WELFARE MEASURES OF RURAL DEVELOPMENT:

A REGIONAL GENERAL EQUILIBRIUM

ANALYSIS INCLUDING

NON-MARKET GOODS

BY

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Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
December, 1993

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ACKNOWLEDGEMENTS

First of all, I would like to express my sincere appreciation to my advisor, Dr. Dean F. Schreiner, for his guidance, encouragement, and support in completing this study. It was an invaluable experience for me to have discussions with him in our weekly meetings. It greatly enriched my insight for approaching research problems. I also wish to thank the members of my committee: Dr. Arthur L. Stoecker, for his helpful comments on the computer programming and the final draft of this study; and Dr. Michael D. Woods and Dr. Michael J. Applegate for their helpful comments and suggestions on the final draft.

I would like to express my appreciation to Dr. David Leslie, Oklahoma Cooperative Fish and Wildlife Research, and Dr. Harold Namminga, Oklahoma Department of Wildlife Conservation for their assistance regarding this study.

Appreciation is extended to all of the faculty and staff in the Department of Agricultural Economics associated with my graduate study. Also, I wish to express a note of thanks to all Korean graduate students and other graduate students from the global village in the department. A special thank you is extended to my friend, Dr. Jung-Hee Lee, in North Dakota.

I would like to express my personal gratitude to the Rural Development Corporation in Korea for its financial support during the study. I would like to thank President Hong-Rae Cho and all of the staff of the corporation for all support they provided me and, especially, for allowing an extension of my study.

My deepest thanks to my parents for everything they have given me - love, support, and encouragement. You are the reason I am about to graduate. My sincere gratitude goes to my brother and sisters, and in-laws for their affection and encouragement.

Finally, I would like to share the pleasure of graduation with my wife, Hye-Young and my lovely sons, Tong-Keun and Myung-Keun. I dedicate this dissertation to my wife whose sacrifice has become part of my degree.

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CHAPTER I

INTRODUCTION

Problem Statement

Rural Development

The definition of rural development has been a murky area among researchers. Tweeten and Brinkman (1975) have defined rural (micropolitan) development as improving the well-being of rural (micropolitan) residents, wherever they eventually reside. As defined, rural development emphasizes people rather than places in measuring welfare change.

Measures of Rural Welfare

To evaluate a change in rural welfare, welfare itself must be defined and measured. A description of welfare (satisfaction) of people will never be complete, because the sources of satisfaction and related aspects of welfare are diverse and difficult to specify in an empirical context.

If some in society value a rural working and living environment over an urban working and living environment (or the reverse) it should be reflected in the measure of welfare.

The fact that some people may put more value on leisure than income compared to others should be incorporated in measures of welfare. Elements other than economic efficiency and growth that enter in evaluating rural welfare change may be important, but they may also be elusive in identifying and measuring because values are not revealed in terms of market preferences. As Shaffer has shown, the conceptual components of a socioeconomic welfare function can be categorized into two types: one is the welfare effects from goods and services with market prices and the other is welfare effects without market prices (Shaffer, pp.89-90). The former can be referred to as market goods and the latter as nonmarket goods.

Basically, how welfare of people is expressed depends upon how exactly their utility (preference) functions are described. A welfare measure should be derived from a utility function and, at the same time, the utility function should include as many components as possible that affect people's welfare. In particular, inclusion of nonmarket goods as components of utility can be critical to improving welfare of people. Examples of nonmarket components of utility are leisure, recreation, pollution (negative utility), and beautiful scenery.

The most widely employed numerical welfare measures derived from utility are the Hicksian compensating variation (CV) and equivalent variation (EV). The concept on which these welfare measures are based is the amount of money an individual is willing to pay or accept to move from one state of equilibrium to another. If nonmarket goods can be expressed in the utility function and if they can be valued, then nonmarket components can also be reflected in measures of welfare and welfare change.

Measuring Welfare Changes through General Equilibrium Methods

When an exogenous shock, such as an increase in export demand for a certain industry product, occurs in a regional economy in equilibrium, all of the economic agents in the region (firms, consumers, governments, commodity and factor markets, etc) react to the exogenous shock to adjust to a new equilibrium as long as they are interrelated with the impact either directly or indirectly.

If the analysis of welfare change is limited to specific groups of people and/or specific sectors, partial equilibrium analysis may be sufficient. That is, in partial equilibrium analysis, prices and quantities of one or several commodities are allowed to adjust to new equilibrium values in response to an exogenous shock while prices and quantities of other goods and even consumer incomes are held constant. On the contrary, a general equilibrium model[1] considers adjustment in all related markets and institutions. Therefore, once welfare measures such as CV and EV are built into a regional general

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1. Shoven and Whalley (1984, p.1009) state, "Everyone seems to agree that a general equilibrium model is one in which all markets clear in equilibrium."

equilibrium model, the model accounts for welfare effects induced by reactions across sectors and institutions composing the regional economy and as affecting the set of regional households.

General equilibrium models also provide relative valuations. For example, general equilibrium models allow interregional labor movement by including migration behavior. It considers opportunity costs of labor in the region and thus provides people the opportunity to choose the location with the higher wage rate adjusted perhaps for nonpecuniary benefits of place or types of work. This is important because welfare is largely dependent on income which is mainly determined by wage income.

In sum, if we are to measure regionwide welfare effects of rural development programs or policies, the advantages of general equilibrium may outweigh the difference between the simplicity of partial equilibrium analysis and the extra resource costs of general equilibrium analysis. Empirically, Thurman and Easley (1992) and Bouchelle et. al. (1993) have used both partial and general equilibrium approaches to analyze the welfare effects of a quota-restricted fishery and their results are indicative of the potential underestimation of welfare changes using the partial equilibrium approach.

Objectives of the Study

The basic objective of this study is to develop an analytical framework for assessing welfare change for households of rural regions and to apply the framework in evaluating rural development programs and policies. The basis of the framework is computable regional general equilibrium with welfare measures of Hicksian compensating and equivalent variation. The welfare changes will be measured both in the distributional context of households at different income levels and in the aggregate. The model differentiates commodities between regional and imported goods and between regional supply and exports. A distinguishing feature of the model is that nonmarket goods are separated from market goods so that the effects of nonmarket goods on expenditures in the regional economy are traced. Labor supplies are determined by labor-leisure choice and a labor migration elasticity.

The specific objectives of this study are:

(1) To provide a theoretical background about features which characterize regional general equilibrium models and review the literature related to these features.

(2) To construct a regional computable general equilibrium model for state and substate geographic levels that incorporate features mentioned above and are able to assess welfare changes from proposed rural development programs and policies.

(3) To empirically measure welfare changes for households from a change in prices of agricultural export commodities at the state level.

(4) To measure welfare changes for a fishery project

producing a nonmarket good at the county level in southeastern Oklahoma.

(5) To describe limitations of the study and provide suggestions for further research.

Organization of the Study

This introductory chapter is followed by a discussion on the analytical (theoretical) background of regional general equilibrium methods in Chapter II. Features characterizing the model of this study are described and presented in diagrammatical form. A review of previous literature regarding these features is also presented. In Chapter III, the regional general equilibrium model is constructed and presented in equational form. Data sources, parameter estimation methods, and method of model solution are reported in Chapter IV. The following two chapters are devoted to empirical applications. In Chapter V, the model is applied at the state level to analyze welfare effects of changes in agricultural export commodity prices. In Chapter VI, the model is applied to evaluate the county level welfare effects of expenditures associated with a nonmarket good. Finally, Chapter VII provides a summary, derives conclusions and policy implications of this study, discusses limitations of this study, and suggests further research.

CHAPTER II

ANALYTICAL (THEORETICAL) BACKGROUND

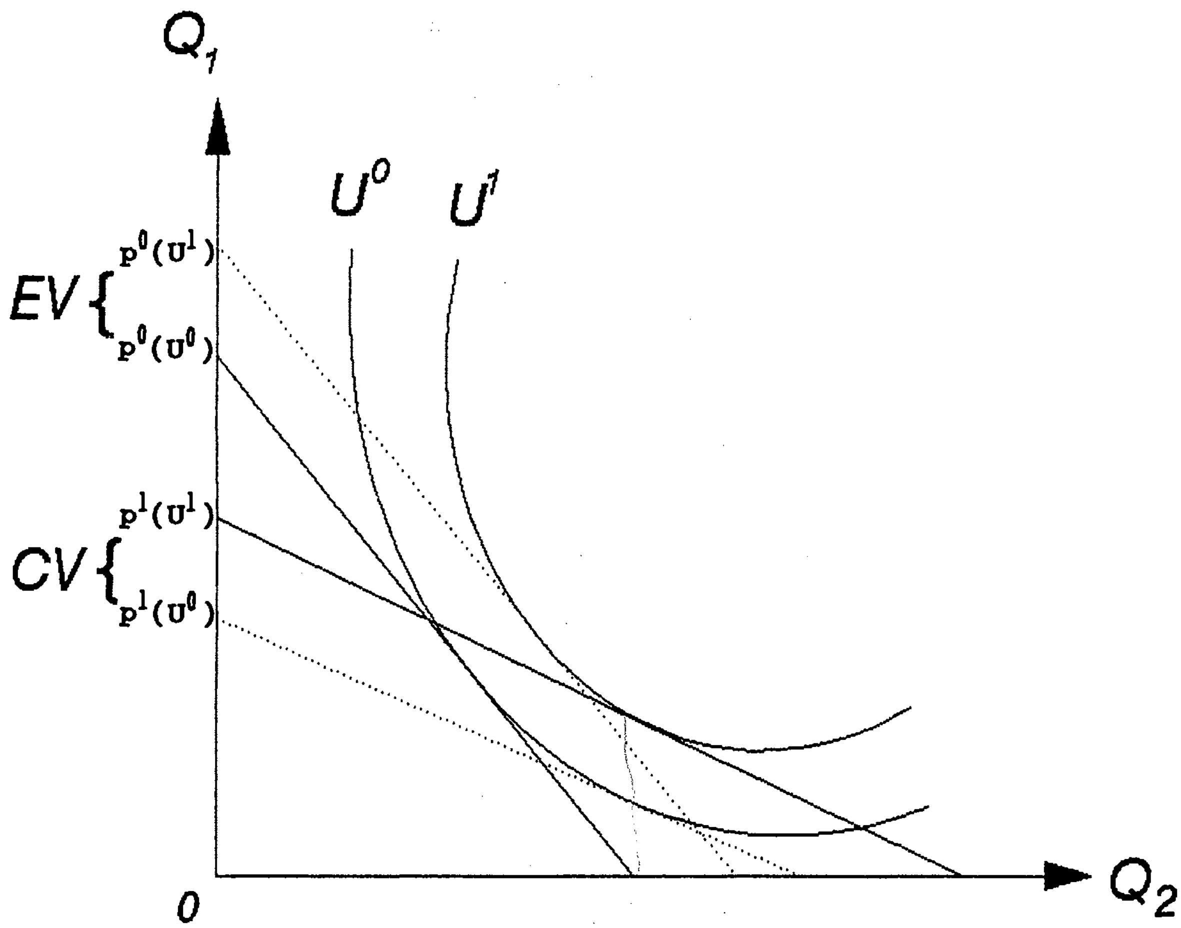
The purpose of the present chapter is to provide theoretical and analytical background for distinguishing features characterized in the model of this study in verbal and/or diagrammatical manner and linked to general equilibrium analysis. These features include regional household welfare measurement, regional product differentiation, regional labor supply, and nonmarket goods. Previous literature is reviewed together with discussion of the model features. In addition, regional computable general equilibrium models are discussed. Specific model formulation by equational forms is presented in the following chapter.

Welfare Measurement

Compensating and Equivalent Variation

Moving from one equilibrium to another presumes a welfare change for most if not all household groups. To measure this change from a policy or program change, welfare itself must be measurable. Because utility is not measurable, an alternative measure must be chosen. "An observable alternative for measuring the intensities of preferences of an individual for one situation versus another is the amount of money the individual is willing to pay or accept to move from one situation to another" (Just et al. page 10). The two most important willingness-to-pay measures are compensating and equivalent variations.

We measure the change in welfare induced by rural development programs by means of compensating and equivalent variations. Compensating and equivalent variations are welfare measures first proposed by John R. Hicks (1943). "Compensating variation (CV) is the amount of money which, when taken away from an individual after an economic change, leaves the person just as well off as before. Equivalent variation (EV) is the amount of money which, if an economic change does not happen, leaves the individual just as well off as if the change had occurred" (Just et al. pages 10 through 11). Which welfare measure is employed depends on whether initial prices or new prices are used. The CV measure is based on new prices and the EV measure on initial prices. In Figure 1, let's suppose the price has changed from p^0 to p^1, and it caused utility of households to increase from U^0 to U^1. The CV is the amount of income (or expenditure) which can be taken away leaving households at their pre-change utility level based on new prices. And the EV computes the amount of money which brings households to the after-change utility level based on initial prices.



CV : Compensating Variation
EV : Equivalent Variation

Figure 1. Compensating and Equivalent Variation

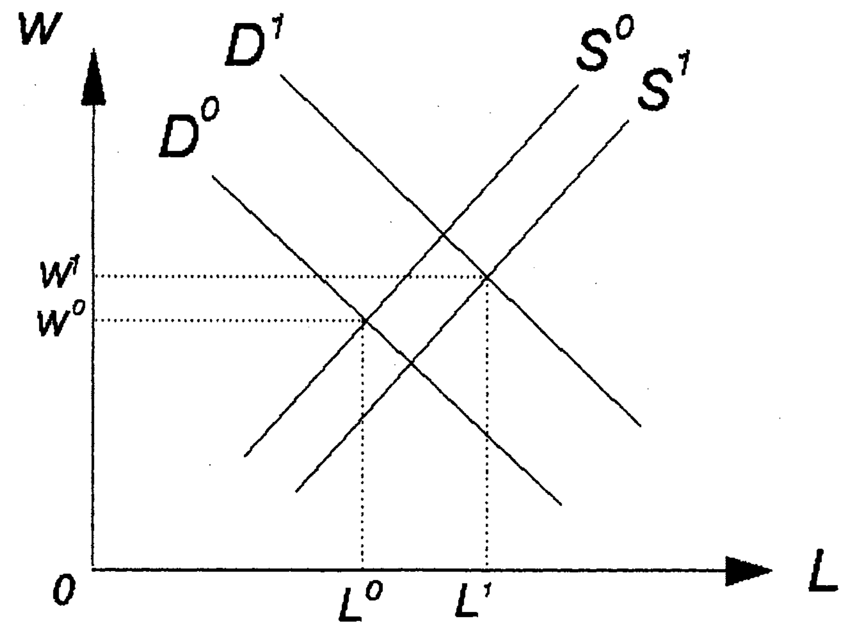
Illustration of Welfare Changes from Exogenous Impact

In this section, we demonstrate how commodity and factor markets adjust under general equilibrium when exogenous shocks occur to a regional economy and how welfare levels change.

Suppose the export price of a commodity increases. Producers respond by increasing regional output of that commodity. This causes an increase in factor demand, for example, for regional labor. This leads to an increase in the wage rate and a subsequent increase in household income, if the labor supply curve is upward sloping (less than infinitely elastic). With increased incomes, demand for commodities increases. Increased demand for commodities results in further increases in commodity prices, unless commodity supplies are perfectly elastic. This again causes producers to increase output. The process continues until a new equilibrium is obtained in the economy.

Figure 2 shows a simplified graphical presentation of this framework. Once an exogenous impact is given such as an export price increase, labor demand shifts from D^0 to D^1 (Figure 2.a). This induces in-migration of labor from other regions triggered by a higher wage rate in the region relative to the rest of country. Therefore, labor supply shifts from S^0 to S^1. The labor market arrives at a new equilibrium with wage rate w^1. The new equilibrium wage rate depends upon the magnitude of the shift in labor demand, the elasticities of labor demand and supply, and the migration response. However,

(a) Factor Market



(b) Commodity Market

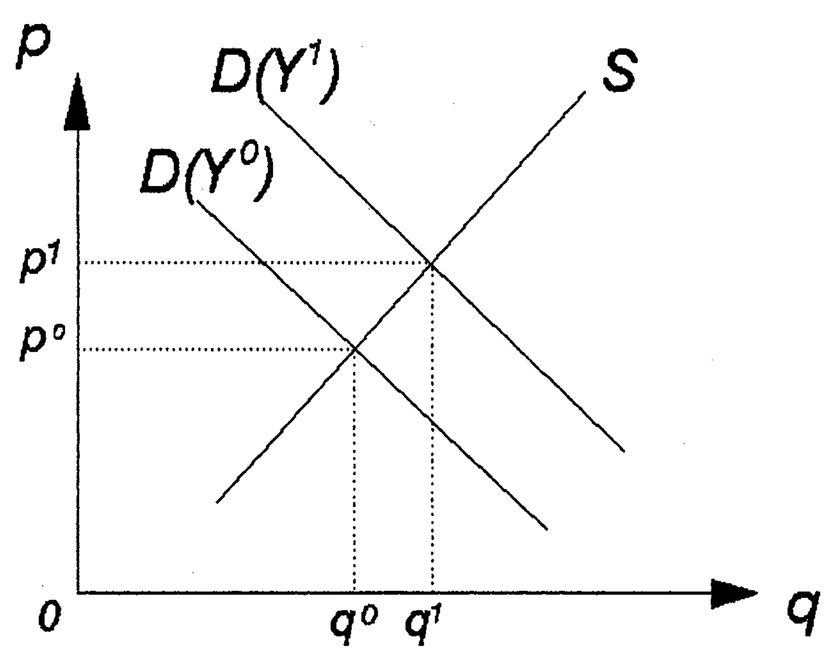


Figure 2. Adjustment of Regional Factor and Commodity Markets

because labor migration generally requires a longer time period than producers' response regarding labor demand, w^1 is expected to be higher than w^0.

As shown in Figure 2.b, increased regional income with more labor (and with higher wage rate under conditions of less than infinitely elastic labor supply) shifts commodity demand from $D(Y^0)$ to $D(Y^1)$. For convenience, the commodity here is a composite of all commodities which are not inferior goods. The commodity market reaches a new equilibrium at commodity price P^1. The degree of commodity price change depends upon the relative elasticities of commodity demand and supply and the amount of income change. However, if labor and commodity supplies are assumed to be infinitely elastic (supply curves are horizontal), wage rate and commodity price are unchanged, thus, only quantities of labor input and commodity output will change in response to the exogenous shock. Results of the impact of an export price change on the regional economy is a new equilibrium in prices, quantities, and incomes.

Figure 3 shows how changes in income and commodity prices induced by exogenous impacts affect welfare level in terms of equivalent variation. The horizontal axis represents an aggregate of non-tradable goods and services and the vertical axis an aggregate of tradable goods and services. Budget line at initial stage is $B(P^0,Y^0)$. For now, it is assumed that wage rate and commodity prices are allowed to change during adjustment to the exogenous shock (upward sloping labor and commodity supply curves). If wage income

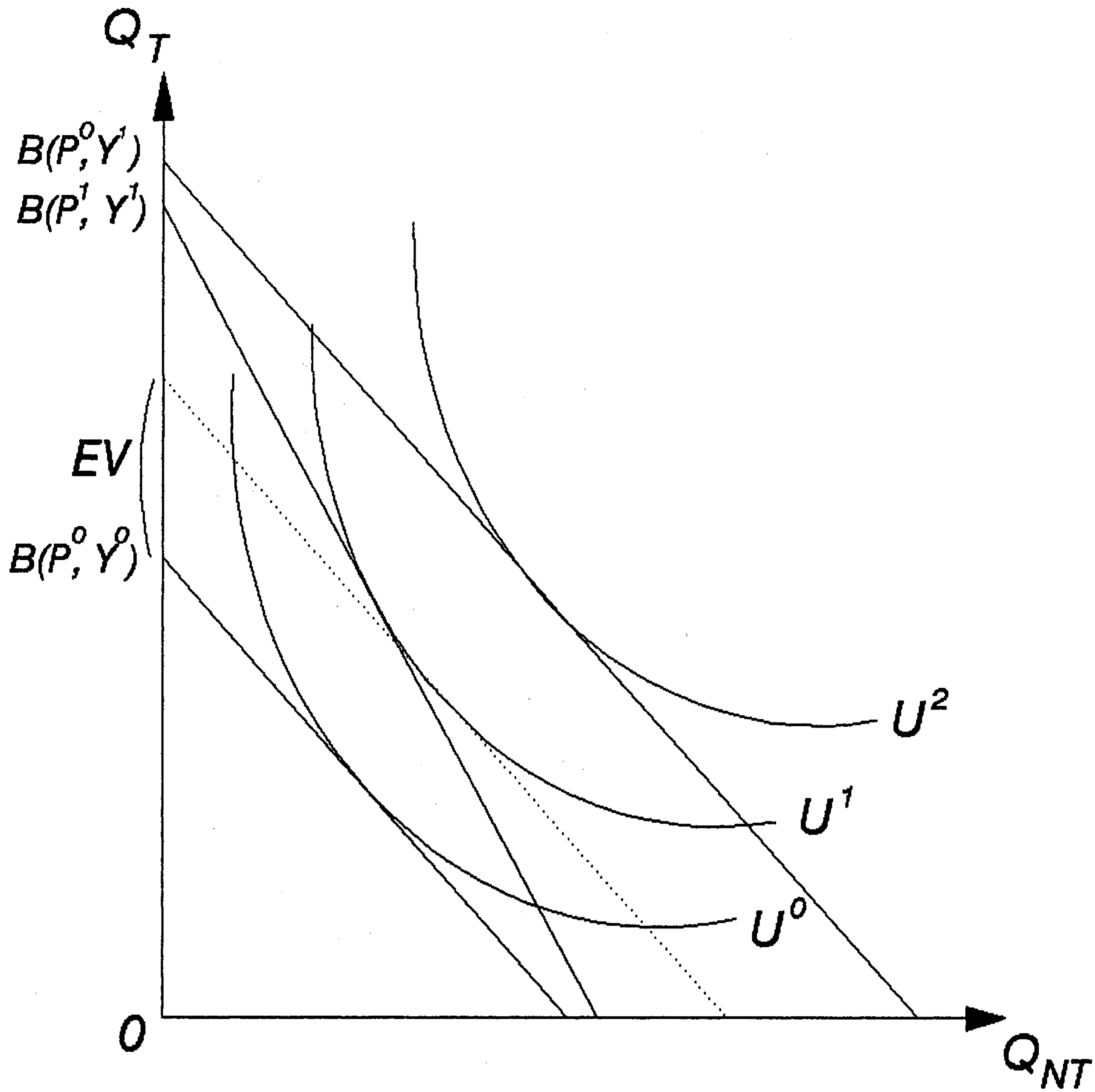


Figure 3. Changes in Regional Household Welfare from Income and Price Changes

and subsequent expenditure increase because of increased demand for labor, the budget line shifts from $B(P^0,Y^0)$ to $B(P^0,Y^1)$. However, increases in commodity prices because of increased demand with higher income shifts the budget line once more to $B(P^1,Y^1)$. Notice that the relative price of tradables and non-tradables has changed, that is, the budget line $B(P^1,Y^1)$ is steeper than the budget line $B(P^0,Y^1)$. This implies that the price of non-tradables has increased more relative to the price of tradables. This is because tradables are more easily supplied from outside the region to meet increased demand while more of the supplies of non-tradables must come from within the region. Finally, utility level changes from U^0 to U^1. Based upon initial prices, welfare of regional households has increased by the amount of EV. The direction and amount of welfare change depends upon the various elasticities and the incidence of the initial wage income increase by household group.

In addition to the above solution, two other solutions are possible with respect to wage rate and price changes during adjustment to the exogenous impact: (1) No wage rate or commodity price changes (perfectly elastic labor and commodity supplies are assumed); and (2) wage rate change, but no commodity price change (perfectly elastic commodity supply is assumed). First, if there are no wage rate or commodity price changes, the budget lines of the initial and new equilibria are the same, and there is no welfare change. Second, if only the wage rate changes without a commodity price change, the budget line of the new equilibrium is $B(P^0,Y^1)$ and utility level of U^2 is obtained. Thus, welfare increases from a wage income increase. By assuming perfectly elastic labor or commodity supplies when in reality supplies are less than perfectly elastic, fixed price multiplier analysis underestimates welfare changes. This is the most critical disadvantage of fixed price multiplier analysis compared to general equilibrium analysis.

Welfare Measures in General Equilibrium Models

Economists have used the concept of compensating variation (CV) and equivalent variation (EV) when analyzing welfare changes of various tax and trade policies using applied general equilibrium models. Shoven and Whalley (1984) demonstrate the use of CV and EV as welfare measures in applied general equilibrium analysis based upon the theoretical structure of CGE models rooted in traditional microtheory. Ahluwalia and Lysy (1979) evaluated welfare effects of demand management policies in Malaysia using welfare related variables such as real household consumption levels.

Ballard, et. al. (1985) analyzed the changes on welfare of alternative corporative and personal income tax integrations and consumption tax alternatives by means of CV and EV in their U.S. CGE model. De Melo and Tarr (1992) used

CV and EV in analyzing welfare effects of U.S. trade policies, presenting specific procedures for deriving the welfare change equations. Both of the above studies analyzed aggregate welfare changes without classifying population groups by income level. This study follows de Melo and Tarr in deriving the regional welfare (CV and EV) functions except that this study classifies household groups by their income level.

Although CGE models have been widely employed in evaluating national tax, trade, and development policies, few CGE models have adapted CV and EV measures for evaluating regional development policies. Because the major objective of regional development is to increase welfare of resident households, explicitly including welfare measures in evaluating rural development policies and programs will be informative for policymakers.

Product Differentiation between Regions

Armington Assumption

Armington (1969) first explored the nature of import demand functions where domestically produced and imported goods are imperfect substitutes in use. The Armington assumption states that domestically produced and imported goods of the same classification qualitatively differ. They are perceived by domestic users as less than perfect substitutes, with an elasticity of substitution, σ ($0 < \sigma <$

∞). Prices of domestically produced and imported goods are generally considered to be different, and domestic users consume a "composite" commodity according to a neoclassical transformation function that is linearly homogeneous and incorporates the elasticity of substitution (σ) between domestically produced and imported goods.

The Armington assumption has been widely adapted in constructing CGE models. Most national CGE models (Robinson et. al., 1990, de Melo and Tarr, and Dervis et. at.) as well as recent regional CGE models (Harrigan and McGregor, Kim, Koh, Morgan et. al., and Rickman) have specified the Armington assumption so that product differentiation between countries and regions is assumed. This specification is a plausible assumption for regional analysis given observed regional cross-hauling patterns for aggregated categories of goods. Product differentiation between the regions provides the necessary condition that the regional prices of goods and services are distinguished from the national prices. Therefore, regional prices should be endogenized separately from the exogenous national prices in general equilibrium models. In this study, products are differentiated not only between regionally produced and imported goods in use, but also between supply of regionally produced goods for the regional and export markets. The following two sections deal with these issues more specifically.

