left(\frac{\text{ELASUB}}{\text{ELASUB}}\right)}}{\left(\text{POP.L} / \text{POPB}\right)};
\]

\[
\text{EXFN.L} = \frac{\left(\text{PRF} \ast \left(\frac{\text{ALPHA} \ast \left(1 - \frac{1}{\text{ELASUB}}\right)}{\text{ELASUB}}\right)^{\left(1 - \frac{\text{ELASUB}}{\text{ELASUB}}}\right) \ast \text{PRF} \ast \left(\frac{\text{ALPHA} \ast \left(1 - \frac{1}{\text{ELASUB}}\right)}{\text{ELASUB}}\right)^{\left(1 - \frac{\text{ELASUB}}{\text{ELASUB}}}\right) \ast \left(\frac{\text{PRF} \ast \left(\frac{\text{ALPHA} \ast \left(1 - \frac{1}{\text{ELASUB}}\right)}{\text{ELASUB}}\right)^{\left(1 - \frac{\text{ELASUB}}{\text{ELASUB}}}\right)}}{\left(\text{POP.L} / \text{POPB}\right)}\right)}{\left(\text{POP.L} / \text{POPB}\right)};
\]

### VALUES OF RGRP AND EXFN IN THE PREVIOUS PERIOD

PARAMETER

\[
\text{RGRPP, EXFNP} ;
\]

\[
\text{RGRPP} = \text{RGRP.L} ;
\]

\[
\text{EXFNP} = \text{EXFN.L} ;
\]

### RESULTS REPORT

SETS LEVEL variable name

\[
/\text{RGRP.L} \quad \text{RGRP level}
\]

\[
/\text{NI.L} \quad \text{net investment level}
\]

\[
/\text{KGU.L} \quad \text{updated capital stock level}
\]

\[
/\text{LTOT.L} \quad \text{total employment}
\]

\[
/\text{LMIG.L} \quad \text{migration level}
\]

\[
/\text{EXFN.L} \quad \text{per capita expenditure}
\]

\[
/\text{EXPD.L} \quad \text{per capita discounted expenditure}
\]

\[
/\text{RGRPP} \quad \text{RGRP level in the previous period}
\]

\[
/\text{EXFNP.L} \quad \text{EXFN level in the previous period}
\]

PCT

\[
/\text{RGRP_P} \quad \text{RGRP percent change}
\]

\[
/\text{EXFNP_P} \quad \text{EXFN percent change}
\]

ACH

\[
/\text{RGRP_A} \quad \text{agg. RGRP}
\]

\[
/\text{EXFN_A} \quad \text{agg. per capita expenditure}
\]

\[
/\text{EXPD_A} \quad \text{agg. per capita discounted expenditure}
\]

\[
/\text{NI_A} \quad \text{agg. net investment}
\]

\[
/\text{LTOT_A} \quad \text{agg. labor employment}
\]

\[
/\text{LMIG_A} \quad \text{agg. labor migration}
\]

YEAR simulation year number /

\[\text{YEAR} \ast \text{YEAR40} /\]

ALIAS(YEAR, YEARP);

PARAMETERS

\[
\text{REPORTA(LEVEL,*)} \quad \text{report aggregate results in levels}
\]

\[
\text{REPORTB(LEVEL,*,1)} \quad \text{report sectoral results in levels}
\]

\[
\text{REPORTP(PCT,*)} \quad \text{report aggregate results in percent change}
\]

\[
\text{REPORTG(ACH,*)} \quad \text{report agg. value of variable}
\]
REPORTJ(ACH,*,I) report agg. sectoral variable;

REPORTA("RGRP_L","YEARO")
REPORTA("LTOT_L","YEARO")
REPORTA("LMIG_L","YEARO")
REPORTA("EXFN_L","YEARO")
REPORTA("EXPD_L","YEARO")
REPORTA("RGRPP_L","YEARO")
REPORTA("EXFNP_L","YEARO")
REPORTA("NI_L","YEARO")
REPORTA("KGU_L","YEARO")

REPORTJ("RGRP_A","YEAR")
REPORTJ("LTOT_A","YEAR")
REPORTJ("LMIG_A","YEAR")
REPORTJ("EXFN_A","YEAR")
REPORTJ("EXPD_A","YEAR")
REPORTJ("RGRPP_A","YEAR")
REPORTJ("EXFNP_A","YEAR")
REPORTJ("NI_A","YEAR")
REPORTJ("KGU_A","YEAR")

RESULTS

*RESULTS

DISPLAY
LD.L,KD.L,TK.L,TL.L,YH.L,FX.L,HEX.L,LOGREVL,LOGREVL,LOGCD.L,LOGCD.L,
STCD.L,SZG.L,Q,L,EXP.L,YCAP.L,RPC.L,FDGREV,L,FDGEXPL,FDGD.L,STOT.L,
SGED.L,SGLOC.L,SGST.L,STL.D,STL.D,DK.L,ID.L,E.L,LMIG.L,LITOT.L,ITOT.L,
GRP.L,CRDTLS.L,CRDTLP.L,INFL.P,LTOT.L,TRST.L,DEPWT.L,TV.L,
RET.L,INT.L,DIY.L,SL.L,LTOTFL.P,POP.L,NFIN.L,PE.L,Z.L,ZGATOT.L,LOGCDATOT.L,
FEDGATOT.L,KG.L,TRFH.L,TRSH.L,TRM.L,LSU.L,KU.L,KU.L,LSU.L,NAFLTL.UTIL.L,
EXFL.L,EXPD.L,KGU.L ;