Constant Elasticity of Substitution (CES) Function

Regionally produced and imported goods are assumed to be imperfect substitutes. This feature can be specified by a constant elasticity of substitution (CES) function. Regional users such as firms, consumers, and governments minimize their costs of commodity use by optimally selecting the proportions of regionally produced and imported commodities. The selection of the proportions is constrained by the extent of substitutability between regionally produced and imported goods, and their relative price. How regional users select the combination of regionally produced and imported goods is shown in Figure 4. The optimum combination of QR and QM is where the price line (budget line) is tangent to the CES curve (point QR_0 and QM_0).

A number of CGE models have allowed product differentiation between regionally produced and imported goods using CES functional forms (de Melo and Tarr, Kim, Robinson et. al., 1990, Dervis et. al., Condon et. al., Koh, and Rickman). Particularly, Kim (1992) used a two stage CES functional structure where foreign products were differentiated from domestically produced products in the first stage, and domestically produced products were again differentiated between regionally produced and imported from other domestic regions.

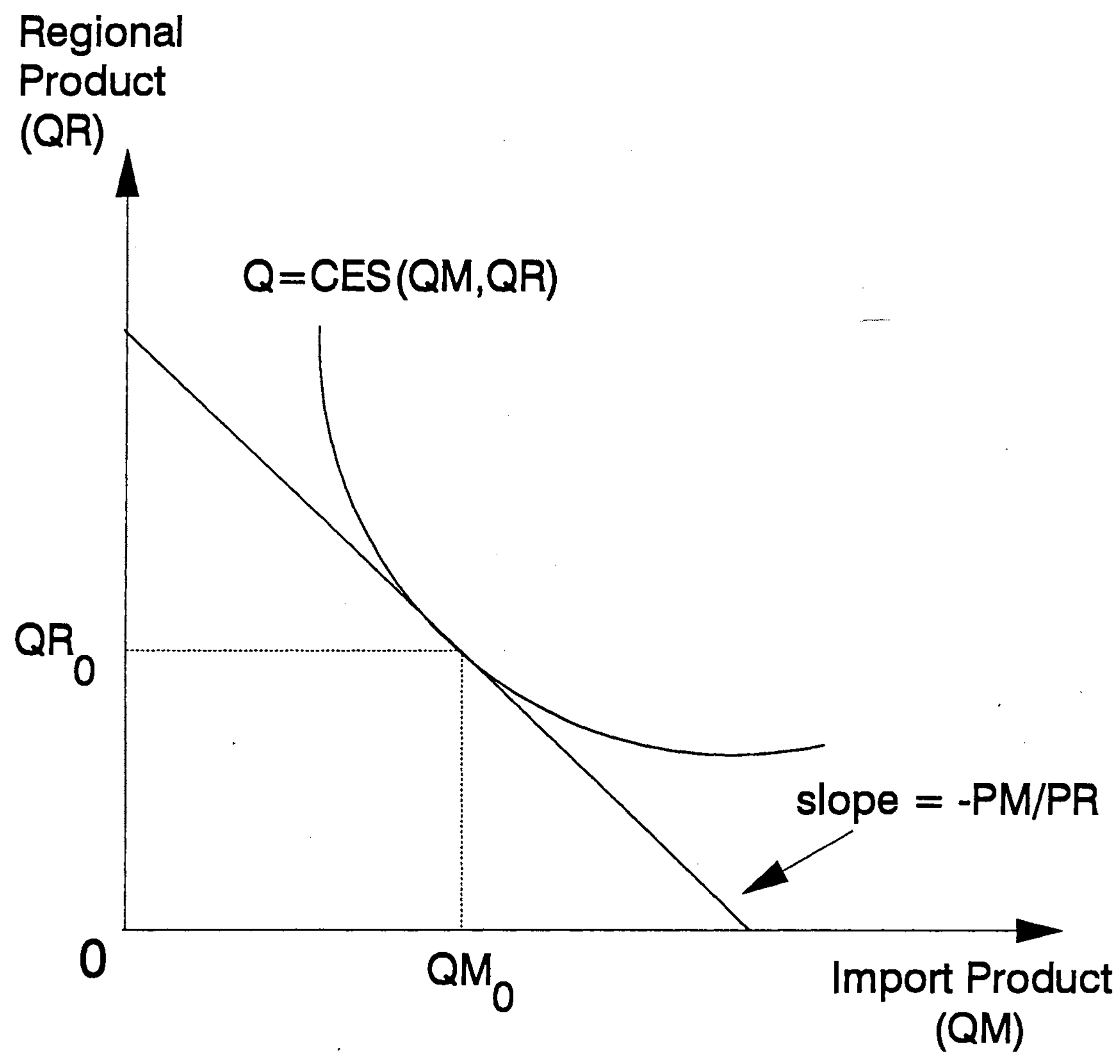


Figure 4. Cost Minimization with Substitution between Regionally Produced and Imported Goods (Source: de Melo and Tarr, p.51)

Constant Elasticity of Transformation (CET) Function

The Armington assumption can be extended to the supply side. In other words, regionally produced goods sold in the regional market differ from regionally produced goods sold in the export market. Regionally produced goods supplied to the region are assumed to be imperfectly transformable to exports of regionally produced goods to the rest-of-world. This feature is characterized by a constant elasticity of transformation (CET) function introduced by Powell and Gruen (1968). Producers are assumed to select markets in which they prefer to sell. The regional producers desiring to maximize revenues decide the proportion of exports and regional supplies based on the elasticity of transformation and relative prices (Figure 5). The combination R_0 and E_0, where the price line is tangent to the CET curve, maximizes revenues.

Fewer CGE models have adapted the imperfect transformability between regional supply and export compared to the imperfect substitutibility between regionally produced and imported goods (de Melo and Tarr, Kim, and Robinson et. al, 1990.). Kim (ibid) also used a two stage nested structure on the supply side as well as the demand side.

Labor Supply

Labor resources play an important role in determining

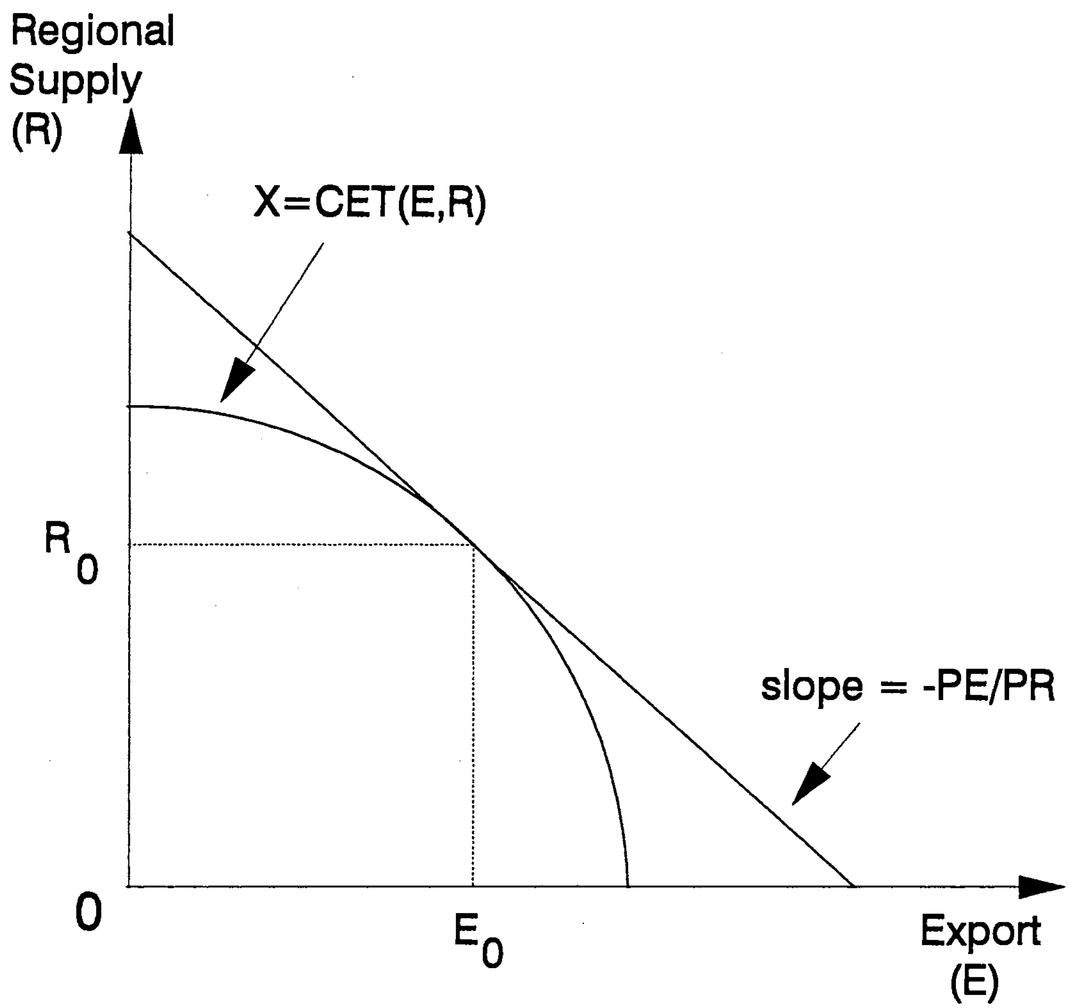


Figure 5. Revenue Maximization with Transformation between Regional Supply and Exports (Source: de Melo and Tarr, p.52)

household income, accounting for about 62 percent of net factor income in Oklahoma (Koh, pp.102-103). Capital and land rents account for the remaining 38 percent of net factor income. Household income from labor depends upon the quantity of their labor resource, how much they are willing to supply at a given wage rate, and the relative wage rate between this region and all other regions. The latter will depend upon the wage elasticity of labor migration for a given quality of labor resource.

The pattern of labor supply in regions is important in analyzing welfare changes of resident households. In this study, labor supply is endogenously determined both by the labor-leisure choice and the labor migration parameters between regions.

Labor-Leisure Choice

The neoclassical model of labor supply treats leisure as a component in the utility function for purposes of deriving the labor supply function. Households make decisions in maximizing utility specifying not only regular goods but also leisure under a budget constraint. Let the utility function be

$$U = U\,(l,\ q)$$

where l is leisure, and q is a consumption vector of n regular goods. Then, the consumer's budget constraint is

$$x + wT = pq + wl$$

where x is nonlabor income, w is the wage rate and the price of leisure, T is the time endowment which is 24 hours minus the time necessary for sleeping and other minimal maintenance tasks, and p is a price vector of n regular goods. The left-hand side of above equation,which is usually called *full income*, represents total purchasing power available to the consumer to be spent on leisure and regular goods. The consumer maximizes her/his utility, U, subject to the budget constraint. The selection of optimal combinations of l and q are depicted in Figure 6. The vertical axis represents the consumption of regular goods, and the horizontal axis represents leisure from the left to the right or, conversely, labor supply. Line AB is the budget constraint which shows the maximum amount of regular goods consumption of 0A by having zero leisure or the maximum amount of leisure of 0T with consuming goods only by amount of q^*. The purchase of q^* is financed from nonlabor income x, because there is no labor income for all of T is used for leisure. The consumer will maximize utility by selecting the amounts of q_0 and l_0 for regular goods and leisure, respectively, where the budget line is tangent to the utility curve U.

Two criticisms can be raised regarding this neoclassical labor supply: (1) most workers cannot select their work hours freely because of the job specification; and (2) wage rate responds to the number of hours supplied and thus it is not fixed (Deaton and Muellbauer, p.87). With respect to the former criticism, in the long run, workers can choose their

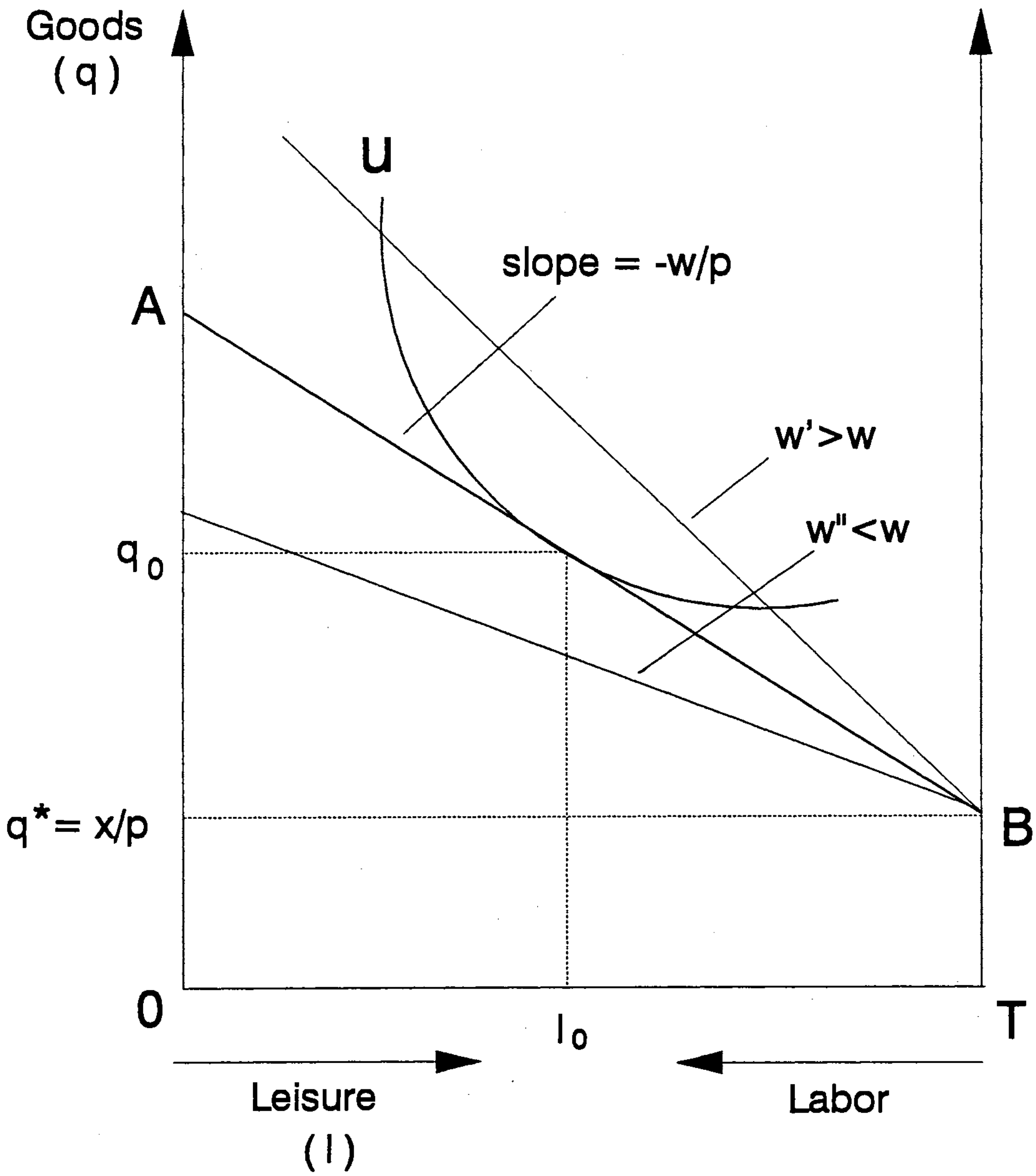


Figure 6. Labor Supply by the Labor-Leisure Choice

work hours by choosing between different jobs. The latter criticism is overcome by the merit of general equilibrium analysis which allows all endogenous prices including factor prices to have feedback interaction with supply and demand through the market mechanism. As shown in Figure 6, if the wage rate increases (decreases) to w′ (w″), the slope of the budget line becomes steeper (less steep). It will affect the choice of demand for goods and supply of labor thus prices of goods and labor. It will, again, affect the budget line which was the starting point of the change. In general equilibrium analysis, these feedback procedures are taken care of within the model.

Values on Leisure by Income Group

In the previous section, labor supply was determined by preference (demand) for leisure. Preferences for leisure are likely to differ by income class. The higher the income, the greater value placed on leisure. The different values on leisure can be reflected by different elasticities of labor supply with respect to income. High income people are willing to decrease supply of labor by greater amounts as income rises compared to low income people. This is because high income people place higher value on leisure, which is competitive in use of their endowed time with labor supply, compared to low income people. These non-pecuniary values on leisure are implicitly reflected in welfare measures of the model in this study following the above procedure.

Labor Migration

Interregional movements of labor and capital play a critical role in theories of regional growth and development (Armstrong and Taylor, p.101). According to classical theory of migration, migration can be interpreted, from an economic point of view, as a flow of labor resource searching for interregional equilibrium (or reducing interregional disparities) in terms of wage rate and job availability. Labor can be assumed to migrate between regions responding to relative wage rate, ignoring the aspect of job availability. The extent of migrating is specified by the elasticity of migration with respect to wage differential. If wage rate is lower in the region than in the rest-of-country, labor will outmigrate from the region. It will decrease the supply of labor in the region, and thus cause wage rate to increase sufficiently to stem any further outmigration.

Migration has been included in general equilibrium models and has turned out to be empirically very important (Dervis et. al., p.178). If migration is included in the CGE model, wage rate, which is returns to labor, must maintain a comparable level with the rest-of-country. This means that labor must be compensated its opportunity cost. One of the main concerns in rural development is to increase or, at least, maintain the rates of return to resources.

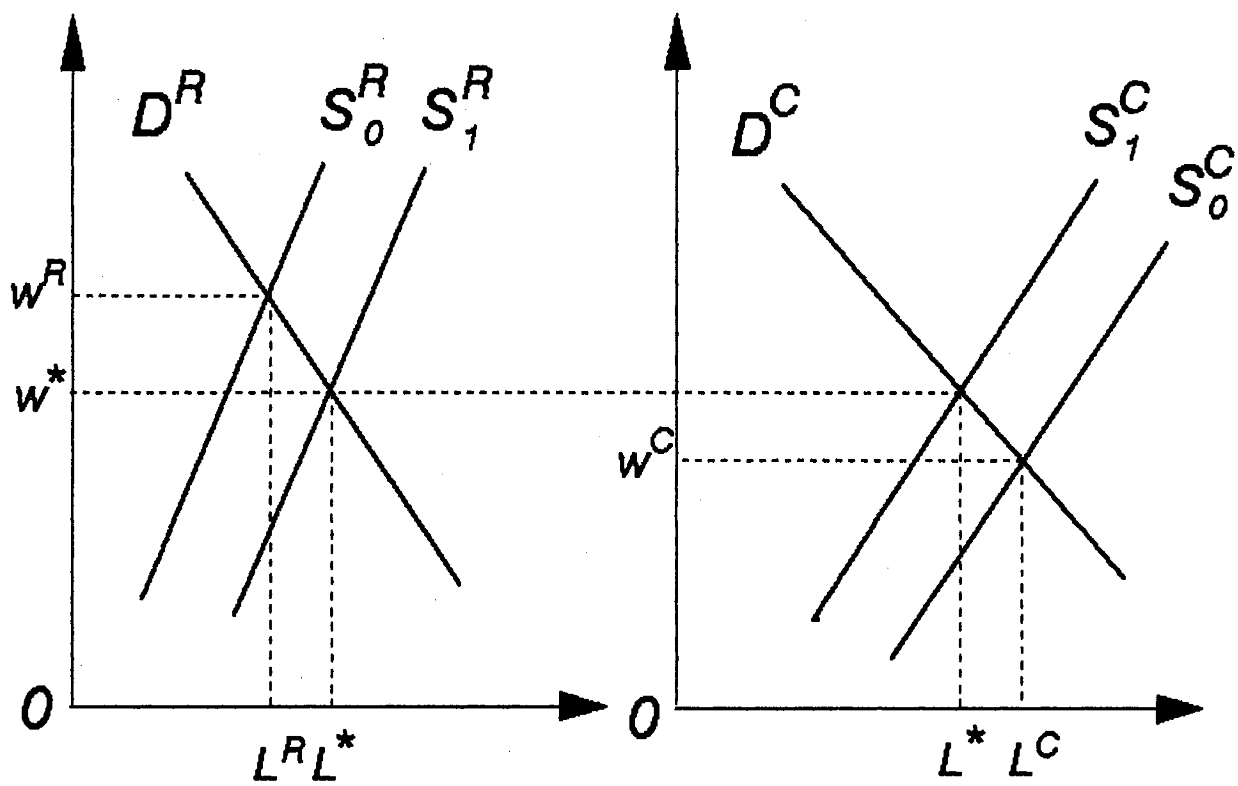
Particularly, returns to labor resources matter because they are significantly related to welfare of people in the region.

Although the classical migration theory has some restrictive assumptions such as perfect availability of information, homogeneity of factors, no other barriers to migration (costlessness as an example), and perfect competition in all markets (Armstrong and Taylor, p.102), it is important to be included in *general* equilibrium analysis. The equilibrating effects of labor migration between regions is illustrated in Figure 7. In the initial stage, wage rate in the region, w^R, is higher than that of the rest-of-country (ROC), w^C. Labor will migrate to the region from the ROC so that wage rate will converge to w^* in both regions by shifting labor supply curves.

Labor Supply in General Equilibrium Models

In many CGE models, labor supply was assumed to be fixed for a given time period. In other words, labor supply is assumed to be perfectly inelastic with respect to wage rate and no labor movement caused by wage differential between regions is assumed. This assumption is not realistic in a society where leisure is valued as well as labor income and information about wage rate is available to people.

De Melo and Tarr (1992) extended their basic model of a national economy by incorporating leisure as a commodity in their utility function to derive an endogenous labor supply



(a) Labor Market in the Region

(b) Labor Market in the Rest-of-Country

Figure 7. The Equilibrating Effects of Labor Migration

function. Ballard et. al. (1985) included leisure as a component of their composite commodity specified by a constant elasticity of substitution function to derive a labor supply (demand for leisure) function. This study followed the procedure introduced by de Melo and Tarr (ibid) in deriving the supply function. However, both of the above models did not classify household group by income level, thus values on leisure were the same regardless of income level. This means that they used one elasticity of labor supply with respect to income (de Melo and Tarr) and one elasticity of substitution between goods and leisure (Ballard et. al.). In the current study, values on leisure are assumed to differ by income level.

Adelman and Robinson (1978) and Dervis et. al. (1982) included rural-urban migration in their national CGE models to allow labor mobility between rural and urban regions. Ko (1985) incorporated labor movements between sectors and regions in his multi-regional CGE model by assuming that the labor supply depends on the wage differences among sectors and on the expected wage differences across regions. Rickman (1992), under his neoclassical closure, incorporated a labor migration between a specific region in the U.S. and the rest of the country by incorporating real after tax wage differentials.

In this study, labor supply will be endogenized both by the labor-leisure choice and labor migration.

Nonmarket Goods

Valuing Nonmarket Goods

In the previous section, leisure was incorporated into household utility through the labor-leisure choice model, thus non-pecuniary value of leisure was reflected in the welfare measure. Similar to leisure, there are elements which affect the welfare (utility) level of the individual, but are not traded in markets. These are commonly categorized as "nonmarket" goods. An excellent example of a nonmarket good is recreation (fishing, hunting, sightseeing). If we are to measure true welfare changes from development policies, both market and nonmarket goods should be included if they affect expenditures and/or time allocations. The difficulty of including nonmarket goods is that they frequently do not have observable prices because no market exist in which preferences are expressed.

There are several inferential techniques, however, for valuing nonmarket goods: travel cost, hedonic price, and contingent valuation. Inferential techniques use market-generated data pertaining to some marketed good in an attempt to infer the value of the nonmarket good under analysis. Valuation of a particular nonmarket good requires the identification of some marketed good for which the demand may provide evidence of the value of the nonmarket good (Randall, p.300).

In the travel cost method, the value of the nonmarket good is inferred from market behavior of those traveling to obtain the benefits of the nonmarket good. For example, the value of a recreational fishery can be inferred from the travel costs (both expenditures and opportunity cost of time) of anglers making a trip to the fishery (Schreiner, 1989, p.288). The travel cost method derives a demand function for the nonmarket good by statistically estimating the relationship between travel costs (a surrogate for price) and usage of the site (an indicator of quantities demanded) using information from random samples of users. This estimated relationship is then used to estimate the value of the nonmarket services provided by the recreation site. (For nonmarket valuation methods, see Randall, 1981, chapter 16; Schreiner, 1989, pp.288-289; and Pearce and Turner, 1990, chapter 10). In this study, a simplified travel cost method was used for valuing nonmarket goods, where "simplified" implies that estimated travel costs were directly used as values of nonmarket goods without estimating the demand function. The more specific procedures are presented in the following subsection.

Nonmarket Goods and General Equilibrium Analysis

Travel costs (expenditures) for nonmarket goods can be sorted according to commodity purchases by industry grouping. The sorted expenditures by sector (industry) are inputs in the production of the nonmarket good. Consumption of the nonmarket good is expressed by total expenditure for the nonmarket good and other demand characteristics. Nonmarket goods are then included as a separate sector interrelated with other sectors in a social accounting matrix (SAM). Once included in a SAM, nonmarket goods can play a role of interacting with other components in a CGE model.

The input-output framework has been extended to account for environmental pollution generation and abatement, which are frequently characterized as nonmarket goods, associated with interindustry activity (Miller and Blair, 1985, p.236). Literature in the 1970s using input-output models to analyze pollution has been extended to the development of economy wide, environmental, CGE models (Hollenbeck, 1979; Hazilla and Kopp, 1990; Jorgenson and Wilcoxen, 1990; and Robinson et. al., 1993). However, few studies have incorporated recreational nonmarket goods in regional general equilibrium models. Furthermore, when the objective is to measure the welfare of households residing in the area where the nonmarket good is produced, a general equilibrium analysis relates that nonmarket good with market goods in the analysis of all regional factor and commodity markets.

Computable General Equilibrium Analysis at the Regional Level

General equilibrium (GE) implies that all individual economic agents (and subsets of the agents) in the system are in "equilibrium" (Koh, 1991, p.33). The GE approach focuses attention upon interdependencies which exist in an economy and analyzes those interdependencies within a consistent analytic and information framework.

GE models range from static input-output models with fixed prices to dynamic computable general equilibrium models with endogenous prices, quantities, technologies, and investments. The input-output models have been widely used in economic impact analysis. However, the fixed-price input-output model only estimates the aggregate quantity effects of an exogenous change on output, employment, and income. The fixed-price social accounting matrix (SAM) multiplier analysis is an alternative to input-output and provides detailed distributive impacts among agents and institutions. The fixed-price SAM multiplier analysis is limited, however, because it does not effectively capture the factor-product price adjustments but rather assumes quantities will adjust at fixed prices.

Computable general equilibrium (CGE) models are an attractive alternative to the fixed-price SAM multiplier model in analyzing economy wide impacts of exogenous disturbances to regional economic systems, allowing factor substitution in production, commodity substitution in consumption, and above all, prices as well as quantities to be treated explicitly as endogenous variables. Furthermore, a CGE model based upon a SAM structure allows analysis of distributional effects.

Kraybill (1993, pp.209-210) effectively describes the conceptual advantages of CGE modeling over input-output modeling at the regional level as follows,

> In the past, a theoretical gap has existed between regional IO (input-output) modeling and other approaches to regional analysis. This gap was perpetuated by crude theoretical foundations that made it difficult or impossible for the IO model to incorporate concepts and econometric results from regional studies related to labor supply and demand, migration, tax incidence, cost-of-living, and other issues. In contrast, CGE models employ variables, parameters and functional forms that are relatively similar to those of conventional microeconomic theory and widely used econometric specifications.

In this sense, a CGE model is one of the most suitable multisectoral models to evaluate economic effects of various development policies.

The CGE model approach, based on Walras general equilibrium theory, was originally developed by Johansen (1960). Since Johansen's work, several CGE models have been developed, most of which are constructed at the national level. Adelman and Robinson (1978), Dervis, de Melo, and Robinson (1982), and Shoven and Whally (1984) are examples of national CGE models. A few key factors have limited application of the CGE framework at the regional level. These are, as Koh, Schreiner, and Shin (1992) have mentioned, the perceived nature of the mobility of regional resources (particularly labor), the perceived closure of regional commodity markets (distinction between tradables and nontradables), and the lack of appropriate regional data and reliability of data. Labor mobility and commodity tradability may be specified by labor migration elasticities and elasticities of substitution for commodity markets. Furthermore, data problems in regional GE modeling for the U.S. are being mitigated by development of data bases such as IMPLAN (IMpact Analysis for PLANning) and by persistent regionalization of data as exemplified by Rose, Stevens, and Davis, and by Koh (Koh et. al.).

In spite of the constraints, several regional CGE models have recently been constructed. These models can be categorized into interregional models and single-region models. Ko (1985), Harrigan and McGregor (1989), Morgan, Mutti, and Partridge (1989), Jones and Whalley (1990), Rickman (1992), and Kim (1992) constructed interregional CGE models to analyze interregional impacts of various policies including tariffs and taxes. Fisher and Despotakis (1989) used a single-region CGE model to estimate the impacts of alternative energy taxes on the California economy. Robinson, Subramanian, and Geoghegan (1993) set up a single-region, environmental CGE model for the Los Angeles basin in southern California to investigate the economic impacts of instituting a marketable permit system to reduce air pollution. Koh (1991) constructed a single-region CGE model for the state of Oklahoma to conduct simulation experiments identifying distributional impacts of regional development policies in Oklahoma. The model constructed in this study belongs to the single-region CGE classification.

CHAPTER III

REGIONAL GENERAL EQUILIBRIUM MODEL SPECIFICATION

Overview of the Model

This regional CGE model is designed to quantify welfare effects of rural development programs on the regional economy by income class size. The model focuses on: (1) commodity trade with differentiation between regionally produced and imported goods which implies imperfect substitution in use by all economic agencies; (2) imperfect transformabilities between production for regional and export markets specified by a constant elasticity of transformation (CET) function; (3) labor supply which is determined by the labor-leisure relationship and by an exogenously determined migration elasticity; (4) measurement of welfare change for each household income group from exogenous impacts to the region; and finally, (5) incorporation of nonmarket goods in regional consumption.

The geographic areas applied in this study are county and state levels. The regional economy is aggregated into four sectors based on homogeneity of production, degree of tradability, and availability of data: agriculture, mining, manufacturing, and services. In addition to the commodities which are actually marketed in the regional economy, this model includes the nonmarket goods of trout fishery (TF) trips to the Mountain Fork River (MFR). TF trips are divided into trips by regional anglers, that is a regionally consumed nonmarket good by regional households, and trips by outside anglers, that is a nonmarket good regionally consumed but classified as an export commodity. The nonmarket goods are produced using composite market inputs. Nonmarket good demand is estimated using the simplified travel cost method based upon the expenditure approach (Choi). In notation, M refers to the set of marketed goods while NM refers to the set of nonmarket goods. Among nonmarket goods, NR refers to the set of nonmarket goods which are consumed within the region and NE refers to the set of nonmarket goods which are exported outside the region. There are n sectors, of which there are m market good sectors, and nr and ne nonmarket goods consumed in the region and exported, respectively. Household groups are categorized into s groups according to annual income size. Subscript i and j denote sectors and h household income group. If double subscripts are used, for example, V_{ji}, it means that "j" was used by "i".

Producing Sectors

Input Demands of Production

The model assumes firms are profit maximizers.

Production is characterized by a multi-level nested production function (Figure 8).

In the first level, each of n production sectors uses a composite of primary factors (or value added) and m composite intermediate inputs (Note that only m composite intermediate goods are used because nonmarket goods cannot be used as intermediate goods for commodity production). At this level, a Leontief production function is used so that the composite of primary factors cannot be substituted for the composite of intermediate inputs, nor can the intermediate input from one sector be substituted for the intermediate input of another sector. Nonmarket goods, however, use only intermediate inputs because they have no value-added:

$$X_i = \min\left[\frac{1}{a_{0i}} VA_i,\ \frac{V_{1i}}{a_{1i}},\ \ldots,\ \frac{V_{mi}}{a_{mi}}\right], \qquad i \in M \tag{3.1}$$

$$X_i = \min\left[\frac{V_{1i}}{a_{1i}},\ \ldots,\ \frac{V_{mi}}{a_{mi}}\right], \qquad i \in NM \tag{3.2}$$

where X_i is the gross output of industry i; VA_i is the composite value added in industry i; V_{ji} is the use of the composite intermediate good j in industry i; a_{0i} is the composite value added requirement per unit of output i; a_{ji} (j=1,...,m) is the requirement of intermediate good j per unit of good i.

For profit maximization, firms select the amount of composite value added (VA_i) and composite intermediate goods (V_{ji}) so that the following equations hold:

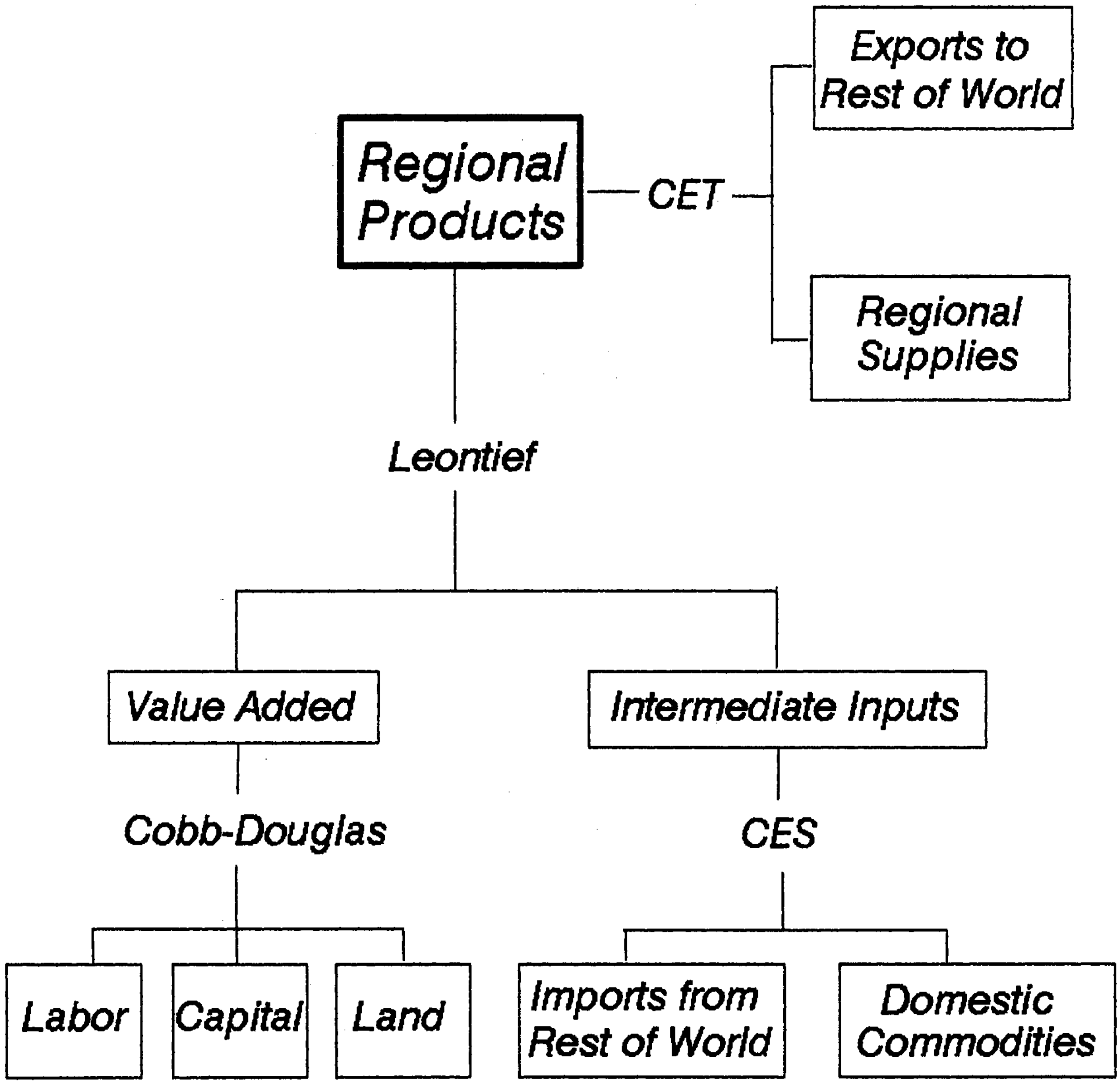


Figure 8. Production Structure of the Model

$$VA_i = a_{0i}X_i \ , \qquad i \in M \tag{3.3}$$

$$V_{ji} = a_{ji}X_i \ , \qquad \forall_i, \ j \in M \tag{3.4}$$

In the second level, each of the composite functions is specified. The composite value added in equation (3.1) is a composite of labor, capital, and land. In this model, these primary factors are assumed to be linearly homogeneous and substitutable with a constant elasticity of substitution of one. The Cobb-Douglas functional form was used for the value added production function:

$$VA_i = \phi_i^{VA} \ LAB_i^{\delta_i^L} \ CAP_i^{\delta_i^K} \ LAND_i^{\delta_i^T} \ , \qquad i \in M \tag{3.5}$$

where LAB_i, CAP_i, and $LAND_i$ denote the amounts of labor, capital, and land used in industry i, respectively; ϕ_i^{VA} is a constant efficiency parameter; and δ_i^L, δ_i^K, and δ_i^T are share parameters for labor, capital, and land, respectively. Profit maximization is employed to derive the demands for primary factors. Each sector is made up of many similar firms maximizing profits which leads to the assumption of perfect competition in product markets. That is, prices are given to firms. The profit function for sector *i* can be denoted as:

$$\Pi_i = PN_iX_i - PL \ LAB_i - PK_iCAP_i - PT_iLAND_i \ , \quad i \in M \tag{3.6}$$

where PN_i is net price of commodity i and PL, PK_i, and PT_i are unit costs of labor, capital, and land, respectively. Among the three primary factors, only labor is assumed to be mobile between sectors, thus one wage rate *PL* prevails across all sectors.

Solving the first order conditions of the above profit function with respect to labor gives:

$$PN_i \frac{\partial X_i}{\partial LAB_i} = PL \ , \qquad i \in M \tag{3.7}$$

The exponent of each primary input variable in the Cobb-Douglas production function is the factor share parameter and the partial elasticity of output with respect to that input. Thus

$$\delta_i^L = \frac{\partial X_i}{\partial LAB_i}\frac{LAB_i}{X_i} \ , \qquad i \in M \tag{3.8}$$

Combining equations (3.6) and (3.7) and rearranging results in demand for labor of sector *i* as:

$$LAB_i = \frac{\delta_i^L \ PN_i \ X_i}{PL} \ , \qquad i \in M \tag{3.9}$$

Demand for capital and land are derived in a similar manner.

$$CAP_i = \frac{\delta_i^K \ PN_i \ X_i}{PK_i} \ , \qquad i \in M \tag{3.10}$$

$$LAND_i = \frac{\delta_i^T \ PN_i \ X_i}{PT_i} \ , \qquad i \in M \tag{3.11}$$

Each of n intermediate goods in equation (3.1) is a composite of regionally produced and imported intermediate goods. As with primary factors, firms optimize the combination of regionally produced and imported intermediate goods according to their relative prices and the amount of the composite intermediate goods determined in equation (3.3). A CES function is used to allow substitution between regionally produced and imported goods:

$$V_{ji} = \phi^{V}_{ji}\left[\delta^{V}_{ji}VM^{\rho^{V}_{j}}_{ji} + (1-\delta^{V}_{ji})\,VR^{\rho^{V}_{j}}_{ji}\right]^{\frac{1}{\rho^{V}_{j}}},\ \rho^{V}_{j}<1,\ i,j \in M \qquad \textbf{(3.12)}$$

$$\sigma^{V}_{j} = \frac{1}{1-\rho^{V}_{j}}$$

where VM_{ji} and VR_{ji} are imported and regional intermediate purchases by sector i from sector j , respectively; $\phi_{ji}{}^{V}$ is a constant efficiency parameter; $\delta_{ji}{}^{V}$ is a share parameter; and $\acute{o}_{j}{}^{V}$ is an elasticity of substitution.

Cost minimization or the dual of profit maximization is used to derive the demand for regionally produced and imported goods. That is, firms minimize production costs for intermediate inputs given substitution possibilities between regionally produced and imported goods, and their relative prices:

$$\textit{Minimize} \quad PMO_{j}VM_{ji} + PR_{j}VR_{ji}$$

$$s.t. \quad V_{ji} = \phi^{V}_{ji}\left[\delta^{V}_{ji}VM^{\rho^{V}_{j}}_{ji} + (1-\delta^{V}_{ji})\,VR^{\rho^{V}_{j}}_{ji}\right]^{\frac{1}{\rho^{V}_{j}}}$$

where PMO_{j} and PR_{j} are the prices of intermediate imported and regional goods of sector j, respectively. Solving the equations for the first order conditions yields the following ratios:

$$\frac{VR_{ji}}{VM_{ji}} = \left[\left(\frac{1-\delta_{ji}^{V}}{\delta_{ji}^{V}} \right) \left(\frac{PMO_j}{PR_j} \right) \right]^{\sigma_j^V} , \qquad i,j \in M \qquad (3.13)$$

It is assumed that intermediate demand for nonmarket goods is for regionally produced goods only:

$$VR_{ji} = V_{ji} , \qquad VM_{ji} = 0 , \qquad i \in NM , \; j \in M \qquad (3.14)$$

Intermediate demands for goods of sector i are the summation of demands for goods of that sector by all of the sectors in the economy. If the goods demanded are regional products,

$$TVR_i = \Sigma_j VR_{ij} , \qquad i \in M, \; \forall_j \qquad (3.15)$$

where TVR_i are demands for regional intermediate goods of sector i.

If the goods demanded are imports,

$$TVM_i = \Sigma_j VM_{ij} , \qquad i \in M, \; \forall_j \qquad (3.16)$$

where TVM_i are demands for imported intermediate goods of sector i.

Demand for composite goods of sector i, TV_i, is,

$$TV_i = \Sigma_j V_{ij} , \qquad i \in M, \; \forall_j \qquad (3.17)$$

Production Supply

On the supply side of production, producers are assumed to have the choice between regional and export markets. As shown in Figure 8, regional production supplied to rest of world as exports is imperfectly transformable into goods supplied to the regional market. This feature is defined by a constant elasticity of transformation (CET) function introduced by Powell and Gruen (1968) as follows:

$$X_i = \phi_i^X \left[\delta_i^X E_i^{\rho_i^X} + (1-\delta_i^X) R_i^{\rho_i^X}\right]^{\frac{1}{\rho_i^X}} , \qquad \rho_i^X > 1 , \quad i \in M \tag{3.18}$$

$$\sigma_i^X = \frac{1}{\rho_i^X - 1}$$

where E_i and R_i are supplies for exports and regional sales, respectively; ϕ_i^X are constant shift parameters; δ_i^X are share parameters; and σ_i^X are elasticities of transformation.

Producers maximize revenues from selling their products either to rest of world or to regional markets. The amounts depend upon relative export and regional prices. That is,

$$\text{Maximize} \quad PEO_i E_i + PR_i R_i$$

$$s.t. \quad X_i = \phi_i^X \left[\delta_i^X E_i^{\rho_i^X} + (1-\delta_i^X) R_i^{\rho_i^X}\right]^{\frac{1}{\rho_i^X}}$$

where PEO_i and PR_i are prices of exported and regionally sold products, respectively.

Solving the first order conditions and rearranging in the form of the ratio of R_i to E_i yields:

$$\frac{R_i}{E_i} = \left|\left(\frac{1-\delta_i^X}{\delta_i^X}\right)\left(\frac{PEO_i}{PR_i}\right)\right|^{-\sigma_i^X} , \qquad i \in M \tag{3.19}$$

In the case of nonmarket goods, none of the regional TF trips are exported and none of the exported TF trips are regionally consumed, thus export demand for TF trips is a function of price (travel cost) of TF trips and an exogenously determined demand elasticity ϵ_i:

$$R_i = X_i \,, \qquad E_i = 0 \,, \qquad i \in NR \tag{3.20}$$

$$R_i = 0 \,, \qquad E_i = E0_i (P_i)^{\epsilon_i} \,, \qquad i \in NE \tag{3.21}$$

Consuming Sectors

The basic assumption of household behavior is that households determine their demands for leisure (or supply of labor) and consumption of commodities such that utility is maximized given their total expenditure and all commodity prices.

Income Generation and Savings

The basic source of household income is factor income which is distributed to households according to ownership of factors by each household group. Factor income is the result of value added by industrial sector. Therefore, factor income is determined by factor prices and amount of factors employed under factor market equilibrium conditions. Labor income is obtained by multiplying wage rate and labor amount:

$$YLAB = \Sigma_i (PL \times LAB_i) + PL(\Sigma_h LHHO_h + LSLGO + LFEDGO), \quad i \in M \qquad \textbf{(3.22)}$$

where *YLAB* is labor income and $LHHO_h$, *LSLGO*, and *LFEDGO* are labor employed by household group *h*, state and local government, and federal government, respectively. One labor market is assumed and i sectors of labor employment.

Similarly, capital and land incomes are expressed by factor prices and amounts of factors employed as determined in factor markets:

$$YCAP = \Sigma_i (PK_i \times CAP_i), \qquad i \in M \qquad \textbf{(3.23)}$$

$$YLAND = \Sigma_i (PT_i \times LAND_i), \qquad i \in M \qquad \textbf{(3.24)}$$

where *YCAP* and *YLAND* are capital and land income, respectively. If capital and land are fixed by sector, there may be a different rate of return for each sector.

Capital income from the agricultural sector is treated separately because it is assumed that capital income from sectors other than agriculture is distributed to the enterprise account first and then distributed to households in the form of returns (profits) while agricultural capital income is distributed directly to households. Agricultural capital income *YAGCAP* is :

$$YAGCAP = PK \times AGCAP \qquad \textbf{(3.25)}$$

Capital income, except *YAGCAP*, goes to the enterprise account in the region after capital tax is subtracted:

$$YENT = (YCAP - YAGCAP) \times (1 - ktr) \quad (3.26)$$

where *YENT* is enterprise income and *ktr* is capital tax rate.

This model allows labor migration between the region and the rest of the country (specification of labor migration will be presented later in this chapter). Thus, labor income, *YLAB*, is labor income earned by people residing in the region at the new equilibrium. In other words, if inmigration occurs, *YLAB* is for the initial households plus inmigrants, and if outmigration occurs, *YLAB* is for the initial households minus outmigrants. On the contrary, other factor incomes, *YCAP, YLAND, YAGCAP*, and *YENT*, are incomes for initial households, because those factors are assumed to be fixed by region (see equation 3.30′ on household expenditures for regional factor payment flows). Labor income in equation (3.22), *YLAB*, is adjusted to the initial base for number of households. Labor income adjusted to the initial number of households, *AYLAB*, is:

$$AYLAB = \frac{YLAB}{adj} \quad (3.22')$$

and

$$adj = \frac{LSTK0 + LMIG}{LSTK0}$$

where *adj* is the adjustment factor, *LSTK0* is the initial equilibrium stock of labor, and *LMIG* is net labor migration.

Factor taxes are deducted from factor incomes and depreciation and retained earnings are subtracted from enterprise income and agricultural capital income before distributions are made to factor owners. Distribution of factor income to households depends upon the fixed distribution coefficients for the base year. Distribution coefficients for agricultural capital income are assumed to be the same as that of land income because the distribution pattern by income class appears to be similar:

$$YH_h = l_h AYLAB(1-sstr)+t_h[YAGCAP(1-ktr-depr)+YLAND(1-ttr)] + e_h[YENT - depr(YCAP - YAGCAP)] \qquad \textbf{(3.27)}$$

where YH_h is factor income distributed to household group h; l_h and t_h are income distribution coefficients to household group h for labor and agricultural capital and land, respectively; e_h is enterprise profit distribution coefficient to household group h; $sstr$ and ttr are factor income tax rates for labor and land, respectively; and $depr$ is the rate of depreciation and retained earnings from capital income. Labor income (*AYLAB*) is adusted to obtain the level of household income for the initial number of households by income group.

In addition to factor income, other sources of household income include government transfers and remittances from outside the region. Income taxes are subtracted from the sum of distributed factor income, government transfers, and remittances to arrive at disposable income by household group h, DYH_h:

$$DYH_h = (YH_h+TRSLGO_h+TRFEDGO_h+REMITO_h)(1-hhtr_h) \qquad (3.28)$$

where $TRSLGO_h$ and $TRFEDGO_h$ are government transfers to household group h from state and local government and federal government,respectively; $REMITO_h$ is net remittances from outside the region to household group h; and $hhtr_h$ is income tax rate for household group h.

Saving by household group is a fixed proportion of household income:

$$HSAV_h = s_h YH_h \qquad (3.29)$$

where $HSAV_h$ is household saving and s_h is saving rate for household group h.

Expenditure of household group h, $HEXP_h$, is disposable income minus saving and payment for labor employed by households:

$$HEXP_h = DYH_h - HSAV_h - PL \times LHHO_h \qquad (3.30)$$

Household expenditure in equation (3.30) is based on the initial number of households in each income group without considering migration. However, it is expected that migrants bring in (inmigration) or take out (outmigration) income from factors owned (capital and land) to their final destination, assuming capital and land are immobile between regions. Therefore, household expenditure which comes from such factor income payments should be adjusted to the current number of households in each income group before it is incorporated into the demand systems. By so doing, the demand systemsare driven by expenditures spent within the region for household consumption. Adjusted household expenditure by income group, $AHEXP_h$, is obtained by multiplying the adjustment factor to $HEXP_h$:

$$AHEXP_h = adj \times HEXP_h \tag{3.30'}$$

Commodity Demand and Labor Supply

Commodities for consumption are supplied either from regional sources or from rest of world. A hierarchical nested structure is used to show demands for leisure and commodities from the various geographical sources (Figure 9). In the first level, consumers are assumed to maximize total utility from leisure, composite market commodities, and nonmarket commodities subject to consumer income (or expenditure) and prices.

Demand functions are required to have the following four properties of classical economic theory: (1) adding up - value of total demands is total expenditure; (2) homogeneity - demands are homogeneous of degree zero in total expenditure and prices; (3) symmetry - cross-price derivatives of the Hicksian demands are symmetric; and (4) negativity - direct substitution effect is negative for the Hicksian demands (Deaton and Muellbauer). Each property defines an exact set of relationships which any complete set of demand functions must possess if it is derivable from the maximization of utility.

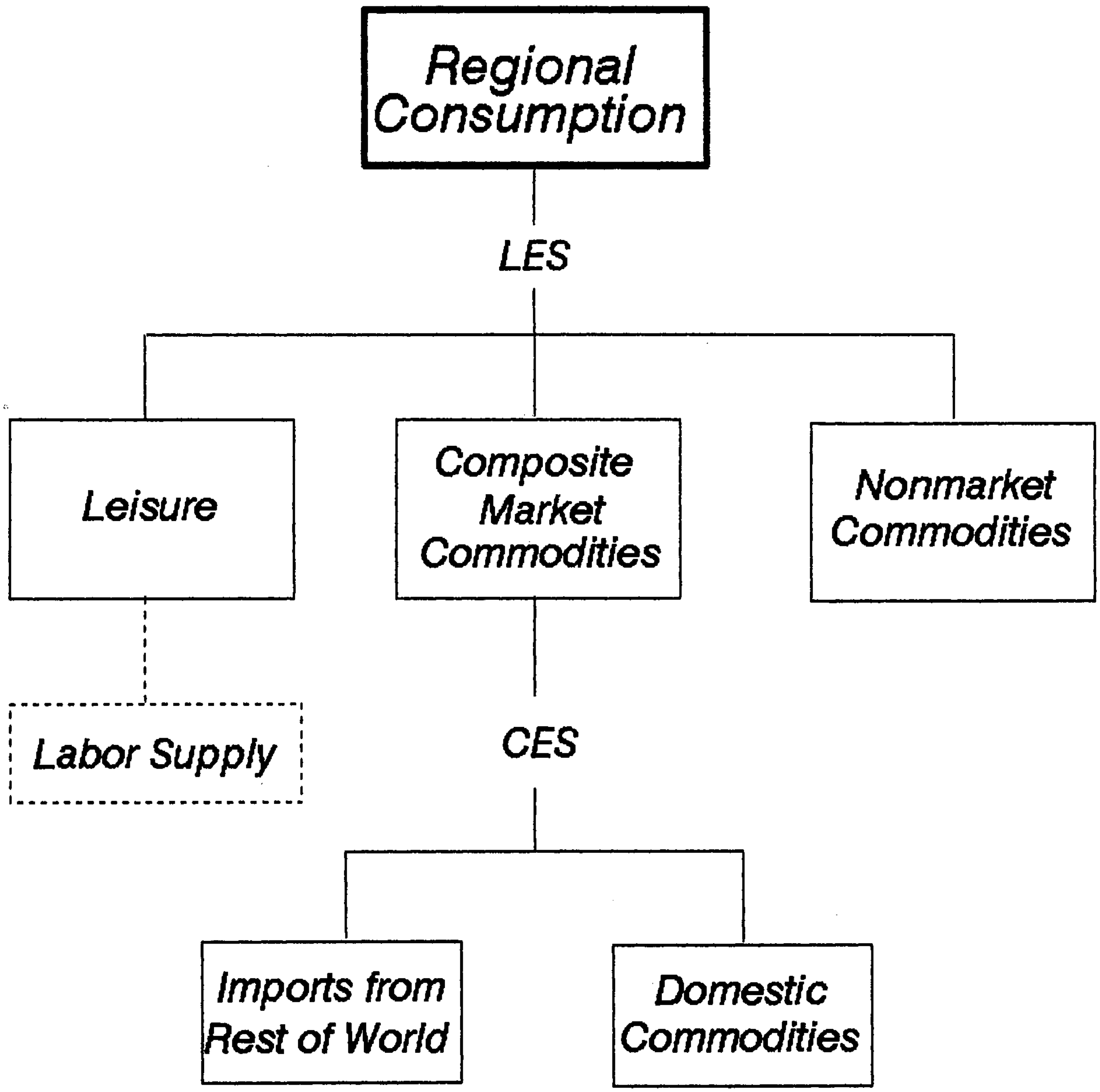


Figure 9. Demand Structure of the Model

Deaton and Muellbauer (1980) discuss the various models with these properties. The linear expenditure system or LES (Details about linear expenditure system are presented in Appendix C.) originating from Stone (1954) imposes the theoretical restrictions of adding up, homogeneity, and symmetry to a general linear formulation of demand:

$$P_i Q_i = P_i \gamma_i + \beta_i (Y - \Sigma_j P_j \gamma_j) \qquad \Sigma_i \beta_i = 1$$

where P_i is price, Q_i is quantity demanded, Y is expenditure, and γ_i and β_i are parameters. The LES is obtained from the constrained maximization of the Klein-Rubin utility function which is also called the Stone-Geary utility function. This utility function is of the form

$$U = \Sigma_i \beta_i \ln(Q_i - \gamma_i) \qquad \Sigma_i \beta_i = 1 \tag{3.31}$$

Maximization of equation (3.31) subject to the budget constraint yields the following demand equations:

$$Q_i = \gamma_i + \left(\frac{\beta_i}{P_i}\right)(Y - \Sigma_j P_j \gamma_j) \tag{3.32}$$

which, by multiplying P_i to both sides, generates the expenditure function which constitutes the LES.