* loop for solving model in successive periods
LOOP(YEAR,

** CURRENT ACCOUNT CLOSURE
ER.FX = ER.L;

** TIME VARIABLE
TIME.FX = ORM(YEAR); 

** FACTOR MARKET CLOSURE
KG.FX(I) = KGU.L(I) ;
KD.FX(I) = KD.L(I) ;
PEP.FX(I) = PE.L(I) ;
LS.FX = LSU.L ;
NI.FX(I) = ADJCOEF(I)*(KD.L(I)-KG.L(I)) ;

** GOVERNMENT
CITRST.FX(I) = CITRST.L(I) ;
CITRST.FX(I) = CITRST.FX(I)$[ORM(YEAR) LE 10] = CITRST.L(I) ;
CITRST.FX(I) = CITRST.FX(I)$[ORM(YEAR) GT 10] = 0.15 ;
LSUMT.FX = -SGST.L ;

SOLVE CHOCCE MAXIMIZING RGRP USING NLP;

* VARIABLES DETERMINED AFTER SOLUTION OF THE EQUATION SYSTEM
KGU.L(I) = KG.L(I)+NI.L(I); 
RTOT.L = SUM(L,KG.L(L));
LSU.L = LS.L*(1+POPG) + LMIG.L ;
XY.L = RLEAKR*SUM(L,DR.L(I)+INT.L(I))+RLEAKR*WAGE.L*LTOT.L ;

** WELFARE MEASUREMENT
UTIL.L = (SUM(L, (ALPHA(I)*(1/ELASUB))**C.L(I)**((ELASUB-1)/
ELASUB))**((ELASUB-(ELASUB-1)))/
EXFL.L = ((SUM(L, (PRF*(ALPHA/1)**(1/ELASUB))**((1-ELASUB)/
ELASUB))**((1-ELASUB)/
EXPD.L = EXPD.L*(1+DCNT)*TIME.L ;

* RESULTS REPORT

REPORTA("RGRP_L","YEAR") = RGRP.L ;
REPORTA("LTOT_L","YEAR") = LTOT.L ;
REPORTA("LMIG_L","YEAR") = LMIG.L ;
REPORTA("EXFN_L","YEAR") = EXFN.L ;
REPORTA("EXPD_L", YEAR) = EXPD_L ;
REPORTA("RGRPP_L", YEAR) = RGRPP ;
REPORTA("EXFN_L", YEAR) = EXFN ;
REPORTB("NI_L", YEAR, I) = NI.L(I);
REPORTB("KGU_L", YEAR, I) = KGU.L(I);
REPORTE("RGRP_L", YEAR) = ((REPORTA("RGRP_L", YEAR) - REPORTA("RGRPP_L", YEAR)) / REPORTA("RGRPP_L", YEAR)) * 100 ;
REPORTF("EXFN_P", YEAR) = ((REPORTA("EXFN_L", YEAR) - REPORTA("EXFN_P", YEAR)) / REPORTA("EXFN_L", YEAR)) * 100 ;
REPORTG("RGRP_A", YEAR) = REPORTA("RGRP_L", "YEAR") + SUM(YEARP, REPORTA("RGRP_L", YEARP)) ;
REPORTH("LTOT_A", YEAR) = REPORTA("LTOT_L", "YEAR") + SUM(YEARP, REPORTA("LTOT_L", YEARP)) ;
REPORTI("LMIG_A", YEAR) = REPORTA("LMIG_L", "YEAR") + SUM(YEARP, REPORTA("LMIG_L", YEARP)) ;
REPORTJ("EXPD_A", YEAR) = REPORTA("EXPD_L", "YEAR") + SUM(YEARP, REPORTA("EXPD_L", YEARP)) ;
REPORTK("NI_A", YEAR, I) = REPORTB("NI_L", "YEAR", I) + SUM(YEARP, REPORTB("NI_L", YEARP, I)) ;

/* ### VALUES OF RGRP AND EXFN IN THE PREVIOUS PERIOD
RGRPP = RGRP_L ;
EXFN_F = EXFN_L ;
*/

/* ### TERMINAL TERM
TERM_L = EXPD_L/DCNT ;

DISPLAY
TERM_L ;

* ******************** REPORT ******************

OPTION
REPORTA:3:0:1, REPORTB:3:2:1, REPORTH:3:0:1, REPORTG:3:0:1, REPORTJ:3:2:1 ;

DISPLAY
REPORTA, REPORTB, REPORTH, REPORTG, REPORTJ ;