Following the method presented by de Melo and Tarr (1992), the Klein-Rubin utility function is modified by incorporating leisure as a component of consumption at the first level of utility for each household group. In addition, regionally consumed nonmarket goods can be separated from market goods:

$$U_h=\beta_{0h}\ln(Q_{0h}-\gamma_{0h})+\Sigma_{i\epsilon M}\beta_{ih}\ln(Q_{ih}-\gamma_{ih})+\beta_{i\epsilon NR,h}\ln(Q_{i\epsilon NR,h}-\gamma_{i\epsilon NR,h}) \quad \textbf{(3.33)}$$

where Q_{0h} is leisure ,Q_{ih} for $i\epsilon$M are composite market goods, and $Q_{i\epsilon NR,h}$ is nonmarket goods demanded by regional household group h. Composite market commodities are composed of imports and regional products. The worker-consumer purchases a combination of leisure, composite market commodities and nonmarket commodities to maximize utility with purchases financed out of full income--nonlabor income plus the imputed value of time. The maximization of equation (3.33) with constraint of $FY = Y_{NL} + wT = wQ_0 + P_iQ_i$ (i=1,...,n), where FY is full income, Y_{NL} is nonlabor income, and T is total time available, yields the LES augmented for leisure and nonmarket goods,

$$Q_{0h} = \gamma_{0h} + \left(\frac{\beta_{0h}}{w}\right)(FY_h - \sum_{j=0}^{n} P_j\gamma_{jh}) \quad \textbf{(3.34)}$$

$$Q_{ih} = \gamma_{ih} + \left(\frac{\beta_{ih}}{P_i}\right)(FY_h - \sum_{j=0}^{n} P_j\gamma_{jh}) \ , \qquad i \in M \quad \textbf{(3.35)}$$

$$Q_{i\epsilon NR,h} = \gamma_{i\epsilon NR,h} + \left(\frac{\beta_{i\epsilon NR,h}}{P_{i\epsilon NR}}\right)(FY_h - \sum_{j=0}^{n} P_j\gamma_{jh}) \quad \textbf{(3.36)}$$

where P_0 is the wage rate w.

If leisure is not considered, only the composite commodities would be purchased with money income Y (not full income FY) so that the relationship, $Y = P_iQ_i$ (i=1,...,n) holds. We express the full income-money income relationship as

$$FY_h = Y_h + w\,Q_{0h} \tag{3.37}$$

Substituting for FY from equation (3.37) into equation (3.34) and rearranging results in

$$Q_{0h} - \gamma_{0h} = \left(\frac{\beta_{0h}}{w}\right)\left(\frac{Y_h - \sum_{j=1}^{n} P_j\gamma_{jh}}{1 - \beta_{0h}}\right) \tag{3.38}$$

Subtracting $w\gamma_{0h} + \sum P_j\gamma_{jh}$ from both sides of equation (3.37), substituting equation (3.38) for $Q_{0h} - \gamma_{0h}$, and rearranging the equation results in

$$FY_h - \sum_{j=1}^{n} P_j\gamma_{jh} - w\,\gamma_{0h} = \frac{Y_h - \sum_{j=1}^{n} P_j\gamma_{jh}}{1 - \beta_{0h}} \tag{3.39}$$

or

$$FY_h - \sum_{j=0}^{n} P_j\gamma_{jh} = \frac{Y_h - \sum_{j=1}^{n} P_j\gamma_{jh}}{1 - \beta_{0h}} \tag{3.40}$$

On the other hand, because labor supply *of* household group *h*, LS_h satisfies

$$LS_h + Q_{0h} = T_h \tag{3.41}$$

Substituting equation (3.34) into equation (3.41) yields

$$LS_h = T_h - \gamma_{0h} - \left(\frac{\beta_{0h}}{w}\right)(FY_h - \sum_{j=0}^{n} P_j\gamma_{jh}) \tag{3.42}$$

Substituting equation (3.40) into equation (3.42) gives the labor supply function from within the region as

$$LS_h = MAXHOURS_h - \left(\frac{\beta_{0h}}{w}\right)\left(\frac{AHEXP_h - \sum_{j=1}^{n} P_j\gamma_{jh}}{1 - \beta_{0h}}\right) \tag{3.43}$$

where $MAXHOURS_h=T_h-\gamma_h$, $AHEXP_h$ is the same as Y_h, and w is the same as *PL* in this model. Another component of labor supply which is from interregional migration will be discussed later.

Substituting equation (3.40) into equations (3.35) and (3.36) provides demand functions for market and nonmarket commodities by household group *h*, respectively:

$$Q_{ih} = \gamma_{ih} + \left[\frac{\beta_{ih}}{(1 - \beta_{0h})P_i}\right] (AHEXP_h - \sum_{j=1}^{n} P_j\gamma_{jh}) \ , \qquad i \in M \tag{3.44}$$

$$Q_{i\in NR,h} = \gamma_{i\in NR,h} + \left[\frac{\beta_{i\in NR,h}}{(1 - \beta_{0h})P_{i\in NR}}\right] (AHEXP_h - \sum_{j=1}^{n} P_j\gamma_{jh}) \tag{3.45}$$

In the second level of consumption, we find the optimal proportion of imports to regional products to meet the amount of composite marketed commodity determined in the first level with given prices of imports and regional products. We assume that imported and regional commodities in a given sector substitute for each other under a CES functional form as:

$$Q_{ih} = \phi_i^Q \left[\delta_i^Q QM_{ih}^{\rho_i^Q} + (1-\delta_i^Q)\, QR_i^{\rho_i^Q}\right]^{\frac{1}{\rho_i^Q}} , \quad \rho_i^Q < 1 , \quad i \in M \tag{3.46}$$

$$\sigma_i^Q = \frac{1}{1-\rho_i^Q}$$

where QM_{ih} and QR_{ih} are consumer demands for imports and regional products, respectively, and ϕ_i^Q , δ_i^Q, and σ_i^Q are the notations similar to the previous CES functions.

Consumers maximize their subutility Q_{ih} subject to allocated budgets. In other words, they minimize their costs for purchasing the predetermined amount of Q_{ih} by optimally rationing those purchases between imported and regional goods according to their substitutabilities and prices. That is,

$$\textit{Minimize} \quad PMO_i QM_{ih} + PR_i QR_{ih}$$

$$s.t. \quad Q_{ih} = \phi_i^Q \left[\delta_i^Q QM_{ih}^{\rho_i^Q} + (1-\delta_i^Q)\, QR_i^{\rho_i^Q}\right]^{\frac{1}{\rho_i^Q}}$$

where PMO_i is price of consumer imports of sector i.

Solving the first order conditions of the above minimization and rearranging the equation in the form of the ratio of QR_i to QM_i, we get

$$\frac{QR_{ih}}{QM_{ih}} = \left[\left(\frac{1-\delta_i^Q}{\delta_i^Q}\right)\left(\frac{PMO_i}{PR_i}\right)\right]^{\sigma_i^Q} , \qquad i \in M \tag{3.47}$$

Because nonmarket goods cannot be substituted by imported ones from other regions:

$$QR_{ih} = Q_{ih} \;, \quad QM_{ih} = 0 \;, \qquad i \in NR \tag{3.48}$$

Commodity demand for commodity i is the summation of demand for commodities of that sector by all household groups. If the goods demanded are regional products,

$$TQR_i = \Sigma_h QR_{ih} \;, \qquad i \in M, NR \tag{3.49}$$

If the goods demanded are imports,

$$TQM_i = \Sigma_h QM_{ih} \;, \qquad i \in M, NR \tag{3.50}$$

For composite goods,

$$TQ_i = \Sigma_h Q_{ih} \;, \qquad i \in M, NR \tag{3.51}$$

Governments

The government is integrated into regional economies primarily through taxation, commodity consumption, and transfer payments. In this model, the government sector is separated into units of (1) state and local and (2) federal.

State and Local Government

The state and local government receives proportions of various government taxes. The other components of state and local government revenue are transfers from federal government and government borrowing from rest-of-world. State and local government revenue is:

$$SLGR = sl^{IBT}(\Sigma_i ibtr_i PR_i X_i) + sl^{SST}(sstr\ YLAB) + sl^{KTT}(ktr\ YCAl$$

$$+ ttr\ YLAND) + sl^{HHT}(\Sigma_h hhtr_h YH_h) + SLGBOR \qquad \textbf{(3.52)}$$

where *SLGR* is state and local government revenue; sl^{IBT}, sl^{SST}, sl^{KTT}, and sl^{HHT} are the state and local government proportions out of the total government tax revenues from indirect business tax, social security tax, capital and land tax, and household income tax, respectively; and *SLGBOR* are transfers and net borrowing.

State and local government expends funds through direct commodity consumption and transfer payments to households. In this model, utility maximization is not appropriate for government consumption, therefore, government demand for commodities is assumed to be exogenously given:

$$SLGEXP = \Sigma_i P_i SLGD0_i + adj(\Sigma_h TRSLG0_h) + PL \times LSLG0 \qquad \textbf{(3.53)}$$

where *SLGEXP* is state and local government expenditure, $SLGD0_i$ is state and local government demand for commodity *i*, and *LSLG0* is the labor employed by state and local government. Notice that transfer to household, $TRSLG0_h$, is adjusted by *adj* to consider transfer to migrants.

Like consumers, the state and local government is assumed to minimize costs by optimally allocating their purchases between imported and regional commodities given substitution possibilities and relative prices. Substitution possibilities are expressed as:

$$SLGDO_i = \phi_i^{SL}\left[\delta_i^{SL}SLGDM_i^{\rho_i^{SL}} + (1-\delta_i^{SL})\,SLGDR_i^{\rho_i^{SL}}\right]^{\frac{1}{\rho_i^{SL}}}, \rho_i^{SL}<1, i\in M \quad \textbf{(3.54)}$$

$$\sigma_i^{SL} = \frac{1}{1-\rho_i^{SL}}$$

where $SLGDM_i$ and $SLGDR_i$ are state and local government demand for imported and regional commodity i, respectively, and parameters are the same as other CES equations.

Result of cost minimization is:

$$\frac{SLGDR_i}{SLDGM_i} = \left[\left(\frac{1-\delta_i^{SL}}{\delta_i^{SL}}\right)\left(\frac{PMO_i}{PR_i}\right)\right]^{\sigma_i^{SL}}, \qquad i\in M \qquad \textbf{(3.55)}$$

Federal Government

Equations for federal government are similar to those for state and local government and hence only final equations are provided here without deriving procedures.

$$FEDGR = fed^{IBT}(\Sigma_i ibtr_i PR_i X_i) + fed^{SST}(sstr\ YLAB) + fed^{KTT}(ktr\ YCAP$$
$$+ttr\ YLAND) + fed^{HHT}(\Sigma_h hhtr_h YH_h) + FEDGBOR \qquad \textbf{(3.56)}$$

$$FEDGEXP = \Sigma_i P_i FEDGDO_i + adj(\Sigma_h TRFEDGO_h) + PL \times LFEDGO \quad \textbf{(3.57)}$$

$$FEDGDO_i = \phi_i^{FED}\left[\delta_i^{FED}FEDGDM_i^{\rho_i^{FED}} + (1-\delta_i^{FED})\,FEDGDR_i^{\rho_i^{FED}}\right]^{\frac{1}{\rho_i^{FED}}}, \rho_i^{FED}<1, i\in M$$
$$\textbf{(3.58)}$$

$$\frac{FEDGDR_i}{FEDDGM_i} = \left[\left(\frac{1-\delta_i^{FED}}{\delta_i^{FED}}\right)\left(\frac{PM0_i}{PR_i}\right)\right]^{\sigma_i^{FED}}, \quad i \in M \tag{3.59}$$

Savings and Investment

In the capital account, total savings is the sum of household savings, depreciation and retained earnings, and savings from rest-of-world:

$$SAV = adj(\Sigma_h HSAV_h) + deprYCAP + ROWSAV \tag{3.60}$$

Capital expenditure includes investment demand that is either for regional goods or for imported goods. Substitution possibilities between regional and imported goods and cost minimization are applied again in investment demand. The related equations are:

$$INVDO_i = \phi_i^{INV}\left[\delta_i^{INV} INVDM_i^{\rho_i^{INV}} + (1-\delta_i^{INV})\, INVDR_i^{\rho_i^{INV}}\right]^{\frac{1}{\rho_i^{INV}}}, \rho_i^{INV} < 1, i \in M \tag{3.61}$$

$$\sigma_i^{INV} = 1/(1-\rho_i^{INV})$$

$$\frac{INVDR_i}{INVDM_i} = \left[\left(\frac{1-\delta_i^{INV}}{\delta_i^{INV}}\right)\left(\frac{PM0_i}{PR_i}\right)\right]^{\sigma_i^{INV}}, \quad i \in M \tag{3.62}$$

Total investment is the sum of investment demand for each sector multiplied by composite price.

$$INV = \Sigma_i P_i INVD0_i, \qquad i \in M \tag{3.63}$$

Equilibrium Conditions

Market equilibrium conditions are given to clear factor and commodity markets. For the labor market, it is required that the sum of sectoral labor demand, which is endogenously determined by equation (3.9), must be equal to total labor supply. Total labor supply is composed of two sources; (1) regional household labor supply determined by labor-leisure choice and (2) labor migration. The first source was obtained by equation (3.43). The second source is expressed in a multiplicative form as:

$$LMIG = \eta \times LSTK0 \times \ln(PL/PL0^{ROC}) \tag{3.64}$$

where *LMIG* is net labor migration, η is labor migration elasticity of response, *LSTK0* is initial equilibrium stock of labor, and $PL0^{ROC}$ is wage rate in the rest-of-country. Market clearing condition for the labor market is:

$$\Sigma_i LAB_i + \Sigma_h LHH0_h + LSLG0 + LFEDG0 = \Sigma_h LS_h + LMIG \tag{3.65}$$

This implies intersectoral and interregional mobility of labor.

While labor supply is endogenously determined within the model, capital and land supplies are assumed to be fixed by sector. Market clearing conditions for capital and land markets are:

$$CAP_i = CAPO_i \,, \qquad i \in M \tag{3.66}$$

$$LAND_i = LANDO_i \,, \qquad i \in M \tag{3.67}$$

where $CAPO_i$ and $LANDO_i$ denote the fixed supply of capital and land in sector i, respectively.

For commodity markets to clear, regional output plus imports should be equal to the sum of the various demands including export demand:

$$X_i + M_i = TV_i + TQ_i + SLGD_i + FEDGD_i + INVD_i + E_i, \; i \in M \tag{3.68}$$

where

$$M_i = TVM_i + TQM_i + SLGDM_i + FEDGDM_i + INVDM_i, \; i \in M \tag{3.69}$$

For nonmarket goods to be in equilibria, the following conditions must hold:

$$X_i = TQ_i \,, \qquad i \in NR \tag{3.70}$$

$$X_i = E_i \,, \qquad i \in NE \tag{3.71}$$

Equilibrium conditions for state and local government, federal government, and capital accounts are:

$$SLGR = SLGEXP \tag{3.72}$$

$$FEDGR = FEDGEXP \tag{3.73}$$

$$SAV = INV \tag{3.74}$$

From the three equations above, *SLGBOR*, *FEDGBOR*, and *ROWSAV* are determined residually.

Prices

The regional price of the composite market good is a weighted average of the imported and regional good prices:

$$P_i = \frac{PR_i R_i + PM0_i M_i}{R_i + M_i}, \qquad i \in M \tag{3.75}$$

Price of nonmarket good is a weighted average of each intermediate input price:

$$P_i = \frac{\sum_j P_j V_{ji}}{\sum_j V_{ji}}, \qquad i \in NM,\ j \in M \tag{3.76}$$

Net price of commodity i is expressed as the regional price minus intermediate input costs and indirect tax:

$$PN_i = PR_i - \Sigma_j a_{ji} P_j - ibtr_i PR_i \,, \qquad i \in M \tag{3.77}$$

where $ibtr_i$ is the indirect business tax rate of sector i.

Because transportation costs are not considered, the producers' receiving prices are the same as the consumers' paying prices.

Welfare Measure

The measures of CV and EV are provided as follows. The original functional form of the Klein-Rubin utility function (equation 3.33) before log-transformation for household group h is

$$U_h = \prod_{i=0}^{n} (Q_{ih} - \gamma_{ih})^{\beta_{ih}} \tag{3.78}$$

Substituting commodity demand functions in terms of full income (equations 3.34, 3.35, and 3.36) into equation (3.78) results in the indirect utility function which represents the maximum utility obtainable given prices and income:

$$IU_h = \prod_{i=0}^{n} \left(\frac{\beta_{ih}}{P_i} \right)^{\beta_{ih}} (FY_h - \sum_{j=0}^{n} P_j \gamma_{jh})^{\beta_{ih}}$$

Because $\sum_{i=0}^{n} \beta_{ih} = 1$,

$$IU_h = \prod_{i=0}^{n} \left(\frac{\beta_{ih}}{P_i} \right)^{\beta_{ih}} (FY_h - \sum_{j=0}^{n} P_j \gamma_{jh}) \tag{3.79}$$

Solving equation (3.79) for *FY* to obtain the expenditure function yields;

$$E_h(P, IU_h) = \prod_{i=0}^{n}\left(\frac{P_i}{\beta_{ih}}\right)^{\beta_{ih}} IU_h + \sum_{j=0}^{n} P_j\gamma_{jh} \tag{3.80}$$

The CV and EV measures are now defined as

$$CV = E\left[P^1,\ IU(P^1, FY^1)\right] - E\left[P^1,\ IU(P^0, FY^0)\right] \tag{3.81}$$

$$EV = E\left[P^0,\ IU(P^1, FY^1)\right] - E\left[P^0,\ IU(P^0, FY^0)\right] \tag{3.82}$$

where superscript 0 denotes the initial equilibrium and superscript 1 the equilibrium after a policy or program change. The first terms of equations (3.81) and (3.82) are the minimum income necessary to reach utility level $IU(P^1, FY^1)$ given prices P^1 and P^0, respectively. The second terms are the minimum income level necessary to reach utility level $IU(P^0, FY^0)$ given prices P^1 and P^0, respectively. The first term of equation (3.81) is equal to FY^1 while the second term of equation (3.82) is equal to FY^0. Therefore,

$$CV = FY^1 - E\left[P^1,\ IU(P^0, FY^0)\right] \tag{3.83}$$

$$EV = E\left[P^0,\ IU(P^1, FY^1)\right] - FY^0 \tag{3.84}$$

Substituting equation (3.80) into equations (3.83) and (3.84) yields:

$$CV_h = FY_h^1 - \prod_{i=0}^{n}\left(\frac{P_i^1}{\beta_{ih}}\right)^{\beta_{ih}} IU_h(P^0, FY^0) - \sum_{j=0}^{n} P_j^1 \gamma_{jh} \quad (3.85)$$

$$EV_h = \prod_{i=0}^{n}\left(\frac{P_i^0}{\beta_{ih}}\right)^{\beta_{ih}} IU_h(P^1, FY^1) - \sum_{j=0}^{n} P_j^0 \gamma_{jh} - FY_h^0 \quad (3.86)$$

Substituting equation (3.79) into equations (3.85) and (3.86) and rearranging gives:

$$CV_h = (FY_h^1 - \sum_{j=0}^{n} P_j^1 \gamma_{jh}) - (FY_h^0 - \sum_{j=0}^{n} P_j^0 \gamma_{jh}) \prod_{i=0}^{n}\left(\frac{P_i^1}{P_i^0}\right)^{\beta_{ih}} \quad (3.87)$$

$$EV_h = (FY_h^1 - \sum_{j=0}^{n} P_j^1 \gamma_{jh}) \prod_{i=0}^{n}\left(\frac{P_i^0}{P_i^1}\right)^{\beta_{ih}} - (FY_h^0 - \sum_{j=0}^{n} P_j^0 \gamma_{jh}) \quad (3.88)$$

Substituting equation (3.40) into equations (3.87) and (3.88) and rearranging, we have

$$CV_h = \left(\frac{1}{1-\beta_{0h}}\right)\left[(AHEXP_h^1 - \sum_{j=1}^{n} P_j^1 \gamma_{jh}) - (AHEXP_h^0 - \sum_{j=1}^{n} P_j^0 \gamma_{hj}) \prod_{i=0}^{n}\left(\frac{P_i^1}{P_i^0}\right)^{\beta_{ih}}\right] \quad (3.89)$$

$$EV_h = \left(\frac{1}{1-\beta_{0h}}\right)\left[(AHEXP_h^1 - \sum_{j=1}^{n} P_j^1 \gamma_{jh}) \prod_{i=0}^{n}\left(\frac{P_i^0}{P_i^1}\right)^{\beta_{ih}} - (AHEXP_h^0 - \sum_{j=1}^{n} P_j^0 \gamma_{jh})\right] \quad (3.90)$$

All of the variables in the welfare measures of equations (3.89) and (3.90) are observable, so we take these CV and EV as measures of the welfare change resulting from a rural development policy or program. Notice that these welfare measures are based upon household expenditure adjusted to the existing households.

Although the true values of welfare are different by household income group, total welfare change in the region is assumed to be the sum of the welfare changes for each household group:

$$TCV = \Sigma_h CV_h \tag{3.91}$$

$$TEV = \Sigma_h EV_h \tag{3.92}$$

Regional Closure

Those variables which are not endogenized in the equation system are exogenously given. Exogenous variables in this model are $PM0_i$, $PE0_i$, $PL0^{ROC}$, $LHH0_h$, $LSLG0$, $LFEDG0$, $TRSLG0_h$, $TRFEDG0_h$, $SLGD0_i$, $FEDGD0_i$, $INVD0_i$, $REMIT0_h$, $LSTK0$, $CAP0_i$, $E0_i$, and $LAND0_i$. These exogenous variables are distinguished from endogenous variables in notation by attaching "0" at the end of the variable name which implies that values for these variables are fixed to those of initial equilibrium.

Because the CGE model is a set of simultaneous equations, the number of endogenous variables should equal the number of equations so that the model has a unique solution. This model has the same number of endogenous variables as equations which is $(4n + 18m + 3(n \times m) + 3(m + nr) + 3s(m + nr) + 8s + 20)$.

Summary of the notation, equations, variables, and parameters are presented in Appendix A.

CHAPTER IV

DATA, PARAMETER ESTIMATION, AND SOLUTION

Social Accounting Matrix

A social accounting matrix (SAM) represents the essential data set needed to implement a CGE model. The structure of a SAM is closely dependent upon the structure of the model and vice versa. A SAM provides a tabular snapshot of the economy at one point in time. A SAM is an extension of the input-output table to describe the full flow of money and commodities in the economy. A SAM is a double-entry bookkeeping system within which revenues (or income) must balance with expenditures (or outgoings). A comprehensive discussion of the concept and construction of the SAM is covered by Pyatt and Round (1985).

Table I conceptually identifies the social accounting matrix in this study which is composed of an array of accounts which describe the socioeconomic structure of the region. The structure of this SAM maintains consistency with the structure of the model in the previous chapter.

Data Sources

TABLE I

STRUCTURE OF SOCIAL ACCOUNTING MATRIX (SAM)

	INDUSTRY Market Goods / Nonmarket Goods	FACTOR Labor / Capital / Land	INSTITUTION Enterprise	INSTITUTION Household	INSTITUTION Gov't	CAPITAL	REST OF WORLD	(TOTAL)
INDUSTRY 1.Market Goods 2.Nonmarket Goods	Inter-sectoral transaction			Household demand	Gov't demand	Invest-ment demand	Exports to ROW	Total outputs
FACTORS 1.Labor				Labor employed by HH and gov't				
2.Capital	Value added							Factor income
3.Land								
INSTITUTION 1.Enterprise		Enterprise income						
2.Household		Household income ditribution	Distri-buted profits		Gov't transfer to HH		Remittance from ROW	Institu tional income
3.Government	Indirect business taxes	Factor taxes		Household income taxes			Transfers & borrowing from ROW	
CAPITAL		Depre-ciation	Depre-ciation	Household savings			Savings from ROW	Total savings
REST-OF-WORLD	Inter-mediate imports			HH demand for imports	Gov't import demand	Investment demand for imports		ROW income
(TOTAL)	Total outlays	Factor expenditure		Institutional expenditure		Total investment	ROW expenditure	

IMPLAN, or IMpact analysis for PLANning, is the major data source in constructing the SAM in this study. IMPLAN is an MS-DOS based microcomputer software developed by the U.S.Department of Agriculture, Forest Service. It contains databases representing county -level economic activity for 528 sectors in the U.S. IMPLAN allows users to develop input-output models for a single county or combination of counties of the U.S. and provides flexibility in data manipulation and analysis. The IMPLAN database consists of (1) the transaction matrix for goods and services between industries, and (2) estimates of gross output, employment, final demand, and final payments by sector (Olson, et al. 1993). This study uses the 1990 IMPLAN database for McCurtain County and State of Oklahoma. Methods used in constructing SAMs from the IMPLAN database are found in Marcouiller, Schreiner, and Lewis (1993).

In addition to the IMPLAN database, data were obtained from other sources including the Personal Income by Major Sources (USDC, Bureau of Economic Analysis); Robinson, Kilkenny, and Hanson (1991); Rose, Stevens, and Davis (1988); Koh (1991); and Marcouiller (1992). Data about nonmarket goods were obtained from Choi (1993).

Aggregation

The production account was aggregated into the following four sectors based upon homogeneity of production, degree of tradability, and availability of data: agriculture, mining, manufacturing, and services. The aggregation scheme for this study related to IMPLAN database is shown in Table II. Among the 528 sectors of IMPLAN, 13 sectors were excluded in the production account for this study because they were not actual producing sectors (Table III).

Households were aggregated into three different groups according to annual income level: low income households whose annual income was less than \$20,000, medium income between \$20,000 and \$40,000, and high income greater than \$40,000.

Calibration

Parameter values for the equations of the model are crucial. A slight change in some parameters may influence results of the model solution significantly. In this study, most of the parameters were calibrated to an observed base year. The calibration method, which is widely used in determining parameter values of CGE models, assumes that the economy is in equilibrium in the base year, thus the model with calibrated parameters should reproduce base year data as a model solution. This procedure can be illustrated by a set of n model equations:

$$f(y, x; \beta) = 0,$$

where y is a vector of endogenous variables, x is a vector of exogenous variables, and β is a vector of unknown parameters. Vectors y and x are calculated from the benchmark data set.

TABLE II

AGGREGATION USED FOR THE PRODUCTION ACCOUNT

Aggregated Sector	IMPLAN Database Sector Number
Agriculture	1-24
Mining	28-33, 35-45, 47
Manufacturing	58-432
Services	25-27, 34, 46, 48-57, 433-515

* Olson et. al. (p.D-11) provide the IMPLAN/SIC Code Bridge Table for comparison of IMPLAN database sector classification and Standard Industry Classification.

TABLE III

IMPLAN DATABASE SECTORS NOT INCLUDED IN THE PRODUCTION ACCOUNT AGGREGATION

Sector Name	IMPLAN Database Sector Number
Noncomparable Imports	516
Scrap	517
Used and Secondhand Goods	518
Federal Government	519-521
State and Local Government	522-523
Rest of the World Industry	524
Household Industry-Low Income	525
Household Industry-Medium Income	526
Household Industry-High Income	527
Inventory Valuation Adjustment	528

Calibration consists of solving the above equation for the vector β (Kraybill, p.208).

The main weakness of the calibration method is that no statistical test of the model specification which has been chosen is applied, because a deterministic procedure of calculating parameter values from the equilibrium observation is employed (Shoven and Whalley). Stochastic estimation methods can be used by an econometric procedure. However, econometric estimation with time series data has tradeoffs in that it requires more data and time hence usually limits the analysis to a more simplified structure of the model. Issues raised by parameter estimation methods are explained in detail in Mansur and Whalley.

Calibration requires some exogenously specified parameter values because for some equational sets, the system is underidentified with respect to the vector β, that is to say, the number of unknown parameters exceeds the number of equations. For this reason, key parameters such as elasticities are specified exogenously using values from previous econometric studies or from expert judgement, so that the remaining parameters can be solved for determinately. In practice, the CGE modeler is faced with a dearth of adequate estimates for key parameters (Kraybill, p.208). Exogenously specified parameters for this model included elasticities of the various CES functions, the CET function, commodity demand and labor supply from LES, and migration function. Elasticities were searched from previous studies including de

Melo and Tarr (1992), Rickman (1992), Abbott and Ashenfelter (1979), Choi (1993), and Lluch, Powell, and Williams (1977). Values for the exogenous parameters and the source of the estimates are presented in Table IV.

Note that the value of σ (elasticity of substitution between imported and regional commodity use) is assumed to be the same regardless of the sector or account destination. For example, the elasticity of substitution between regional and imported manufacturing is the same whether manufacturing is used in agriculture or services sector. Similarly, the elasticity of substitution holds for household consumption, government use, and capital formation.

In the following subsections, the procedures of calibrating the equational sets which require exogenously specified parameters are described.

Cobb-Douglas Production Function

Although, in a Cobb-Douglas production function, the number of parameters exceeds that of equations, we do not need exogenous parameters. It is well known that the exponent of each input variable in the linearly homogeneous Cobb-Douglas production function, if each input is assumed to be paid by the amount of its marginal product, indicates the relative share of that input in the total product (For detail about this relationship, see Chiang, pp.414-416). And we can obtain the exponent of each input variable through calibration with

Table IV.

Exogenous Parameter Estimates and Their Sources

Parameter	Parameter Value	Source
Elasticity of Substitution (σ^V, σ^Q, σ^{SL}, σ^{FED}, σ^{INV})		de Melo and Tarr (1992)
Agriculture	1.42	
Mining	0.50	
Manufacturing	3.55	
Services	2.00	
Elasticity of Transformation (σ^X)		de Melo and Tarr (1992)
Agriculture	3.90	
Mining	2.90	
Manufacturing	2.90	
Services	0.70	
Income Elasticity of Household Consumption		
Agriculture	0.30	de Melo and Tarr (1992)
Mining	0.89	de Melo and Tarr (1992)
Manufacturing	1.06	de Melo and Tarr (1992)
Services	1.05	de Melo and Tarr (1992)
Regional TF Trips	0.082	Choi (1993)
Price Elasticity of Exported TF Trips (ϵ)	0.5775	Choi (1993)
Income Elasticity of Labor Supply		Abbot and Ashenfelter (1979)
Low Household	-0.12	
Medium Household	-0.18	
High Household	-0.24	
Frisch Parameter		Lluch, Powell, and Williams (1977)
Low Household	-1.80	
Medium Household	-1.60	
High Household	-1.40	
Labor Migration Elasticity (η)	0.92	Rickman (1992)

the initial equilibrium data set for each input and total output for each sector. Once exponent of each input is obtained, the value of constant efficiency parameter, ϕ, can also be calculated by calibration.

CES and CET Functions

The same procedures were followed to calibrate the various CES functions and the CET function because they have analogous functional forms. The general form of the CES and CET functions was expressed as

$$Y = \phi \left[\delta X_1^{\rho} + (1-\delta) X_2^{\rho} \right]^{\frac{1}{\rho}} \tag{4.1}$$

$$\sigma = \frac{1}{1-\rho}$$

where parameters are as specified in the previous chapter regarding model formulation. The first-order condition of the above equation with respect to X_1 and X_2 is derived and expressed as the ratio of the amount of X_1 to X_2

$$\frac{X_2}{X_1} = \left[\left(\frac{1-\delta}{\delta} \right) \left(\frac{P_1}{P_2} \right) \right]^{\sigma} \tag{4.2}$$

Equation (4.2) is rearranged in the form of

$$\frac{1-\delta}{\delta} = \left(\frac{P_2}{P_1} \right) \left(\frac{X_2}{X_1} \right)^{\frac{1}{\sigma}} \tag{4.3}$$

From equation (4.3), the value for δ was obtained based on initial values for X's and P's, and a value for σ, the elasticity of substitution (elasticity of transformation in the CET function), employed from exogenous sources. Once the value for δ was calculated, the value for ϕ (constant efficient parameter) was obtained from equation (4.1).

Functions from the LES

Labor supply and commodity demand functions were derived from a linear expenditure system. Values were specified for the parameters β_0, β_i (i=1,...,n), γ_i (i=1,...,n), and *MAXHOURS*. First, β_0 were calculated from the elasticity of labor with respect to income. From the labor supply function, the elasticity of labor with respect to income is

$$\varepsilon_h^{LY} = \frac{-\beta_{0h}\ HEXP_h}{(1-\beta_{0h})\ \ w\ LS_h} \tag{4.4}$$

The values for $HEXP_h$, w, LS_h were available from the initial data and the labor elasticity was obtained from other studies. The value of β_{0h} was calculated from equation (4.4).

From the commodity demand equation, the elasticity of demand for commodity i with respect to income is

$$\varepsilon_{ih}^{Y} = \frac{\beta_{ih}\ HEXP_h}{(1-\beta_{0h})\ \ P_i\ Q_{ih}} \tag{4.5}$$

Similarly, the value of β_{ih} was calculated to be consistent with the exogenous estimates of the elasticity of commodity demand with respect to income from equation (4.5). Because the β_{ih} parameters are the marginal budget shares, β_{ih} (i=0,1,..,n) should add up to one with respect to i. Therefore, the employed values of commodity elasticity were adjusted so that the above adding up condition was satisfied.

To obtain the parameter γ_{ih}, an exogenously specified "Frisch parameter" is needed. Frisch is meant to measure the elasticity of the marginal utility of income with respect to income. In this sense, it is sometimes called the flexibility of money (Pyles, 1989). The Lagrangian to the utility maximization problem when deriving the demand function from the Klein-Rubin utility function is

$$L = \Sigma_i \beta_i \ln(Q_i - \gamma_i) + \lambda(HEXP - \Sigma_i P_i Q_i) \tag{4.6}$$

Frisch is the elasticity of λ with respect to *HEXP*. Solving the first-order conditions for the above Lagrangian results in

$$\lambda = \frac{\Sigma_i \beta_i}{HEXP - \Sigma_i P_i \gamma_i} = \frac{1}{HEXP - \Sigma_i P_i \gamma_i} \quad (\because \Sigma_i \beta_i = 1) \tag{4.7}$$

The elasticity of λ with respect to *HEXP*, which is the Frisch parameter, is

$$Frisch = -\frac{HEXP}{HEXP - \Sigma_i P_i \gamma_i} \tag{4.8}$$

Hence, the parameter γ_{ih}, which is interpreted as the minimum subsistence requirements, was calculated from the following equation

$$\gamma_{ih} = Q_{ih} + \left[\frac{\beta_{ih}}{(1-\beta_{oh})P_i}\right]\left(\frac{HEXP}{Frisch}\right) \tag{4.9}$$

Finally, the value for $MAXHOURS_h$, which the time endowment, T_h, (24 hours minus the time necessary for sleeping and other minimal maintenance tasks) minus minimum requirement for leisure, γ_{0h}, was determined by the previously calculated parameter values and initial data

$$MAXHOURS_h = LS_h + \left(\frac{\beta_{0h}}{w}\right)\left(\frac{HEXP_h - \sum_{j=1}^{n} P_j \gamma_j}{1 - \beta_{0h}}\right) \tag{4.10}$$

Digression into Elasticity of Substitution (Transformation)

In the CES function above, when the price ratio P_1/P_2 rises, we normally expect the optimal quantity ratio X_2/X_1 to also rise, because X_2 (now relatively cheaper) will tend to be substituted for X_1. The extent of substitution can be measured by the following point-elasticity expression, called elasticity of substitution and denoted by σ:

$$\sigma \equiv \frac{\text{relative change in } (X_2/X_1)}{\text{relative change in } (P_1/P_2)} \tag{4.11}$$

The value of σ can be anywhere between 0 and ∞; the larger the σ, the greater the substitutability between the two products. The limiting case of $\sigma = 0$ is where the two goods must be used (or consumed) in a fixed proportion as complements to each other. The other limiting case, with $\sigma = \infty$, is where the two goods are perfect substitutes (Chiang p.425).

The geographically or institutionally smaller the region under study, the higher is the expected elasticity of substitution, because a small region is generally more accessible to the rest-of-world compared to a large region. For example, a nation has stronger barriers to entry such as tariffs, quotas, or transportation costs in trading with the rest-of-world compared to a region. Therefore, a region can more easily substitute their input uses or consumption between regional and imported products according to their relative prices. The same should hold for a state compared to a county. In the case of the elasticity of transformation, the situation is the same except that the sign becomes the opposite to the elasticity of substitution.

Exogenously employed estimates for elasticity of substitution and transformation in this study were originally taken from national data sets. Thus, those parameter values were expected to be higher (in terms of absolute values in the case of the elasticity of transformation) for the state and county models used in this study. However, because estimates of those parameters for state and county levels were not available, it was assumed that substitutability between regional (or domestic) and imported goods were the same regardless of the level of region. As a complement for that limitation, sensitivity analysis was implemented for some exogenously employed estimates including elasticities of substitution and transformation by varying the values for parameters.

Solution

Solution Process

A variety of approaches have been used to solve CGE models. Dervis et. al. classified solution algorithms and discussed the advantages and disadvantages of each (Dervis et. al. pp.491-496).

This study used the software package GAMS (General Algebraic Modeling System) for model solution. The GAMS is a mathematical programming software package designed to solve both linear and non-linear problems. Because the syntax of GAMS closely resembles standard algebraic notation, the system facilitates the communication of model assumption and results (Condon et. al.). The GAMS package is described in detail in Brooke, Kendrick, and Meeraus (1988). The GAMS has increasingly been used to solve CGE models by researchers: Condon et. al. (1987); Robinson et. al. (1990); Koh (1991); Kim (1992); Robinson et. al. (1993); and Webb et. al (1993).

The CGE model is a "square" simultaneous equation system that contains the same number of linear and non-linear equations (constraints) as that of endogenous variables. In solving the CGE model, the GAMS program uses software designed for nonlinear programming problems. The solver most commonly used is the MINOS program developed at Stanford University.

The CGE model is treated by MINOS as a special programming problem that happens to have a unique feasible basis. The syntax of the SOLVE statement in GAMS requires that an objective variable be specified. Because there is only one feasible solution that satisfies the constraint equations, it does not matter what the objective function is (Robinson et. al.). In this model, the optimal solutions were achieved when the sum of a set of slack variables were minimized. As Koh (1991) suggested, two positive slack variables were introduced in one of the equations. If the sum of the slack variables is zero, the solution will be optimal. Initial period prices were set to unity for convenience of interpreting the results of counterfactual experiments. A listing of the GAMS program constructed for solving the model in this study is provided in Appendix D.

Testing the Model

This model was tested by one of the general consistency tests for square CGE models suggested by Condon et. al. That is, the CGE model represents a circular-flow so there can be no leakages in the model. It amounts to saying that a solution should yield a balanced SAM. This condition was tested by checking whether row sums were equal to column sums. If they were not, some inconsistencies were present in the model. The base year model solution should be a balanced SAM that reproduces the initial data set with all prices at unity.

If the model solution in the base year is not the same as the initial equilibrium data, a problem exists and further checking is needed (Condon et. al.).

CHAPTER V

WELFARE EFFECTS OF AGRICULTURAL EXPORT PRICE CHANGE IN OKLAHOMA

In this chapter and the following chapter, empirical applications are made for the model developed in Chapter III. In these chapters, the impacts of a change in agricultural prices and implementation of a rural natural resource project are analyzed at the state and county geographic levels, respectively. Measures of rural welfare are assessed including distributional aspects. Effects on other economic variables are measured including commodity use and prices, factor prices and income, employment demand and migration.

In addition, selected parameters are changed to determine sensitivity to welfare change. Also the sensitivity analysis indirectly reveals certain characteristics of the model. Finally, welfare impacts are evaluated under alternative closure rules with respect to labor mobility.

Empirical Implementation

Social Accounting Matrix of Oklahoma

Procedures of IMPLAN were followed in constructing input-output data files as presented in Chapter IV. These results were combined with other data to estimate the 1990 social accounting matrix (SAM) for Oklahoma as shown in Table V.

Industrial output totaled $103.4 billion in 1990. For that industrial output, a total of $46.0 billion of intermediate inputs were used and a total of $57.5 billion was added from indirect business taxes and primary factors of labor, capital, and land. Of intermediate inputs, $23.1 billion was regionally produced and $22.9 billion was imported. Of total output, $47.1 billion was exported, and $56.3 billion was consumed within the state.

Total household income was $48.5 billion, of which $11.2 billion occurred to low income households, $23.1 billion to medium income households, and $14.2 billion to high income households. Total final consumption by households amounted to $41.1 billion, of which $27.9 billion was consumed out of regional production and $16.9 billion was imported. State and local government revenue (and expenditure) summed to $7.2 billion. Federal government revenue from Oklahoma was estimated at $11.8 billion. Aggregate savings including depreciation and retained earnings was $8.1 billion.

Agriculture in Oklahoma

Agriculture was an important part of Oklahoma's economy in 1990. Oklahoma ranked in the top five states nationally in

TABLE V

SOCIAL ACCOUNTING MATRIX FOR OKLAHOMA, 1990 (IN MILLIONS OF 1990 DOLLARS)

	(INDUSTRY)					(FACTOR)					
	Ag	Min	Manuf	Ser	Total	Labor	Capital	Land	Total	Enterpr	----- low
(INDUSTRY)											
1.Agriculture	816.9	0.3	561.4	63.1	1441.7						37.3
2.Mining	14.1	1586.9	2113.8	921.0	4635.7						36.9
3.Manufacture	173.1	58.1	1848.7	1634.0	3713.8						610.9
4.Service	610.4	609.9	2950.6	9139.1	13310.0						6261.9
Total	1614.4	2255.1	7474.4	11757.3	23101.3						6946.9
(FACTORS)											
1.Labor	511.8	1850.2	5513.9	20275.8	28151.7						95.9
2.Capital	396.1	9458.0	3493.9	8451.4	21799.5						
3.Land	676.6				676.6						
Total	1584.5	11308.3	9007.8	28727.2	50627.7						95.9
(INSTITUTION)											
1.Enterprise							18556.7		18556.7		
2.Household											
-low						2909.5	6.1	18.0	2933.6	2764.8	
-medium						12572.2	85.9	255.6	12913.7	5534.8	
-high						15144.9	99.0	294.8	15538.7	2016.9	
-subtotal						30626.6	190.9	568.5	31386.0	10316.4	
3.Government											
-st & local	155.8	2271.5	207.8	2484.4	5119.5	763.9	982.6	36.6	1783.1		74.9
-federal	52.4	764.0	69.9	835.7	1722.0	3975.1	1916.7	71.5	5963.3		340.1
-subtotal	208.2	3035.5	277.7	3320.1	6841.5	4739.0	2899.3	108.1	7746.4		415.0
Total	208.2	3035.5	277.7	3320.1	6841.5	35365.6	21647.0	676.6	57689.2	10316.4	415.0
(CAPITAL)							152.5		152.5	8240.3	-482.3
(REST OF WORLD)											
1.Agriculture	475.2	0.4	814.0	45.9	1335.5						12.8
2.Mining	8.2	1778.0	3064.9	670.4	5521.5						0.6
3.Manufacture	100.7	65.0	2680.5	1189.5	4035.7						2021.9
4.Service	355.1	683.4	4278.2	6652.7	11969.4						2204.4
Total	939.1	2526.8	10837.6	8558.6	22862.1						4239.7
(TOTAL)	4346.2	19125.7	27597.5	52363.1	103432.6	35365.6	21799.5	676.6	57841.7	18556.7	11215.2

TABLE V (continued)

(INSTITUTION)							(CAPITAL)	(ROW)	(TOTAL)
Household				Gov't		Total			
medium	high	subtotal	st & l	federal	subtotal				
53.8	24.0	115.1	6.9	0.4	7.3	122.3	3.9	2778.3	4346.2
64.3	23.4	124.6	12.2	19.2	31.4	156.0	209.1	14124.9	19125.7
1199.1	556.1	2366.0	192.2	236.5	428.7	2794.7	1106.9	19982.1	27597.5
11025.3	5579.4	22866.5	1159.9	772.8	1932.7	24799.2	4022.4	10231.5	52363.1
12342.5	6182.8	25472.2	1371.2	1028.8	2400.1	27872.2	5342.3	47116.7	103432.6
		95.9	4462.1	2655.9	7118.1	7214.0			35365.6
									21799.5
									676.6
		95.9	4462.1	2655.9	7118.1	7214.0			57841.7
									18556.7
			357.5	4600.3	4957.7	7722.5		559.1	11215.2
			218.1	2806.6	3024.6	8559.4		1615.0	23088.1
			19.3	248.8	268.1	2285.0		-3632.4	14191.3
			594.9	7655.7	8250.5	18566.9		-1458.3	48494.7
387.6	450.8	913.3				913.3		-629.5	7186.4
1759.6	2046.8	4146.5				4146.5		13.5	11845.3
2147.2	2497.7	5059.8				5059.8		-616.1	19031.6
2147.2	2497.7	5059.8	594.9	7655.7	8250.5	23626.8		-2074.4	86083.0
831.2	1844.9	2193.8				10434.1		-2471.5	8115.1
18.4	9.6	40.8	3.8	0.2	4.0	44.8	2.0		1382.3
0.4	0.2	1.2	6.8	9.4	16.2	17.4	108.5		5647.5
3762.8	1713.7	7498.4	106.3	116.1	222.3	7720.7	574.5		12331.0
3985.7	1942.5	8132.6	641.4	379.2	1020.6	9153.2	2087.7		23210.2
7767.3	3666.0	15673.0	758.2	504.9	1263.1	16936.1	2772.8		42570.9
23088.1	14191.3	48494.7	7186.4	11845.3	19031.6	86083.0	8115.1	42570.9	298043.2

the production of winter wheat and cattle and calves, and in the top ten states in the production of rye, grain sorghum, cotton, pecans, and peanuts. The location quotient of Oklahoma employment with respect to United States employment was 1.88 for the farm sector in 1984, where a location quotient greater than 1.00 implies that the state is producing more than needed for its own use and is exporting the excess to the rest of the country or the world (Woods and Sanders). The linkages between agriculture and the rest of Oklahoma's economy are strong, particularly in areas (counties) where the primary economic base is agriculture (ibid). Therefore, changes in the demand for agricultural commodities potentially has significant influence on welfare of households in the state, particularly in rural areas where agriculture dominates.

Agricultural commodity prices showed a sizable decrease during the mid-1980's and contributed to considerable stress and change in rural Oklahoma. Farm foreclosures and bankruptcies were several times higher than normal for the state (ibid). Low agricultural commodity prices together with depressed energy prices decreased income and employment levels throughout the state, and particularly, rural areas in Oklahoma.

Specifically, a 1982 based price index (1982 = 100) for overall agricultural commodities produced in the state was 89.0 by 1986 (Koh, p.1). This implies about a ten to eleven percent decrease in export prices of agricultural commodities during a relatively short time period. In this context, a counterfactual experiment of a ten percent decrease in export (national) prices of agricultural commodities are shown on the Oklahoma economy focusing on measuring welfare changes by household income group.

Simulation Results

Welfare Effects

Results of the counterfactual experiment showed that welfare changes in terms of equivalent variation were similar to compensating variation. Therefore, welfare changes are reported only in terms of compensating variation. Welfare changes (CV) of the counterfactual experiment where export prices of agricultural commodities were assumed to decrease by ten percent are shown in Table VI. Total welfare loss amounted to about $123,702,000.

Welfare loss was greatest for the high income group of households ($83,525,000), and equalled $51,281,000 for the medium income household group. Low income households show a slight welfare gain of $11,104,000. The latter is a result of lower commodity prices, particularly for nontradable commodities.

When compared to the initial level of expenditure for each household income group, welfare change for high income households was -0.86 percent, medium income households was

TABLE VI

WELFARE CHANGES (CV) FROM TEN PERCENT DECREASE IN AGRICULTURAL EXPORT PRICES, OKLAHOMA, 1990

Household Income Group	Welfare Change (thousand $)	Percent[a]
Low Income	11,104	0.10
Medium Income	-51,281	-0.26
High Income	-83,525	-0.86
Total	-123,702	-0.30

a Welfare change compared to initial level of expenditures of each household group.

-0.26 percent, and low income households was 0.10 percent. In the aggregate, the ten percent decrease in agricultural commodity prices bring about a welfare change equal to 0.30 percent of total household expenditure in Oklahoma.

Impacts on Commodity Markets

Changes in commodity markets of Oklahoma from a ten percent decrease in agricultural commodity prices are presented in Table VII. Changes in the variables are expressed in terms of an index with the base year (1990) value equal to one.

Export price decrease in agriculture resulted in different impacts on outputs by sector. It caused decreased output for agriculture by about 7.2 percent and for services by 0.1 percent. However, sectoral outputs increased for mining and manufacture. This implies that resources flowed from agriculture (and services) to mining and manufacturing because resource demand had decreased in agriculture due to the export price decrease.

Regional commodity supplies increased in all sectors except services. The reason regional supply of agriculture increased is that the relative price of regional supply compared to export price increased. Exports decreased for agriculture by more than 10 percent (about 11.7 percent) and increased or maintained the same level for the other sectors. Exports for agriculture decreased by a higher rate than the

TABLE VII

CHANGES IN COMMODITY MARKETS IN OKLAHOMA STATE ECONOMY FROM TEN PERCENT DECREASE IN AGRICULTURAL EXPORT PRICES (INDEX WITH BASE YEAR = 1.000)

	Output	Regional Supply	Export	Import	Composite Price
Sector					
Agriculture	0.928	1.007	0.883	0.931	0.962
Mining	1.001	1.002	1.000	1.004	1.000
Manufacturing	1.007	1.002	1.009	0.994	0.999
Services	0.999	0.998	1.001	0.994	0.998

exogenous export price decrease rate (10 percent). This is consistent with the increase in regional supply in that producers are shifting towards the higher relative price of the regional commodity market. Imports decreased for all sectors except mining and composite prices decreased for all sectors except mining.

In general, impacts of the ten percent decrease in national agricultural commodity prices were most significant in the agricultural commodity markets as expected. The effect was most negatively felt in the services sector compared to the other sectors. In fact, outputs, regional supply, and exports increased in manufacturing and mining. However, output, regional supply, composite price, and exports all decreased for services. Exports increased because of the relative price increase compared to regional supply.

Impacts on Factor Markets

Table VIII shows the changes in various variables for the factor markets in Oklahoma from the ten percent decrease in national agricultural commodity prices.

The wage rate decreased by 0.4 percent across all sectors because of intersectoral mobility of labor assumed in the model. As shown in the next section, decreased wage rate is an important factor for the decrease in total welfare of households. Rental price of capital decreased by 20.9 percent for agriculture, by 0.5 percent for services, but increased

TABLE VIII

CHANGES IN FACTOR MARKETS IN OKLAHOMA FROM TEN PERCENT DECREASE IN AGRICULTURAL EXPORT PRICES (INDEX WITH BASE YEAR = 1.000)

	Wage Rate	Rental Price of Capital	Rental Price of Land	Factor Income	Labor Demand	Migration[a]
Sector						
Agriculture	0.996	0.791	0.791		0.793	
Mining	0.996	1.002			1.006	
Manufacturing	0.996	1.008			1.011	
Services	0.996	0.995			0.998	
Factor						
Labor				0.995		-0.003
Capital				0.993		
Land				0.789		

a Represents the ratio of migration compared to the initial level of labor supply.

for mining and manufacturing. Direction of change in the rental price of capital is consistent with the sectoral output changes. This again shows the results of resources flowing from agriculture and services to mining and manufacturing. The rental price of land in agriculture (land was used only in agriculture in the Oklahoma SAM) decreased by the same amount as the rental price of capital. Factor incomes decreased for all primary factors of labor, capital, and land. Factor income for land decreased by the higher rate than that of land rent, 20.9 percent, because some portion of land (and capital) are taken out to the other regions by outmigrants.

Labor demand decreased for agriculture and services by 20.7 percent and 0.2 percent, respectively, and increased for mining and manufacturing by 0.6 percent and 1.1 percent, respectively. Directions of labor demand changes are again consistent with those of sectoral output changes. Labor outmigrated from Oklahoma to the rest-of-country by the rate of 0.3 percent of the initial level of total labor supply. Outmigration results from the decrease in the relative wage rate for the state.

Impacts on Household Groups

Table IX presents how the three household income groups in the state are affected by the ten percent decrease in national agricultural commodity prices.

Each household group showed a decrease in household

TABLE IX

EFFECTS ON HOUSEHOLD GROUPS IN OKLAHOMA FROM TEN PERCENT DECREASE IN AGRICULTURAL EXPORT PRICES (INDEX WITH BASE YEAR = 1.000)

	Income and Saving	Commodity Consumption			Labor Supply	Welfare
		Regional Goods	Imported Goods	Total		
Low Household	0.999				1.003	1.001
Agriculture		1.035	0.935	1.009		
Mining		1.000	1.000	1.000		
Manufacturing		1.006	0.998	1.000		
Services		1.002	0.996	1.001		
Medium Household	0.996				1.004	0.998
Agriculture		1.034	0.934	1.008		
Mining		0.998	0.998	0.998		
Manufacturing		1.003	0.995	0.997		
Services		1.000	0.994	0.998		
High Household	0.992				1.005	0.991
Agriculture		1.035	0.935	1.006		
Mining		0.994	0.994	0.994		
Manufacturing		0.998	0.998	0.992		
Services		0.995	0.989	0.994		

income with the high income class showing the largest decrease (0.8 percent), followed by the medium income class (0.4 percent), and the low income class (0.1 percent). Savings by household group showed the same change as household income because household saving was assumed to be a fixed proportion of household income in model specification.

In general, total consumption by sectoral commodity by the medium and high income household groups decreased except for agricultural commodities. Total consumption by the low income households increased or unchanged for all sectors. Final consumption for imported commodities decreased for all sectors and by all household groups. The level of decreases in commodity consumption by household income group showed consistency with the level of decreases in income.

Labor supply by household income group is determined by the leisure-labor choice. Labor supply increased for all income groups with the high income group highest (0.5 percent) followed by the medium income group (0.4 percent). The low income group showed the lowest increase in labor supply. This implies that household group which faced greater decrease in household income try to restore their reduced income by decreasing more time for leisure and increasing more labor supply.

As shown in the previous section, for low income households, welfare increased by 0.1 percent whereas household income decreased by 0.1 percent. These phenomena are explained by Figure 10. Suppose that budget line for low

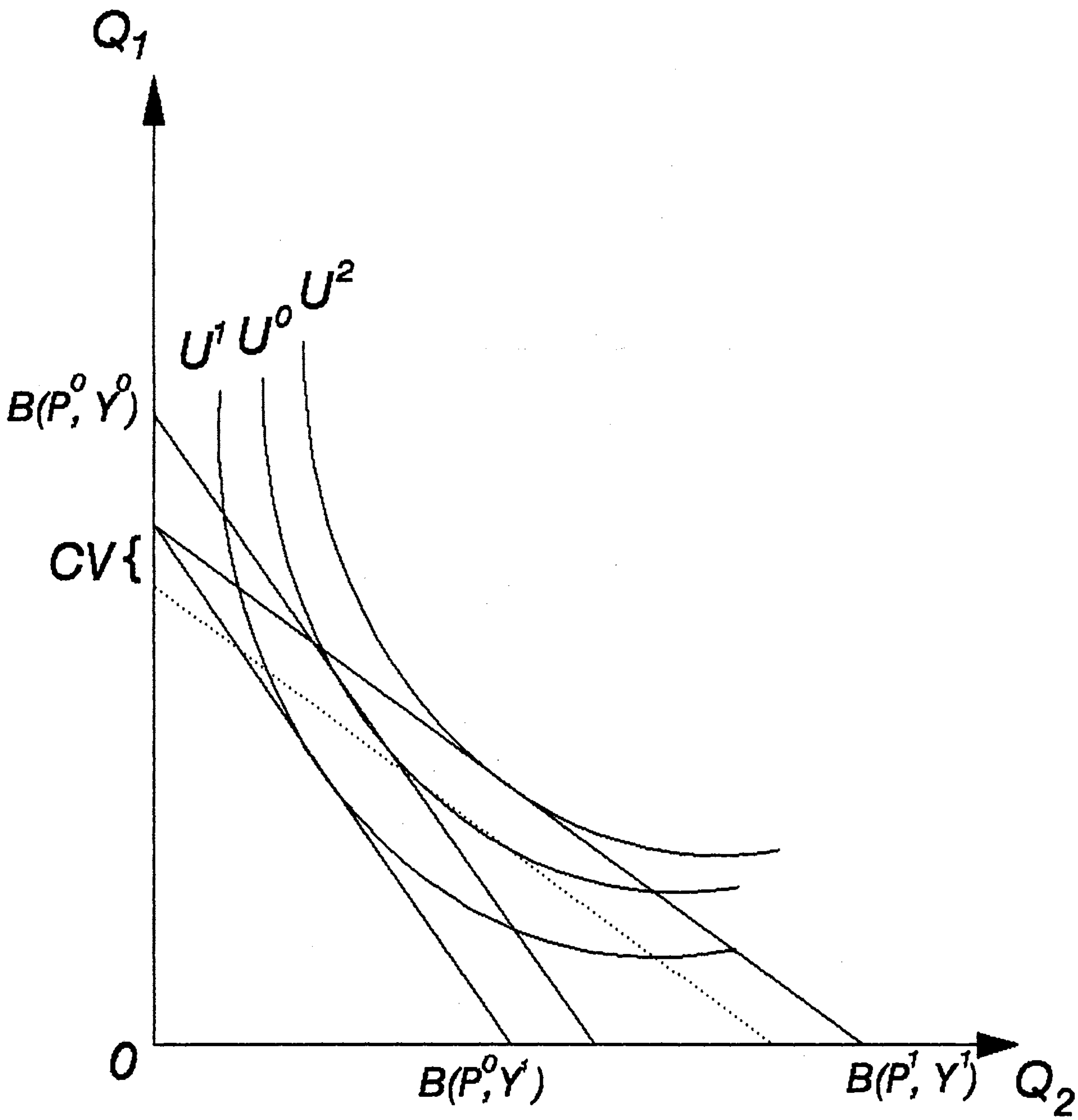


Figure 10. Income and Price Effects on Welfare Change (CV)

income households shifted from $B(P^0,Y^0)$ to $B(P^0,Y^1)$ because of reduced household income (0.1 percent). The horizontal axis (Q_2) represents commodities of agriculture and the vertical axis (Q_1) represents aggregated commodities of the other sectors. The composite price of the aggregated commodity is assumed to be unchanged though it decreased slightly as shown in Table VII. Composite price of agriculture decreased sufficiently so that the price effect compensated the income effect and brought about a positive welfare change to arrive at final budget line $B(P^1,Y^1)$. These results effectively show the distinguishing feature of general equilibrium analysis which is endogeniety of prices including factor prices and quantities.

Sensitivity Analysis

To examine the sensitivity of the results different exogenous parameter values were introduced into the regional equilibrium model. This should also help to understand the characteristics and features of the model. In this section, selected parameters were given different values to analyze sensitivity of model results. Only welfare effects are compared to the base results reported above, leaving out effects on other variables.

Labor Migration Elasticity

Labor migration elasticity (η) was parameterized upward and downward by 0.5 with results shown in Table X. If migration elasticity is replaced by the smaller value, 0.42, compared to the base value of 0.92, total welfare loss of the state increased from $123,702,000 to $138,661,000 or a decrease of 0.30 percent versus 0.34 percent, respectively. When the migration elasticity was increased to 1.42, welfare loss decreased to $113,005,000 or 0.28 percent. These results imply that a one percent decrease in the labor migration elasticity leads to a 0.22 percent increase in the welfare loss. Conversely, a one percent increase in the labor migration elasticity leads to a 0.16 percent decrease in welfare loss.

As migration elasticities change, welfare changes vary by income group. Because the welfare change is computed on the basis of the typical household in each income class size, the percentage changes in welfare given in Table X are representative of welfare change by household by income group. Thus, for example, the welfare change for the high income group goes from a 0.78 percent loss at the high labor migration elasticity to a 0.96 percent loss at the low labor migration elasticity. This result is based not only on effects of wage and income changes but also on the commodity price changes and subsequent real expenditure changes.

Elasticity of Substitution

TABLE X

COMPARISONS OF WELFARE CHANGES (CV) FROM TEN PERCENT DECREASE IN AGRICULTURAL EXPORT PRICES WHEN LABOR MIGRATION ELASTICITY IS VARIED

Household Income Group	Labor Migration Elasticity					
	η = 0.92		η = 0.42		η = 1.42	
	Welfare Change (1,000$)	Percent[a]	Welfare Change (1,000$)	Percent[a]	Welfare Change (1,000$)	Percent[a]
Low	11,104	0.10	11,449	0.10	10,860	0.10
Medium	-51,281	-0.26	-56,267	-0.28	-47,714	-0.24
High	-83,525	-0.86	-93,842	-0.96	-76,151	-0.78
Total	-123,702	-0.30	-138,661	-0.34	-113,005	-0.28

a Welfare change compared to base level of expenditures for each household group.

The elasticity of substitution was varied both upward and downward by about 0.5 for each sector and the welfare effects were compared (Table XI). These elasticities measure the substitution between regional and imported products in intermediate input use by industry, final consumption by households, demands by state and local government, demands by federal government, and invest demands. A zero elasticity implies that regional and imported components of the composite commodity must be in fixed proportion. As the size of the elasticity increases, it implies that components are more perfect substitutes.

If the elasticity of substitution increases by about 0.5 for each sector, total welfare loss decreases from $123,702,000 to $115,103,000 or a change in welfare of -0.30 percent to -0.28 percent. If the elasticity is decreased by 0.5 for each sector, total welfare loss increases to $134,188,000. The implication is that as relative commodity prices change, at low elasticities of substitution, regional commodity users have less opportunity to substitute imported commodities for regionally produced commodities and welfare losses are greater. Conversely, as elasticities of substitution increase, welfare losses decrease.

High income households face the most significant welfare changes from changes in elasticities of substitution. Low income households show welfare gains at all levels of elasticities of substitution, but it is exceptional that the welfare gain is less at high elasticities compared to low

TABLE XI

COMPARISONS OF WELFARE CHANGES (CV) FROM TEN PERCENT DECREASE IN AGRICULTURAL EXPORT PRICES WHEN ELASTICITIES OF SUBSTITUTION ARE VARIED

Household Income Group	Elasticity I[a]		Elasticity II[b]		Elasticity III[c]	
	Welfare Change (1,000$)	Percent[d]	Welfare Change (1,000$)	Percent[d]	Welfare Change (1,000$)	Percent[d]
Low	11,104	0.10	10,008	0.09	12,498	0.11
Medium	-51,281	-0.26	-47,885	-0.24	-55,393	-0.28
High	-83,525	-0.86	-77,226	-0.79	-91,293	-0.94
Total	-123,702	-0.30	-115,103	-0.28	-134,188	-0.33

a σ's are 1.42 for agriculture, 0.50 for mining, 3.55 for manufacturing, and 2.00 for services.

b σ's are 1.92 for agriculture, 1.01 for mining, 4.05 for manufacturing, and 2.50 for services.

c σ's are 0.92 for agriculture, 0.15 for mining, 3.05 for manufacturing, and 1.50 for services.

d Welfare change compared to base level of expenditures for each household group.

elasticities.

Elasticity of Transformation

As in the case of the elasticity of substitution, the elasticity of transformation was varied both upward and downward by about 0.5 for each sector and the welfare effects compared (Table XII). These elasticities measure the ability to transform production systems from producing for domestic markets into systems producing for export when the domestic to export price ratio changes. At low elasticities production systems are limited in transforming outputs whereas at high elasticities production systems can easily adapt.

The results showed little change in welfare from the changes in elasticity of transformation. If the value for elasticity of transformation increased by about 0.5 for each sector compared to the base, total welfare loss increased from $123,702,000 to $126,145,000 and if the elasticity was decreased by about 0.5 for each sector, total welfare loss decreased to $120,463,000. It means that if elsticities of transformation increase, welfare losses also increase. This response is the opposite direction compared to the welfare response in case of elasticity of substitution change.

Welfare Changes under Alternative Closures

In this section, welfare impacts of a ten percent

TABLE XII

COMPARISONS OF WELFARE CHANGES (CV) FROM TEN PERCENT DECREASE IN AGRICULTURAL EXPORT PRICES WHEN ELASTICITIES OF TRANSFORMATION ARE VARIED

Household Income Group	Elasticity I[a]		Elasticity II[b]		Elasticity III[c]	
	Welfare Change (1,000$)	Percent[d]	Welfare Change (1,000$)	Percent[d]	Welfare Change (1,000$)	Percent[d]
Low	11,104	0.10	11,088	0.10	10,916	0.10
Medium	-51,281	-0.26	-52,427	-0.26	-49,846	-0.25
High	-83,525	-0.86	-84,806	-0.87	-81,533	-0.84
Total	-123,702	-0.30	-126,145	-0.31	-120,463	-0.30

a σ^X's are 3.90 for agriculture, 2.90 for mining, 2.90 for manufacturing, and 0.70 for services.

b σ^X's are 4.40 for agriculture, 3.40 for mining, 3.40 for manufacturing, and 1.20 for services.

c σ^X's are 3.40 for agriculture, 2.40 for mining, 2.40 for manufacturing, and 0.40 for services.

d Welfare change compared to base level of expenditures for each household group.

decrease in agricultural export prices are evaluated under three alternative closure rules with respect to labor mobility. Alternative closure rules are: (1) full employment and labor market equilibrium through labor migration; (2) full employment and labor market equilibrium with no migration; and (3) wage rate is fixed at the initial level, no labor migration, and unemployment results. The first closure rule was that adopted in the current study. These comparisons are meaningful in that the first closure is based on the concept of people prosperity whereas the second and the third closures are based on the concept of place prosperity. In other words, the first closure provides the people with the opportunity to choose the place where their wage compensation is equal to the opportunity cost of labor. The results under that closure represent the welfare effects on people wherever they eventually reside. However, the other two closure rules emphasize development of regions and what it would take to maintain welfare at the previous level.

The regional CGE model was modified for the last two closure rules. For the second closure (full employment and no migration), the equation for migration and migration related variables were excluded from the model. For the third closure (fixed wage rate, unemployment, and no migration), in addition to the above modification for the second closure, the following modifications were necessary: (1) an equation was added that fixes wage rate to the initial level; (2) the equation for labor market equilibrium was deleted; and (3) an equation for unemployment was added and is equal to the difference between the labor supply and labor demand.

Results from the alternative closures are presented in Table XIII. Welfare loss was the greatest for the third closure rule and is more than twice the level as with the first closure rule. To be more specific, with a ten percent decrease in agricultural export prices and a fixed wage rate, the welfare loss is $288,430,000 across all household income groups in Oklahoma. This welfare loss equals 0.7 percent of total initial expenditures for all households in Oklahoma. Under the second closure rule which assumes full employment but no migration, total welfare loss would amount to $156,734,000 which equals 0.38 percent of the initial expenditures. Those two closure rules brought about greater welfare losses compared to the first closure rule adopted in this study which assumed full employment with migration. This implies that if more restrictions are placed on economic behavior of people, it will result in greater negative welfare effects. Under the assumption of no migration, the welfare loss is greater under the unemployment closure (the third closure) compared to full employment (the second closure). This is because of significantly decreased incomes of the unemployed group.

Although not presented in Table XIII, under the third closure, about 0.7 percent of the initial level of labor supply would be unemployed. This compares to the amount of outmigration which would occur under the first closure which

TABLE XIII

COMPARISONS OF WELFARE CHANGES (CV) FROM TEN PERCENT DECREASE IN AGRICULTURAL EXPORT PRICES UNDER ALTERNATIVE CLOSURE RULES

Household Income Group	Full Employment Migration		Full Employment No Migraion		Fixed Wage Rate No Migration	
	Welfare Change (1,000$)	Percent[a]	Welfare Change (1,000$)	Percent[a]	Welfare Change (1,000$)	Percent[a]
Low	11,104	0.10	11,873	0.11	-13,678	-0.12
Medium	-51,281	-0.26	-62,433	-0.31	-122,581	-0.61
High	-83,525	-0.86	-106,633	-1.08	-152,170	-1.55
Total	-123,702	-0.30	-156,734	-0.38	-288,430	-0.70

a Welfare change compared to base level of expenditures for each household group.

is 0.3 percent of the initial level of labor supply. This is because, under the third closure, wage rate is fixed at the initial level while it is not fixed under the first closure. However, the assumption under the first closure is that markets and thus wage rates are not affected in other regions as they are in the study region.

Summary

The impacts that a ten percent decrease in national agricultural (export) commodity prices would have on welfare and other economic variables in the Oklahoma economy were examined through implementation of the CGE model constructed in chapter III. In addition, a sensitivity analysis was completed for selected parameters of the model. As a whole, welfare effects on Oklahoma households and impacts on other variables in the state economy were marginal from the change in agricultural commodity prices. However, results tell clearly relative welfare changes among the different household groups and the direction of change in other variables. The analysis measured not only aggregate effects in the regional economy, but also specific effects by industry, household group, and primary factor resources. In addition, unlike fixed-price multiplier analysis, it simulates commodity and factor price changes as well as quantity and income changes. This type of information is helpful for policymakers in evaluating rural development policies and programs.

CHAPTER VI

WELFARE EFFECTS OF MOUNTAIN FORK RIVER TROUT FISHERY IN MCCURTAIN COUNTY, OKLAHOMA

Following chapter V, in this chapter, impacts of the Mountain Fork River (MFR) trout fishery on selected variables including welfare levels for different household groups in McCurtain County, Oklahoma is analyzed for another empirical application. The analysis includes all aspects of the regional equilibrium model described in Chapters II and III including the labor-leisure choice, labor migration, and expenditure impact of a nonmarket good. In addition, a sensitivity analysis is conducted on selected elasticity parameters.

Empirical Implementation

Mountain Fork River Trout Fishery

The Mountain Fork River (MFR) is located in McCurtain County in the extreme southeastern part of Oklahoma. From January 1, 1989, the Oklahoma Department of Wildlife Conservation (ODWC) designated approximately 12 miles of the MFR and tributaries from Broken Bow Dam downstream to the U.S.

Highway 70 bridge as a cold water fishery area. Catchable rainbow trout are stocked by the ODWC for operation of a year-round put-and-take trout fishery with the assistance from U.S. Army Corps of Engineers (Choi 1993). Although before implementation of the trout fishery the area had strong recreation activities and visitation at the Beavers Bend State Park, the Broken Bow Lake, and the Mountain Fork River including boating, fishing, and canoeing, the trout fishery brought about increased visitation particularly at MFR. Trout fishing anglers come from McCurtain County, from other counties of Oklahoma, and from other states, particularly from Texas. The demand for increased trips to the MFR because of the trout fishery was estimated by Choi using the indirect travel cost method based on the expenditure approach (Randall). In addition to the nonmarket benefits of the trout fishery, angler expenditures affect area commodity and factor markets and thus welfare of McCurtain County households.

McCurtain County does not belong to the group of small counties in Oklahoma in terms of population but is one of the poorest in terms of personal income. It has a population of 33,433 in 1990 which ranks 25th among the 77 counties of Oklahoma and a per capita income of $11,180 in 1990 (average of Oklahoma is $15,451) which ranks 75th in the state.

Social Accounting Matrix of McCurtain County

Angler trip expenditures to the Mountain Fork River trout fishery by sector and by residence origin of anglers were estimated using the information in Choi (1993). Estimation procedures are presented in Appendix C. As shown in Table XXVII of Appendix C, total expenditures were $42,650 for McCurtain County anglers and $612,350 for outside anglers in 1990. McCurtain County anglers spent $15,795 from the manufacturing sector and $26,855 from the services sector, while outside anglers spent $162,006 from manufacturing and $450,344 from services. Of the total expenditures of McCurtain County anglers, $9,916 was from low income households, $16,271 from medium income households, and $16,463 from high income households. Expenditures by anglers from outside the county were allocated to the rest-of-world export account.

These expenditures were incorporated into the social accounting matrix (SAM) of McCurtain County as components of nonmarket goods. The sorted expenditures by sector (industry) are inputs in the production of the nonmarket good. Consumption of the nonmarket good is expressed by total expenditure for the nonmarket good and other demand characteristics. Nonmarket goods are then included as a separate sector interrelated with other sectors in a social accounting matrix (SAM). Once included in a SAM, nonmarket goods can play a role of interacting with other components in a CGE model. Table XIV shows the SAM for McCurtain County incorporating expenditures of nonmarket goods .

TABLE XIV

SOCIAL ACCOUNTING MATRIX FOR MCCURTAIN COUNTY, OKLAHOMA, 1990 (IN THOUSANDS OF 1990 DOLLARS)

	(INDUSTRY)								
	Ag	Min	Manuf	Ser	TFR	TFE	Total	Labor	Capital
(INDUSTRY)									
1.Agriculture	3801.6	0.0	37943.7	270.8			42016.1		
2.Mining	4.3	1.0	29.9	13.5			48.7		
3.Manufacture	243.5	0.6	31149.9	1911.2	4.8	49.7	33359.6		
4.Service	6380.8	70.3	36106.6	33522.2	7.9	132.2	76219.9		
5.TFR									
6.TFE									
Total	10430.1	71.9	105230.1	35717.7	12.7	181.9	151644.4		
(FACTORS)									
1.Labor	4815.9	664.6	96346.4	116736.2			218563.1		
2.Capital	3727.5	317.1	23826.5	46777.9			74649.0		
3.Land	6366.6						6366.6		
Total	14910.0	981.7	120172.9	163514.1			299578.7		
(INSTITUTION)									
1.Enterprise									61488.9
2.Household									
-low								44268.8	57.0
-medium								93191.5	808.0
-high								89559.2	931.7
-subtotal								227019.4	1796.7
3.Government									
-st & local	1105.6	55.2	1847.8	12801.2			15809.9	5662.6	3364.7
-federal	371.9	18.6	621.5	4305.9			5317.8	29465.1	6563.6
-subtotal	1477.5	73.8	2469.3	17107.1			21127.7	35127.7	9928.3
Total	1477.5	73.8	2469.3	17107.1			21127.7	262147.1	73213.9
(CAPITAL)									1435.1
(REST OF WORLD)									
1.Agriculture	12711.5	0.1	85089.1	649.6			98450.4		
2.Mining	14.3	5.9	67.0	32.5			119.7		
3.Manufacture	814.1	3.4	69454.4	4584.4	10.9	112.3	74979.5		
4.Service	21335.7	408.0	80969.5	79266.3	19.0	318.2	182316.6		
5.TFR									
6.TFE									
Total	34875.7	417.3	235580.1	84532.7	29.9	430.5	355866.2		
(TOTAL)	61693.3	1544.7	463452.3	300871.7	42.7	612.4	828217.0	262147.1	74649.0

TABLE XIV (continued)

(FACTOR)		(INSTITUTION)								
Land	Total	Enterpr	Household				Gov't			Total
			low	medium	high	subtotal	st & l	federal	subtotal	
			327.0	219.1	61.8	607.9	35.0		35.0	642.9
			0.5	0.2	0.1	0.8	1.0		1.0	1.8
			2017.6	2278.3	736.7	5032.6	183.1		183.1	5215.7
			44813.3	42868.7	13189.8	100871.7	7944.6	4341.1	12285.7	113157.4
			9.9	16.3	16.5	42.7				42.7
			47168.3	45382.5	14004.9	106555.7	8163.7	4341.1	12504.8	119060.5
			689.0			689.0	37348.2	5546.8	42895.0	43584.0
			689.0			689.0	37348.2	5546.8	42895.0	43584.0
	61488.9									
169.6	44495.3	9161.4					4215.2	54247.6	58462.8	67624.1
2405.5	96405.0	18339.8					2571.6	33095.6	35667.2	54007.1
2774.1	93265.0	6683.0					228.0	2934.0	3162.0	9845.0
5349.2	234165.3	34184.2					7014.8	90277.2	97292.0	131476.2
344.8	9372.1		1013.9	2569.7	1808.7	5392.2				5392.2
672.6	36701.3		4603.2	11666.8	8211.7	24481.7				24481.7
1017.4	46073.4		5617.0	14236.5	10020.4	29873.9				29873.9
6366.6	341727.6	34184.2	5617.0	14236.5	10020.4	29873.9	7014.8	90277.2	97292.0	161350.1
	1435.1	27304.8	-6527.9	5510.9	7401.4	6384.4				33689.2
			332.1	248.9	71.1	652.1	44.1		44.1	696.2
			16.8	6.0	1.9	24.7	23.2		23.2	47.9
			32970.7	29917.9	8257.9	71146.5	5549.6		5549.6	76696.1
			71545.8	57778.2	17176.3	146500.3	5023.1		5023.1	151523.4
			104865.4	87951.0	25507.2	218323.6	10640.0		10640.0	228963.6
6366.6	343162.7	61488.9	151811.8	153080.9	56933.9	361826.6	63166.7	100165.1	163331.8	586647.4

TABLE XIV (continued)

<CAPITAL>	<ROW>	<TOTAL>
41.2	18993.1	61693.3
0.2	1494.0	1544.7
2882.1	421994.9	463452.3
55208.6	56285.7	300871.7
		42.7
	612.4	612.4
58132.1	499380.0	828217.0
		262147.1
		74649.0
		6366.6
		343162.7
		61488.9
	39692.4	151811.8
	2668.9	153080.9
	-46176.1	56933.9
	-3814.8	361826.6
	32592.5	63166.7
	33664.3	100165.1
	66256.8	163331.8
	62442.0	586647.4
	25202.8	60327.1
67.0		99213.6
9.3		176.9
1477.1		153152.7
641.6		334481.6
2195.0		587024.8
60327.1	587024.8	2405378.9

Simulation Scenario

Choi (1993) estimated the MFR fishery benefits before and after implementation of the trout fishery project. Benefits before and after were $89,630 and $965,000, respectively (Choi, p.143). That is, the ratio of before and after was 0.093. It was assumed in this study that expenditures for MFR trips by anglers were proportional to the before and after benefits. In this way, a counterfactual experiment was established by incorporating the above ratio in the two trip demand functions (equations 3.21, 3.45) of the model for purpose of determining the equilibrium of the model before and after implementation of the trout fishery project in McCurtain County.

Simulation Results

Welfare Effects

Results of the counterfactual experiment showed that welfare changes in terms of equivalent variation were almost identical to the compensating variation. Therefore, welfare changes are reported only in terms of compensating variation (CV). Welfare change (CV) of the counterfactual experiment where regional (county) and/or exported (outside) MFR trip demands are assumed to decrease to the level prior to implementation of the trout fishery project are shown in Table

XV. If demand for MFR trips decreased for both regional and outside anglers (level prior to trout fishery), it would result in a welfare loss of $608,537 to the McCurtain County households.

Among household groups, welfare loss is $287,652 (47.3 percent) for high income households, $245,849 (40.4 percent) for medium income, and $75,036 (12.3 percent) for low income. As a whole, the welfare change from decreased demand for MFR trips is not significant. Welfare change from decreased demand for MFR trips by county anglers (-$56,941) is much smaller compared to outside county anglers (-$558,080). The ratio of welfare change from decreased county angler trips to that from decreased outside county angler trips is about 0.10. This compares to the ratio of county anglers' expenditures ($42,650) to outside county anglers' expenditures ($612,350) of about 0.07. The former ratio is higher than the latter, which may indicate that the welfare effects from decreased county angler trips are relatively more significant than decreased outside county angler trips. This implies that per unit expenditure associated with county consumption demand brings about more impacts on McCurtain County than export demand although the level of expenditure for the latter is much greater. This may be the result that county consumption demand is more strongly linked with the county economy through labor supply and household budgets than is export demand.

When compared to the base level of expenditure for each household group, the welfare change did not exceed one percent

TABLE XV

WELFARE CHANGES (CV) FROM DECREASED MOUNTAIN FORK RIVER TRIP DEMAND, MCCURTAIN COUNTY, OKLAHOMA, 1990

Household Income Group	Without TFR[a]		Without TFE[b]		Without TF[c]	
	Welfare Change ($)	Percent[d]	Welfare Change ($)	Percent[d]	Welfare Change ($)	Percent[d]
Low	-7,309	-0.01	-68,630	-0.05	-75,036	-0.05
Medium	-22,935	-0.02	-225,508	-0.17	-245,849	-0.19
High	-26,697	-0.07	-263,943	-0.67	-287,652	-0.73
Total	-56,941	-0.02	-558,080	-0.17	-608,537	-0.19

a Demand decrease for county anglers.

b Demand decrease for outside anglers.

c Demand decrease for county and outside anglers.

d Welfare change compared to base level of expenditures for each household group.

of total household expenditure. This is because angler expenditures for MFR trips are small relative to the total economy of McCurtain County. Welfare change is the highest for high income households (-0.73 percent), followed by medium income households (-0.19 percent), and lowest (-0.05 percent) for low income households.

Impacts on Commodity Markets

Changes in commodity markets of the McCurtain County regional economy from decreased demand for MFR trips are presented in Table XVI. Changes in the variables are expressed in terms of an index with the base year (1990) value equal to one.

Output decreased slightly in the manufacturing and services sectors, increased in mining, and increased slightly in the agriculture and mining sectors. Nonmarket goods decreased by the ratio (0.093) assumed for the counterfactual scenario of MFR trips before and after establishment of the trout fishery. Regional supply decreased in manufacturing and services and maintained the base level in agriculture and mining. Exports increased for agriculture and mining by the same percentage (0.2 percent), and did not change for services and manufacturing.

Composite price decreased slightly (0.999) for services because of strong linkages to trip expenditures. This resulted in a decrease in composite price of both kinds of

TABLE XVI

CHANGES IN COMMODITY MARKETS IN MCCURTAIN COUNTY REGIONAL ECONOMY FROM DECREASED DEMAND FOR TRIPS WITHOUT THE TROUT FISHERY (INDEX WITH BASE YEAR = 1.000)

	Output	Regional Supply	Export	Composite Price	Import
Sector					
Agriculture	1.001	1.000	1.002	1.000	0.999
Mining	1.002	1.000	1.002	1.000	0.999
Manufacturing	0.999	0.997	1.000	1.000	0.997
Services	0.999	0.998	1.000	0.999	0.997
TFR[a]	0.093	0.093		0.999	
TFE[b]	0.093		0.093	0.999	

a Trout fishery trips by county anglers.

b Trout fishery trips by outside county anglers.

trout fishery trips (TFE and TFR) by the same rate. Other sectors did not change in composite prices. Decreased demand for MFR trips brings about decreased imports in all sectors of McCurtain County.

Impacts on Factor Markets

Table XVII shows changes in various variables in factor markets of the McCurtain County economy from decreased demand for MFR trips by county and outside county anglers.

The wage rate decreased by 0.2 percent and is the same across all sectors because of intersectoral mobility of labor assumed in the model. Rental prices of capital decreased for manufacturing and services, increased for mining, and did not change for agriculture. Manufacturing and services have lower rental price of capital compared to agriculture and mining. Rental price of land for agriculture decreased slightly. Factor incomes decreased for all primary factors. Labor, capital, and land income decreased by 0.3 percent, by 0.5 percent, and by 0.2 percent, respectively.

Labor demand increased for agriculture and mining by 0.2 percent and 0.3 percent, respectively, and decreased for manufacturing and services by 0.1 percent. Labor outmigrated from McCurtain County to the rest of country by 0.19 percent of the initial total labor supply of McCurtain County.

TABLE XVII

CHANGES IN FACTOR MARKETS IN MCCURTAIN COUNTY REGIONAL ECONOMY FROM DECREASED DEMAND FOR TRIPS WITHOUT THE TROUT FISHERY (INDEX WITH BASE YEAR = 1.000)

	Wage Rate	Rental Price of Capital	Rental Price of Land	Factor Income	Labor Demand	Migration[c]
Sector						
Agriculture	0.998	1.000	0.998		1.002	
Mining	0.998	1.001			1.003	
Manufacturing	0.998	0.997			0.999	
Services	0.998	0.996			0.998	
TFR[a]						
TFE[b]						
Factor						
Labor				0.997		-0.0019
Capital				0.995		
Land				0.998		

a Trout fishery trips by county anglers.

b Trout fishery trips by outside county anglers.

c Represents the ratio of migration compared to the initial level of labor supply.

Impacts on Household Groups

Table XVIII presents how the three household income groups in McCurtain County are affected by the decreased demand for MFR trips.

Each household group showed a decrease in household income with the high income class showing the largest decrease (0.5 percent), followed by the medium income class (0.2 percent), and the low income class (0.1 percent). These results are consistent with the results of the welfare losses. Savings of each household group showed the same change as with household income because the former is a fixed ratio of the latter.

High income households reduced commodity consumption for regional, imported, and composite goods for all sectors except agriculture. The decreases of commodity consumption by high income households is more significant compared to the other household income groups. Consumption for imported commodities decreased for all household income groups except agriculture. Consumption for regionally produced goods by low and medium household income groups, however, increased for almost all sectors.

Labor supply for each household income group which is determined by leisure-labor choice increased by 0.2 percent for the low and the medium income groups and increased by 0.3 percent for the high income group.

TABLE XVIII

EFFECTS ON HOUSEHOLD GROUPS IN MCCURTAIN COUNTY FROM DECREASED DEMAND FOR TRIPS WITHOUT THE TROUT FISHERY (INDEX WITH BASE YEAR = 1.000)

	Income and Saving	Commodity Consumption			Labor Supply	Welfare
		Regional Goods	Imported Goods	Total		
Low Income Household	0.999				1.002	0.9995
Agriculture		1.001	1.001	1.001		
Mining		1.000	0.999	0.999		
Manufacturing		1.002	0.999	0.999		
Services		1.002	0.999	0.999		
TFR[a]		0.093		0.093		
Medium Income Household	0.998				1.002	0.9981
Agriculture		1.001	1.001	1.001		
Mining		0.999	0.999	0.999		
Manufacturing		1.001	0.998	0.998		
Services		1.001	0.997	0.999		
TFR[a]		0.093		0.093		
High Income Household	0.995				1.003	0.9927
Agriculture		1.000	1.000	0.999		
Mining		0.996	0.996	0.996		
Manufacturing		0.997	0.994	0.995		
Services		0.997	0.994	0.995		
TFR[a]		0.093		0.093		

a Trout fishery trips by county anglers.

Sensitivity Analysis

Sensitivity of the results to changes in selected exogenous parameters are examined to help understand the characteristics and features of the model. Welfare effects are compared to the base results in analyzing sensitivity of the model to changes in selected parameters.

Labor Migration Elasticity

Labor migration elasticity (η) was parameterized upward and downward by 0.5 with results shown in Table XIX. If migration elasticity value is replaced by lower (0.42) value than that used in simulation (0.92), total welfare of the region decreased by $465,096. If migration elasticity value is replaced by greater (1.42) value, total welfare of the region decreased by $733,791. It implies that if labor migration responds more sensitively to the same wage difference, welfare of people who remain in the region decreases more significantly. As migration elasticity increases from 0.42 to 1.42, additional welfare loss is the most significant for medium income group in absolute value terms ($51,193) while it is the most significant for high income household group in terms of percentage of initial household group expenditures (from 0.73% to 0.86%). It also shows that as migration elasticity value becomes larger, the extent of additional welfare decrease becomes smaller for all

TABLE XIX

COMPARISONS OF WELFARE CHANGES (CV) FROM DECREASED MOUNTAIN FORK RIVER TRIP DEMAND WHEN LABOR MIGRATION ELASTICITY IS VARIED

Household Income Group	Labor Migration Elasticity					
	η = 0.92		η = 0.42		η = 1.42	
	Welfare Change ($)	Percent[a]	Welfare Change ($)	Percent[a]	Welfare Change ($)	Percent[a]
Low	-75,036	-0.05	-48,670	-0.03	-98,060	-0.06
Medium	-245,849	-0.19	-187,223	-0.14	-297,042	-0.22
High	-287,652	-0.73	-229,203	-0.58	-338,688	-0.86
Total	-608,537	-0.19	-465,096	-0.14	-733,791	-0.23

a Welfare change compared to base level of expenditures for each household group.

household income groups.

Elasticity of Substitution

The model was run with the same scenario as original simulation except that elasticity of substitution was varied both upward and downward by about 0.5 for each sector and the welfare effects are compared in Table XX. Values for elasticity of substitution between regional and imported products is common for intermediate input use by industry, final consumption by households, demands by state and local government, demands by federal government, and invest demands.

If the values for elasticity of substitution increases by about 0.5 for each sector, total welfare loss decreases from $608,537 to $553,907 whereas if elasticity decreases by about 0.5 for each sector, total welfare loss increases from $608,537 to $676,428. This result is because as the elasticity of substitution is increases, related economic agencies (firms, consumers, and governments) are more free to make their decisions for their optimal choices. Thus it links to the increase of welfare.

High income household group faces the most significant additional welfare changes in both terms of absolute values and percentage of household group expenditures.

Elasticity of Transformation

TABLE XX

COMPARISONS OF WELFARE CHANGES (CV) FROM DECREASED MOUNTAIN FORK RIVER TRIP DEMAND WHEN ELASTICITIES OF SUBSTITUTION ARE VARIED

Household Income Group	Elasticity I[a]		Elasticity II[b]		Elasticity III[c]	
	Welfare Change ($)	Percent[d]	Welfare Change ($)	Percent[d]	Welfare Change ($)	Percent[d]
Low	-75,036	-0.05	-69,388	-0.05	-81,964	-0.05
Medium	-245,849	-0.19	-223,558	-0.17	-273,574	-0.21
High	-287,652	-0.73	-260,961	-0.67	-320,890	-0.82
Total	-608,537	-0.19	-553,907	-0.17	-676,428	-0.21

a σ's are 1.42 for agriculture, 0.50 for mining, 3.55 for manufacturing, and 2.00 for services.

b σ's are 1.92 for agriculture, 1.01 for mining, 4.05 for manufacturing, and 2.50 for services.

c σ's are 0.92 for agriculture, 0.10 for mining, 3.05 for manufacturing, and 1.50 for services.

d Welfare change compared to base level of expenditures for each household group.

As in the case of elasticity of substitution, the model was run with the same scenario as original simulation except the elasticity of transformation was varied both upward and downward by about 0.5 for each sector. The welfare effects are compared in Table XXI.

The results are similar to the results for the elasticity of substitution. If the values for elasticity of transformation increase by about 0.5 for each sector, total welfare loss decreases from $608,537 to $555,005 whereas if elasticity decreases by about 0.5 for each sector, total welfare loss increases from $608,537 to $669,605. High income households have the most significant positive welfare changes.

Summary

The impacts that decreased demand for Mountain Fork River trout fishery trips have on welfare and other economic variables in McCurtain County, Oklahoma were examined through implementation of simulation with the CGE model constructed in Chapter III. In addition, a sensitivity analysis was completed for selected elasticity parameters. Although, as a whole, welfare effects for McCurtain County households and impacts on other variables in the regional economy were not significant, simulation results clearly show relative welfare changes among income groups and the directions of change in other variables. Particularly, this study separates nonmarket goods from market goods so that effects of those nonmarket

TABLE XXI

COMPARISONS OF WELFARE CHANGES (CV) FROM DECREASED MOUNTAIN FORK RIVER TRIP DEMAND WHEN ELASTICITIES OF TRANSFORMATION ARE VARIED

Household Income Group	Elasticity I[a]		Elasticity II[b]		Elasticity III[c]	
	Welfare Change ($)	Percent[d]	Welfare Change ($)	Percent[d]	Welfare Change ($)	Percent[d]
Low	-75,036	-0.05	-68,522	-0.05	-82,713	-0.06
Medium	-245,849	-0.19	-224,215	-0.17	-270,470	-0.20
High	-287,652	-0.73	-262,269	-0.67	-316,422	-0.81
Total	-608,537	-0.19	-555,005	-0.17	-669,605	-0.21

a σ^X's are 3.90 for agriculture, 2.90 for mining, 2.90 for manufacturing, and 0.70 for services.

b σ^X's are 4.40 for agriculture, 3.40 for mining, 3.40 for manufacturing, and 1.20 for services.

c σ^X's are 3.40 for agriculture, 2.40 for mining, 2.40 for manufacturing, and 0.40 for services.

d Welfare change compared to base level of expenditures for each household group.

goods on the regional economy as well as welfare can be traced. This type of information is helpful for policymakers in evaluating rural development policies and programs.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Summary

Objectives

Rural development programs or policies are best evaluated on the basis of how they change the welfare of rural residents. Changes in aggregate employment and income in rural areas should be evaluated on how welfare of rural residents has changed and the loss in efficiency from promoting place prosperity. The overall objective of this study was to develop an analytical framework for assessing welfare change of rural residents from rural development programs and policies and apply it for empirical analyses.

Procedures

The Hicksian welfare measures of compensating variation (CV) and equivalent variation (EV) are firmly rooted in utility theory. What has not been firmly rooted are the linkages between measures of welfare of rural development programs and policies and the open economies of rural regions.

This study has linked general equilibrium methods for open regions and Hicksian welfare measures for purposes of measuring changes in welfare of households from external shocks to rural regions and from rural development programs and policies.

A regional equilibrium model was developed based on beginning distributions of a social accounting matrix (SAM). Distributions included identifying resource ownership by three household income levels in 1990.

In addition to the welfare measurement for evaluating rural development, several additional features were incorporated into the models of this study: (1) Based upon the Armington assumption, commodities were differentiated between regional and imported goods by the constant elasticity of substitution (CES) function and between regional supply and exports by the constant elasticity of transformation (CET) function; (2) Labor supplies were endogenously determined by the labor-leisure choice model and a labor migration elasticity. By allowing migration through wage differentials, the model compensates labor equal to the opportunity costs of labor in other regions; and (3) Nonmarket goods were separated from market goods so that the effects of expenditures associated with nonmarket goods on the regional economy are traced.

Social accounting matrices for regions under empirical analysis were constructed based on 1990 data sets from various sources including IMPLAN. Industries were aggregated into four sectors and household groups were classified into three groups by household income level. The calibration method was used to estimate most but not all of the parameters of the models based on the equilibrium conditions for the 1990 base. Some parameter values (elasticities) were taken from other studies because of underidentification problems of certain equational sets in the model. The software package GAMS was used to solve the nonlinear model.

To study the relationships of a ten percent decrease in agricultural export prices which prevailed in the Oklahoma economy from 1982 to 1986, a state level model was constructed and implemented. From simulation results, welfare, commodity and factor markets, and households were studied and analyzed. Sensitivity analyses were carried out on the parameter elasticities of labor migration, commodity substitutions, and commodity transformations. Evaluations were carried out on alternative model closure rules based on concepts of people versus place prosperity.

To study the impacts of a trout fishery project producing a nonmarket good in southeastern Oklahoma, a county level model was constructed and implemented. Demand parameters for trips to the Mountain Fork River trout fishery were taken from another study (Choi, 1993) and incorporated into the regional equilibrium model through expenditure functions. Simulation of the economy with and without the fishery was analyzed with respect to changes in welfare, commodity and factor markets, and household incomes.

Sensitivity analyses were carried out on elasticity parameters.

Results

Decrease in Agricultural Export Prices. A ten percent decrease in agricultural export commodity prices would result in a total welfare loss of about $124 million across all household income groups in Oklahoma. This amount of welfare loss is equal to 0.30 percent of total initial expenditures of all households in Oklahoma. The high household income group showed the most significant welfare loss among the three household income groups studied. The low household income group obtained a slight welfare gain. Because of the ten percent decrease in national agricultural commodity prices, sectoral outputs, rental price of capital, and labor demand decreased for agriculture and services, and increased for mining and manufacturing. This implies that resources flowed from agriculture and services to mining and manufacturing. The wage rate decreased by 0.4 percent across the state. Factor income decreased for all primary factors, especially land income which decreased by 20.9 percent. Labor which amounts to 0.3 percent of the initial total labor supply in Oklahoma outmigrated from Oklahoma to the rest-of-country because of the decreased relative wage rate. Household income and saving decreased for all household income groups with the high income group showing the highest decrease.

Under the closure rule which allows unemployment and no migration to maintain the initial level of wage rate, welfare loss was the greatest (about $288 million). With full employment and no migration, welfare loss was about $157 million.

<u>Effects of a Trout Fishery</u>. Results of the application of the CGE model to the trout fishery in southeastern Oklahoma was presented earlier in terms of welfare loss without the fishery. However, the emphasis here is placed on welfare gain because of the fishery. The trout fishery resulted in a total welfare gain of about $609,000 to all household income groups in McCurtain County, Oklahoma. This amount of welfare gain is equal to about 0.19 percent of total expenditures of all household groups in McCurtain County. The high income group showed the most significant welfare gain among the three income groups followed by the medium income group, and the lowest loss for the low income group. Welfare gain from increased demand for MFR trips by outside county anglers ($558,080) was much greater compared to that from county anglers ($56,941). Increased demand for MFR trout fishery trips brought about less than a one percent change in the various economic variables for McCurtain County. Labor which amounts to 0.19 percent of the initial total labor supply in McCurtain County inmigrated to McCurtain County from the rest-of-country because of an increased relative wage rate. Household income and saving increased for all household income

groups with the high income group showing the most significant increase.

General Conclusions and Policy Implications

Most rural regional development strategies look for short to intermediate term results. As such, those strategies have had limited success because most development programs are structural in nature and require long term changes in regional comparative advantage. The state of Oklahoma lost aggregate income and employment because of the 10 percent decrease in agricultural export commodity prices from 1982 to 1986. Policymakers became obsessed with trying to replace this loss and as quickly as possible. However, the strategies proposed were by and large long term in nature. Investments in value added activities, international trade development, and development of alternative crop and livestock enterprises require long term commitment and results of such development strategies are not felt immediately. Rural development research has not adequately recognized thes differences between proposed development strategies and policy expectations. In part, this is because rural development research has not focused on how factor and commodity markets work in rural regions in the short to intermediate term versus the long term.

The regional equilibrium model developed and applied at the state level in this study has tried to simulate the conditions operating in markets for Oklahoma from the decrease in agricultural export commodity prices. Factor resources of land and capital were held fixed for the state and by sector whereas labor was assumed mobile between sectors and between regions. Hence, simulation results should approach the short to intermediate term effects that correspond with expectations of policymakers. Some conclusions and policy implications drawn from the results are as follows:

(1) The welfare changes to households from the 10 percent decrease in agricultural export commodity prices were marginal compared to the aggregate level of welfare (expenditure). The welfare loss was about $124 million or about 0.3 percent of initial expenditure. The welfare loss helps us understand why policymakers are concerned about replacing the loss in aggregate income and employment for the state. Households would be willing to have policymakers pay (subsidize) for reestablishment of economic activity if part or all of the welfare loss was restored. In fact, high income households would be willing to pay a higher proportion of their aggregate expenditure compared to medium income households because there proportionate welfare loss was greater (0.86 percent for high income households versus 0.26 percent for medium income households). Low income households would have no incentive to pay because they actually have a welfare gain from the decrease in agricultural commodity export prices.

(2) Agriculture and service sectors are effected

negatively by the price decreases whereas the sectors of manufacturing and mining are effected positively. This result is because composite prices decrease in agriculture and service sectors and increase in manufacturing and mining thus pulling resources (labor) out of the former and putting them in the latter. This result would also imply that those households involved in agriculture and services would be more willing to have policymakers pay for reestablishment of economic activity than would the manufacturing and mining sectors.

(3) Resource owners also have a stake in the reestablishment of economic activity. Land owners have a 20.9 percent reduction in land rents and capital owners have a reduction of capital rents ranging from 20.9 percent in agriculture to 0.5 percent in services. Those resource owners with the greatest loss would be more willing to have policymakers pay for reestablishment of economic activity then would resource owners with less loss. Labor compensation was reduced by 0.5 percent which because of mobility between sectors and regions is significantly less than the loss by land and capital resource owners. In fact, labor that migrated has the lowest loss in resource compensation.

(4) The results from the alternative regional equilibrium closure rules imply further consequences for changes in rural household welfare and additional policy considerations. The closure rule of no labor migration and commodity and factor markets are allowed to reach equilibrium

implies greater welfare loss. This would imply that either households or policymakers will try to maintain population levels no matter the cost. Again, the different household income groups, sectors, and resource owners would differ in the levels to which they would go to present the large welfare losses.

The Keynesian closure rule of no labor migration, parity wage rate with other regions (fixed wage), and unemployed labor presents still a different level and distribution of welfare loss. This result may imply what would exist when all labor markets (nationally) are in disequilibrium and there is no incentive for labor to migrate.

The empirical result from establishment of a natural resource project in a rural region that supplies a nonmarket good shows the economic development contribution to a region's households as well as the nonmarket good benefits. Some conclusions and policy implications drawn from this empirical analysis are as follows:

(1) The welfare gains to households of the small region are minimal, amounting to less than one percent of aggregate household expenditure. The main benefits of the trout fishery accrue to those participating directly in the fishery as pointed out by Choi. Such projects should not be looked to for providing major economic development benefits;

(2) The analysis of the nonmarket good within the context of a regional general equilibrium model indicates that the method may allow future analyses in trade-offs of

noncompatibilities of resource use. That is, forest regions may be used for timber, recreation, and livestock grazing and then may exist trade-offs among the alternative uses. Utility and profit maximization may be evaluated within the context of a general equilibrium model if nonmarket goods can be quantified within the utility function and if the compatibility and noncompatibility of forest uses can be quantified within the production systems.

Limitations

The most critical limitation of this study is the untested exogenous parameters employed from other previous studies. Most exogenous parameter estimates of CGE models have been estimated using national data. Little research has been completed on the limitations of applying those parameter estimates to regional models. As shown in the sensitivity analysis, selected elasticity parameters in this study give significantly different results in model simulations. Critical parameters of regional general equilibrium models are lacking and await further empirical research in their estimation.

A second problem of this study is the availability and reliability of regional data. Although IMPLAN was used as the main source of data, IMPLAN has not developed to the stage of constructing social accounting matrices as specified for the models of this study. Therefore, some components of data set came from other sources which may not be consistent with the IMPLAN sources. Because column and row sums must balance, data was available for only one direction, the other direction was balanced by assuming residual results.

Finally, this study is limited to general theoretical knowledge of regional CGE models in the context of macroeconomic closures for regional economic systems. The current model structure is but one of many structures that could be used. For example, one labor market was assumed when in reality, labor markets exist for different labor skills. Limitations of the current CGE model include fixed supply of capital and land, fixed government and invest demand, and static coefficients.

REFERENCES

Abbott, M. and O. Ashenfelter. 1976. Labour Supply, Commodity Demand and the Allocation of Time. Review of Economic Studies, vol.43, pp.389-411.

Adelman, I. and S. Robinson. 1978. Income Distribution Policy in Developing Countries. Stanford University Press, Stanford, CA.

Ahluwalia, M. and F. Lysy. 1979. "Welfare Effects of Demand Management Policies: Impact Multipliers Under Alternative Model Structures." Journal of Policy Mdeling, vol.1(3): pp.317-342.

Aradhyula, S., K. Eswaramoorthy, and K. Frohberg. 1988. "An Application of the Computable General Equilibrium Model to Analyze U. S. Agriculture." Working Paper 88-WP 26, CARD, Iowa State University, Ames, IA.

Armstrong, H., and J. Taylor. 1985. Regional Economics and Policy. Philip Allan Publishers Limited, Oxford, UK.

Bartels, C. 1977. Economic Aspects of Regional Welfare, Income Distribution and Unemployment. Martinus Nijhoff Social Sciences Division, Leiden, The Netherlands.

Bergstrom, J., H. Cordell, G. Ashley, and A. Watson. 1990. "Economic Impacts of Recreational Spending on Rural Areas: A Case Study." Economic Development Quarterly, vol.4(1), pp.29-39.

Blair, J. 1991. Urban and Regional Economics. Irwin, Homewood, IL.

Blakely, E. 1989. Planning Local Economic Development, Theory and Practice. Sage Publications, Newbury Park, CA.

Bouchelle, E., E. Thunberg, C. Adams, and J. Seale Jr. 1993. A General Equilibrium Welfare Analysis of North Atlantic Swordfish Quotas. Paper presented at the meetings of the Southern Agricultual Economics Association, Tulsa, OK, January 31-February 3, 1993.

Brooke, A., D. Kendrick, and A. Meeraus. 1988. GAMS A Users Guide. International Bank for Reconstruction and development, The Scientific Press, Redwood City, CA.

Chiang, A. 1984. Fundamental Methods of Mathematical Economics, third ed., McGraw-Hill Book Company, New York, NY.

Choi, S. 1993. Economic Analysis of the Mountain Fork River Trout Fishery in Southeastern Oklahoma Using Travel Cost Method. Unpublished Ph.D. Dissertation, Oklahoma State University, Stillwater, OK.

Condon, T., H. Dahl, and S. Devarajan. 1987. "Implementing a Computable General Equilibrium Model on GAMS: The Cameroon Model." DRD Discussion Paper, The World Bank.

Cornwall, R. 1984. Introduction to the Use of General Equilibrium Analysis. North-Holland, the Netherlands.

Deaton, A., and J. Muellbauer. 1980. Economics and Consumer Behavior. Cambridge University Press, Cambridge, MA.

de Melo, J. 1977. "Distortions in the Factor Market: Some General Equilibrium Estimates." Review of Economics and Statistics, vol.59(4): pp.398-405.

de Melo, J. and D. Tarr. 1992. A General Equilibrium Analysis of US Foreign Trade Policy. The MIT Press, Cambridge, MA.

Dervis, K., J. de Melo, and S. Robinson. 1982. General Equilibrium Models for Development Policy, Cambridge University Press, Cambridge, MA.

Fisher, A., and K. Despotakis. 1989. "Energy Taxes and Economic Performance: A Regional General Equilibrium Analysis." Energy Economics, vol.11(2), pp.153-157.

Fletcher, J. 1989. "Input-Output Analysis and Tourism Impact Studies." Annals of Tourism Research, vol.16(4), pp.514-529.

Frisch, R. 1959. "A Complete Scheme for Computing All Direct and Cross Demand Elastocotoes in a Model With Many Sectors." Econometrica, vol.27: pp.177-196.

Gittinger, J. P. 1982. Economic Analysis of Agricultural Projects, Second Edition. The Johns Hopkins University Press. Baltimore, MD.

Harrigan, F. and P. McGregor. 1989. "Neoclassical and Keynesian Perspectives on the Regional Macro-Economy: A Computable General Equilibrium Approach." Journal of Regional Science, vol.29(4): pp.555-573.

Hazilla, M., and R. Kopp. 1990. "Social Cost of Environmental Quality Regulations: A General Equilibrium Analysis." Journal of Political Economy, vol.98(4): pp.853-873.

Hicks, J. 1943. "The Four Consumers' Surplus." Review of Economic Studies, vol.11(1): pp.31- 41.

Hollenbeck, K. 1979. "The Employment and Earnings Impacts of the Regulation of Stationary Source Air Pollution." Journal of Environmental Economics and Management, vol.6: pp.208-221.

Johansen, L. 1960. A multi-Sectoral Study of Economic Growth. North-Holland, Amsterdam, The Netherlands.

Jones, R. and J. Whalley. 1990. "Regional Balance Sheets of Gains and Losses from National Policies: Calculation from an Applied General Equilibrium Model for Canada." Regional Science and Urban Economics, vol.20: pp.421-435.

Jorgenson, D., and P. Wilcoxen. 1990. "Intertemporal General Equilibrium Modeling of U. S. Environmental Regulation." Journal of Policy Modeling, vol.12(4): pp.715-744.

Just, R., D. Hueth, and A. Schmitz. 1982. Applied Welfare Economics and Public Policy. Prentice-Hall, Englewood Cliffs, NJ.

Kim, E. 1993. Government Regional Investment Policies and National Economic Growth: A Recursively Dynamic General Equilibrium Approach. Paper prepared for a North America Regional Science Association 39th Annual Meeting, Chicago, November 12-15, 1993.

Ko, S. 1985. A Regional Computable General Equilibrium Model for Korea. Unpublished Ph.D. Dissertation, University of Illinois, Urbana-Champagne, IL.

Koh, Y. 1991. Analysis of Oklahoma's Boom and Bust Economy by Means of a CGE Model. Unpublished Ph.D. Dissertation, Oklahoma State University, Stillwater, OK.

Koh, Y., D. Schreiner, and H. Shin. 1992. Comparisons of Fixed Price Multiplier Analysis with Regional Equilibrium Analysis or Exogenous Changes in the Oklahoma Economy. Paper presented at the Mid-Continent Regional Science Association Meetings, Oklahoma State University, Stillwater, OK, June 4-6, 1992.

Kraybill, D. 1993. "Computable General Equilibrium Analysis at the Regional Level." in Otto, D. M., and T. G. Johnson (ed.). Microcomputer-Based Input-Output Modeling, pp.198-215. Westview Press, Boulder, CO.

Little, I. and J. A. Mirrlees. 1974. Project Appraisal and Planning for Developing Countries. Basic Books, New York, NY.

Lluch, C., A. Powell, and R. Williams. 1977. Patterns in Household Demand and Savings. Oxford University Press, Oxford, UK.

Mansur, A, and J. Whalley. 1984. "Numerical Specification of Applied General Equilibrium Models: Estimation, Calibration, and Data." in Scarf, H. E. and J. B. Shoven(ed.). Applie dGeneral Equilibrium Analysis, Chapter 3, pp.69-138. Cambridge University Press, Cambridge, MA.

Marcouiller, D. 1992. Development and Use of a Supply Determined Social Accounting Matrix to Evaluate Socioeconomic Impacts of Forest Productivity on Distribution of Regional Factor income. Unpublished Ph.D. Dissertation, Oklahoma State University, Stillwater, OK.

Marcouiller, D., D.Schreiner, and D.Lewis. 1993. The Impact of Forest Land Use on Regional Value Added: A Supply-Determeined SAM Analysis. Paper presneted at the Regional Association International Meetings, Houston, TX, November 11-14, 1993.

Meier, G. 1989. Leading Issues in Economic Development, fifth ed. Oxford University Press, New York, NY.

Miller, R., and P. Blair. 1985. Input-Output Analysis: Foundations and Extensions. Prentice-Hall, Englewood Cliffs, NJ.

Morgan, W., J. Mutti, and M. Partridge. 1989. "A Regional General Equilibrium Model of the United States: Tax Effects on Factor Movements and Regional Production." Review of Economics and Statistics, vol.71:pp.626-635.

Olson, D., S. Lindall, and W. Maki. 1993. Micro IMPLAN User's Guide, Version 91-F. Minnesota IMPLAN Group, St.Paul, MN.

Pearce, D., and K. Turner. 1990. Economics of Natural Resources and the Environment. The Johns Hopkins University Press, Baltimore, MD.

Powell, A., and F. Gruen. 1968. "The Constant Elasticity of Transformation Production Frontier and Linear Supply System." International Economic Review, vol.9: pp.315-328.

Pyatt, G. and J. Round. 1985. Social Accounting Matrices, A Basis for A Planning, The World Bank.

Pyles, D. 1989. "Demand Theory and Elasticity Matrix Consturction." in Tweeten, L.(ed.). Agricultural Policy Analysis Tools for Economic Development, Chapter 4, pp.56-72. Westview Press, Boulder, CO.

Randall, A. 1981. Resource Economics: An Economic Approach to Natural Resource and Environmental Policy. Grid Publishing Inc., Columbus, OH.

Raunikar, R., and C. Huang. 1987(ed.). Food Demand Analysis: Problems, Issues, and Empirical Evidence. Iowa State University Press, Ames, IA.

Rickman, D. 1992. "Estimating the Impacts of Regional Business Assistance Programs: Alternative Closures in a Computable General Equilibrium Model." Papers in Regional Science, vol.71(4): pp.421-435.

Robinson, S., M. Kilkenny, and K. Hanson. 1990. "The USDA/ERS Computable General Equilibrium (CGE) Model of the United States." Staff Report No.AGES 9049, Agricultural and Rural Economy Division, Economic Research Service, USDA.

Robinson, S., S. Subramanian, and J. Geoghegan. 1993. A Regional, Environmental, Computable General Equilibrium Model of the Los Angeles Basin. Project Paper, Depeartment of Agricultural and Resource Economics, University of California, Berkeley, CA.

Rose, A., B. Stevens, and G. Davis. 1988. National Resource Policy and Income Distribution. The Johns Hopkins University Press, Baltimore, MD.

Scheppach, Raymond C.,Jr. 1972. State Projections of the Gross National Products, 1970, 1980. Lexington: Lexington Books, Lexington, MA.

Schreiner, D. 1989. "Policy Applications in Natural Resource Projects." in Tweeten, L.(ed.). Agricultural Policy Analysis Tools for Economic Development, Chapter 11, pp.276-321. Westview Press, Boulder, CO.

Shaffer, R. 1989. Community Economics: Economic Structure and Change in Smaller Communities. Iowa State University Press, Ames, IA.

Shoven, J. B. and J. Whalley. 1984. "Applied General-Equilibrium Models of Taxation and International Trade: An Introduction and Survey." Journal of Economic Literature, vol.22: pp.1007-1051.

Squire, L., H. van der Tak. 1975. Economic Analysis of Projects. The Johns Hopkins University Press, Baltimore, MD.

Stone, R. 1954. "Linear Expenditure Systems and Demand Analysis: An Application to the British Pattern of Demand." Economic Journal, vol.64: pp.511-527.

Thurman, W., and J. Easley Jr. 1992. "Valuing Changes in Commercial Fishery Harvests: A General Equilibrium Derived Demand Analysis". Journal of Environmental Economics and Management, vol.22: PP.226-240.

Tweeten, L. 1989. "Classical Welfare Analysis." in Tweeten, L. (ed.). Agricultural Policy Analysis Tools for Economic Development, Chapter 6, pp.96-127. Westview Press, Boulder, CO.

Tweeten, L., and G. Brinkman. 1976. Micropolitan Development: Theory and Practice of Greater-Rural Economic Development. The Iowa State University Press, Ames, IA.

USDC, Bureau of Economic Analysis. 1992. Personal Income by Major Sources and Transfer Payments by Type, Regional Economic Information System.

Uwakonye, M., D. Schreiner, D. Badger, and M. Woods. 1992. "Estimating the Impact of a Large Water-Based Natural Resource Project on the Local Economy by Means of a SAM." Research Report P-926, Agricultural Experiment Station, Oklahoma State University, Stillwater, OK.

Ward, F. and J. Loomis. 1986. "The Travel Cost Demand Model as an Environmental Policy Assessment Tool: A Review of Literature." Western Journal of Agricultural Economics, vol.11(2): pp.164-178.

Webb. S., K. Hanson, C. Halbrendt, and I. Sundaresan. 1993. An Application of a CGE Model to Analyze the Impact of Agricultural Reforms on China's Economy and World Agriculture. Paper Presented at the American Agricultural Economics Association Annual Meetings, August, 1-4, Orlando, FL.

Woods, M., and L. Sanders. "Economic Development for Rural Oklahoma." OSU Extension Facts, No.858, Cooperative extension Service, Division of Agriculture, Oklahoma State University, Stillwater, OK.

World Bank. 1981. "A General Equilibrium Analysis of Foreign Exchange Shortages in a Developing Economy." World Bank Staff Working Paper No.443.

APPENDIXES

APPENDIX A

MODEL SUMMARY

In this appendix, notation, equations, variables, and parameters of the model in this study are summarized.

TABLE XXII

NOTATION USED IN THE MODEL

Index	Description
i, j	Sectors
h	Household Income Groups
M	Set of Market Goods
NM	Set of Nonmarket Goods
NR	Set of Nonmarket Goods Consumed in the Region
NE	Set of Nonmarket Goods Exported
n	Number of Sectors
m	Number of Market Goods Sectors
nr	Number of Nonmarket Goods Consumed in the Reion
ne	Number of Nonmarket Goods Exported
s	Number of Household Income Groups

* If double subscripts are notated, for example, V_{ji}, it means that "j" was used by "i".

TABLE XXIII

SUMMARY OF EQUATIONS OF THE MODEL

Equation	Number of Equations
Demand for Value Added Use	m
$VA_i = a_{0i}X_i \,, \qquad i \in M$	
Demand for Intermediate Use	n x m
$V_{ji} = a_{ji}X_i \,, \qquad \forall_i,\ j \in M$	
Value Added Production Function	m
$VA_i = \phi_i^{VA}\ LAB_i^{\delta_i^L}\ CAP_i^{\delta_i^K}\ LAND_i^{\delta_i^T} \,, \qquad i \in M$	
Labor Demand	m
$LAB_i = \dfrac{\delta_i^L\ PN_i\ X_i}{PL} \,, \qquad i \in M$	
Capital Demand	m
$CAP_i = \dfrac{\delta_i^K\ PN_i\ X_i}{PK_i} \,, \qquad i \in M$	
Land Demand	m
$LAND_i = \dfrac{\delta_i^T\ PN_i\ X_i}{PT_i} \,, \qquad i \in M$	
Substitutability of Intermediate Use	m^2
$V_{ji} = \phi_{ji}^V \left[\delta_{ji}^V VM_{ji}^{\rho_j^V} + (1-\delta_{ji}^V)\ VR_{ji}^{\rho_j^V}\right]^{\frac{1}{\rho_j^V}},\ \rho_j^V<1,\ i,j \in M$	

TABLE XXIII (continued)

Equation	Number of Equations
Demands for Imported and Regional Intermediate Goods	$m^2+2(n-m)m$
$\frac{VR_{ji}}{VM_{ji}} = \left[\left(\frac{1-\delta^V_{ji}}{\delta^V_{ji}}\right)\left(\frac{PM0_j}{PR_j}\right)\right]^{\sigma^v_j}$, $i,j \in M$	
$VR_{ji} = V_{ji}$, $VM_{ji} = 0$, $i \in NM$, $j \in M$	
Total Demand for Regional Intermediate Goods	m
$TVR_i = \Sigma_j VR_{ij}$, $i \in M, \forall_j$	
Total Demand for Imported Intermediate Goods	m
$TVM_i = \Sigma_j VM_{ij}$, $i \in M, \forall_j$	
Total Demand for Composite Intermediate Goods	m
$TV_i = \Sigma_j V_{ij}$, $i \in M, \forall_j$	
Transformability of Products Supply	m
$X_i = \phi^X_i \left[\delta^X_i E_i^{\rho^X_i} + (1-\delta^X_i) R_i^{\rho^X_i}\right]^{\frac{1}{\rho^X_i}}$, $\rho^X_i > 1$, $i \in M$	
Regional Supply and Exports	m+2(n-m)
$\frac{R_i}{E_i} = \left[\left(\frac{1-\delta^X_i}{\delta^X_i}\right)\left(\frac{PE0_i}{PR_i}\right)\right]^{-\sigma^X_i}$, $i \in M$	
$R_i = X_i$, $E_i = 0$, $i \in NR$	
$R_i = 0$, $E_i = E0_i(P_i)^{\epsilon_i}$, $i \in NE$	

TABLE XXIII (continued)

Equation	Number of Equations
Labor Income	1
$YLAB = \Sigma_i (PL \times LAB_i) + PL(\Sigma_h LHH0_h + LSLG0 + LFEDG0)$, $i \in M$	
Adjusted Labor Income	1
$AYLAB = \frac{YLAB}{adj}$	
Adjustment Factor	1
$adj = \frac{LSTK0 + LMIG}{LSTK0}$	
Capital Income	1
$YCAP = \Sigma_i (PK_i \times CAP_i)$, $i \in M$	
Land Income	1
$YLAND = \Sigma_i (PT_i \times LAND_i)$, $i \in M$	
Agricultural Capital Income	1
$YAGCAP = PK \times AGCAP$	
Enterprise Income	1
$YENT = (YCAP - YAGCAP) \times (1 - ktr)$	
Household Income	s
$YH_h = l_h YLAB(1-sstr) + t_h [YAGCAP(1-ktr-depr) + YLAND(1-ttr)] + e_h [YENT - depr(YCAP - YAGCAP)]$	
Disposable Household Income	s
$DYH_h = (YH_h + TRSLG0_h + TRFEDG0_h + REMIT0_h)(1-hhtr_h)$	

TABLE XXIII (continued)

Equation	Number of Equations
Household Saving	s
$HSAV_h = s_h YH_h$	
Household Expenditure	s
$HEXP_h = DYH_h - HSAV_h - PL \times LHH0_h$	
Adjusted Household Expenditure	h
$AHEXP_h = adj \times HEXP_h$	
Labor Supply	s
$LS_h = MAXHOURS_h - \left(\frac{\beta_{0h}}{w}\right)\left(\frac{AHEXP_h - \sum_{j=1}^{n} P_j \gamma_{jh}}{1 - \beta_{0h}}\right)$	
Demand for Final Consumption Goods	s(m+nr)
$Q_{ih} = \gamma_{ih} + \left[\frac{\beta_{ih}}{(1 - \beta_{0h}) P_i}\right] (AHEXP_h - \sum_{j=1}^{n} P_j \gamma_{jh}), \quad i \in M, NR$	
Substitutability of Final Consumption Goods	s x m
$Q_{ih} = \phi_i^Q \left[\delta_i^Q QM_{ih}^{\rho_i^Q} + (1-\delta_i^Q) QR_i^{\rho_i^Q}\right]^{\frac{1}{\rho_i^Q}}, \quad \rho_i^Q < 1, \; i \in M$	
Demands for Imported and Regional Consumption Goods	s(m+2nr)
$\frac{QR_{ih}}{QM_{ih}} = \left[\left(\frac{1-\delta_i^Q}{\delta_i^Q}\right)\left(\frac{PM0_i}{PR_i}\right)\right]^{\sigma_i^Q}, \quad i \in M$	
$QR_{ih} = Q_{ih}, \quad QM_{ih} = 0, \quad i \in NR$	
Total Demand for Regional Consumption Goods	m+nr
$TQR_i = \Sigma_h QR_{ih}, \quad i \in M, NR$	

TABLE XXIII (continued)

Equation	Number of Equations
Total Demand for Imported Consumption Goods	m+nr
$TQM_i = \Sigma_h QM_{ih}$, $\quad i \in M, NR$	
Total Demand for Composite Consumption Goods	m+nr
$TQ_i = \Sigma_h Q_{ih}$, $\quad i \in M, NR$	
State and Local Government Revenue	1
$SLGR = sl^{IBT}(\Sigma_i ibtr_i PR_i X_i) + sl^{SST}(sstr\ YLAB) + sl^{KTT}(ktr\ YCAP + ttr\ YLAND) + sl^{HHT}(\Sigma_h hhtr_h YH_h) + SLGBOR$	
State and Local Government Expenditure	1
$SLGEXP = \Sigma_i P_i SLGD0_i + adj(\Sigma_h TRSLG0_h) + PL \times LSLG0$	
Substitutability of State and Local Government Demand	m
$SLGD0_i = \phi_i^{SL}\left[\delta_i^{SL} SLGDM_i^{\rho_i^{SL}} + (1-\delta_i^{SL}) SLGDR_i^{\rho_i^{SL}}\right]^{\frac{1}{\rho_i^{SL}}}, \rho_i^{SL}<1, i \in M$	
State and Local Government Demands for Imported and Regional Goods	m
$\frac{SLGDR_i}{SLDGM_i} = \left[\left(\frac{1-\delta_i^{SL}}{\delta_i^{SL}}\right)\left(\frac{PM0_i}{PR_i}\right)\right]^{\sigma_i^{SL}}$, $\quad i \in M$	
Federal Government Revenue	1
$FEDGR = fed^{IBT}(\Sigma_i ibtr_i PR_i X_i) + fed^{SST}(sstr\ YLAB) + fed^{KTT}(ktr\ YCAP + ttr\ YLAND) + fed^{HHT}(\Sigma_h hhtr_h YH_h) + FEDGBOR$	
Federal Government Expenditure	1
$FEDGEXP = \Sigma_i P_i FEDGD0_i + adj(\Sigma_h TRFEDG0_h) + PL \times LFEDG0$	

TABLE XXIII (continued)

Equation	Number of Equations
Substitutability of Federal Government Demand	m
$FEDGD0_i = \phi_i^{FED}\left[\delta_i^{FED} FEDGDM_i^{\rho_i^{FED}} + (1-\delta_i^{FED})\, FEDGDR_i^{\rho_i^{FED}}\right]^{\frac{1}{\rho_i^{FED}}}, \ \rho_i^{FED} < 1, \ i \in M$	
Federal Government Demands for Imported and Regional Goods	m
$\frac{FEDGDR_i}{FEDDGM_i} = \left[\left(\frac{1-\delta_i^{FED}}{\delta_i^{FED}}\right)\left(\frac{PM0_i}{PR_i}\right)\right]^{\sigma_i^{FED}}, \quad i \in M$	
Total Saving	1
$SAV = adj(\Sigma_h HSAV_h) + deprYCAP + ROWSAV$	
Substitutability of Investment Demand	m
$INVD0_i = \phi_i^{INV}\left[\delta_i^{INV} INVDM_i^{\rho_i^{INV}} + (1-\delta_i^{INV})\, INVDR_i^{\rho_i^{INV}}\right]^{\frac{1}{\rho_i^{INV}}}, \ \rho_i^{INV} < 1, i \in M$	
Investment Demands for Imported and Regional Goods	m
$\frac{INVDR_i}{INVDM_i} = \left[\left(\frac{1-\delta_i^{INV}}{\delta_i^{INV}}\right)\left(\frac{PM0_i}{PR_i}\right)\right]^{\sigma_i^{INV}}, \quad i \in M$	
Total Investment	1
$INV = \Sigma_i P_i INVD0_i, \quad i \in M$	
Labor Migration	1
$LMIG = \eta \times LSTK0 \times \ln(PL/PL0^{ROC})$	
Equilibrium for Labor Market	1
$\Sigma_i LAB_i + \Sigma_h LHH0_h + LSLG0 + LFEDG0 = \Sigma_h LS_h + LMIG$	
Equilibrium for Capital Markets	m
$CAP_i = CAP0_i, \quad i \in M$	

TABLE XXIII (continued)

Equation	Number of Equations
Equilibrium for Land Markets	m
$LAND_i = LAND0_i \, , \qquad i \in M$	
Equilibrium for Commodity Markets	m
$X_i + M_i = TV_i + TQ_i + SLGD_i + FEDGD_i + INVD_i + E_i \, , \; i \in M$	
Imports	m
$M_i = TVM_i + TQM_i + SLGDM_i + FEDGDM_i + INVDM_i \, , \qquad i \in M$	
Equilibrium for Nonmarket Goods	nr+ne
$X_i = TQ_i \, , \qquad i \in NR$	
$X_i = E_i \, , \qquad i \in NE$	
Equilibrium for State and Local Government	1
$SLGR = SLGEXP$	
Equilibrium for Federal Government	1
$FEDGR = FEDGEXP$	
Equilibrium for Capital Account	1
$SAV = INV$	
Composite Prices of Market Goods	m
$P_i = \dfrac{PR_i R_i + PM0_i M_i}{R_i + M_i} \, , \qquad i \in M$	
Prices of Nonmarket Goods	nr+ne
$P_i = \dfrac{\sum_j P_j V_{ji}}{\sum_j V_{ji}} \, , \qquad i \in NM \, , \; j \in M$	

TABLE XXIII (continued)

Equation	Number of Equations
Net Prices	m
$PN_i = PR_i - \Sigma_j a_{ji} P_j - ibtr_i PR_i \,, \qquad i \in M$	
Compensating Variation	s
$CV_h = \left(\frac{1}{1-\beta_{0h}}\right)\left[(AHEXP_h^1 - \sum_{j=1}^{n} P_j^1 \gamma_{jh}) - (AHEXP_h^0 - \sum_{j=1}^{n} P_j^0 \gamma_{hj}) \prod_{i=0}^{n} \left(\frac{P_i^1}{P_i^0}\right)^{\beta_{ih}}\right]$	
Equivalent Variation	s
$EV_h = \left(\frac{1}{1-\beta_{0h}}\right)\left[(AHEXP_h^1 - \sum_{j=1}^{n} P_j^1 \gamma_{jh}) \prod_{i=0}^{n} \left(\frac{P_i^0}{P_i^1}\right)^{\beta_{ih}} - (AHEXP_h^0 - \sum_{j=1}^{n} P_j^0 \gamma_{jh})\right]$	
Total Compensating Variation	1
$TCV = \Sigma_h CV_h$	
Total Equivalent Variation	1
$TEV = \Sigma_h EV_h$	

Total : 4n + 18m + 3(n x m) + 3(m+nr) + 3s(m+nr) + 8s + 20

TABLE XXIV

SUMMARY OF ENDOGENOUS VARIABLES OF THE MODEL

Variable	Description	Number of Variables
X_i	Sectoral Output	n
VA_i	Value Added	m
V_{ji}	Demand for Composite Intermediate Good	n x m
LAB_i	Labor Demand	m
CAP_i	Capital Demand	m
$LAND_i$	Land Demand	m
VM_{ji}	Demand for Imported Intermediate Good	n x m
VR_{ji}	Demand for Regional Intermediate Good	n x m
TVR_i	Total Demand for Imported Intermediate Good	m
TVM_i	Total Demand for Regional Intermediate Good	m
TV_i	Total Demand for Composite Intermediate Good	m
E_i	Export of Regional Product	n
R_i	Regional Supply of Regional Product	n
YLAB	Labor Income	1
AYLAB	Adjusted Labor Income	1
adj	Adjustment Factor	1
YCAP	Capital Income	1
YLAND	Land Income	1
YAGCAP	Agricultural Capital Income	1
YENT	Enterprise Income	1
YH_h	Household Income	s

TABLE XXIV (continued)

Variable	Description	Number of Variables
DYH_h	Disposable Household Income	s
$HSAV_h$	Household Saving	s
$HEXP_h$	Household Expenditure	s
$AHEXP_h$	Adjusted Household Expenditure	h
LS_h	Labor Supply by Households	s
Q_{ih}	Demand for Composite Consumption Good	s(m+nr)
QM_{ih}	Demand for Imported Consumption Good	s(m+nr)
QR_{ih}	Demand for Regional Consumption Good	s(m+nr)
TQM_i	Total Demand for Imported Consumption Good	m+nr
TQR_i	Total Demand for Regional Consumption Good	m+nr
TQ_i	Total Demand for Composite Consumption Good	m+nr
SLGR	State and Local Government Revenue	1
SLGEXP	State and Local Government Expenditure	1
$SLGDM_i$	State and Local Government Demand for Imported Good	m
$SLGDR_i$	State and Local Government Demand for Regional Good	m
FEDGR	Federal Government Revenue	1
FEDGEXP	Federal Government Expenditure	1
$FEDGDM_i$	Federal Government Demand for Imported Good	m
$FEDGDR_i$	Federal Government Demand for Imported Good	m
SAV	Total Saving	1

TABLE XXIV (continued)

Variable	Description	Number of Variables
$INVDM_i$	Investment Demand for Imported Good	m
$INVDR_i$	Investment Demand for Regional Good	m
INV	Total Investment	1
LMIG	Labor Migration	1
M_i	Import	m
SLGBOR	Transfer and Borrowing of State and Local Government	1
FEDGBOR	Transfer and Borrowing of Federal Government	1
ROWSAV	Saving from Rest-of-World	1
P_i	Composite Price	n
PR_i	Regional Price	m
PN_i	Net Price	m
PL	Wage Rate or Labor Price	1
PK_i	Rental Price of Capital	m
PT_i	Rental Price of Land	m
CV_h	Compensating Variation	s
EV_h	Equivalent Variation	s
TCV	Total Compensating Variation	1
TEV	Total Equivalent Variation	1

Total : $4n + 18m + 3(n \times m) + 3(m+nr) + 3s(m+nr) + 8s + 20$

TABLE XXV

SUMMARY OF EXOGENOUS VARIABLES OF THE MODEL

Variable	Description
$PM0_i$	Import Price
$PE0_i$	Export Price
$E0_i$	Initial Amount of Export
$LHH0_h$	Labor Employed by Households
LSLG0	Labor Employed by State and Local Government
LFEDG0	Labor Employed by Federal Government
$TRSLG0_h$	State and Local Government Transfer to Households
$TRFEDG0_h$	Federal Government Transfer to Households
$REMIT0_h$	Remittance from outside the Region to Households
$SLGD0_i$	Commodity Demand by State and Local Government
$FEDGD0_i$	Commodity Demand by Federal Government
$INVD0_i$	Investment Demand
LSTK0	Initial Stock of Labor
$PL0^{ROC}$	Wage Rate of Rest-of-Country
$CAP0_i$	Supply of Capital
$LAND0_i$	Supply of Land

TABLE XXVI

SUMMARY OF PARAMETERS OF THE MODEL

Parameter	Description
a_{0i}	Value Added Requirement per Unit of Output
a_{ji}	Intermediate Good Requirement per Unit of Output
ϕ	Constant Efficiency Parameter
δ	Share Parameter
σ	Elasticity of Substitution or Transformation
ϵ	Price Elasticity of Nonmarket Good Export Demand
ktr	Capital Tax Rate
sstr	Social Security Tax Rate
ttr	Land Tax Rate
depr	Rate of Depreciation
l_h	Labor Income Distribution Coefficient to Household
t_h	Land Income Distribution Coefficient to Household
e_h	Enterprise Profit Distribution Coefficient to Household
$hhtr_h$	Household Income Tax Rate
s_h	Household Saving Rate
γ_{ih}	Minimum Requirement of Commodity Consumption
β_{0h}	Marginal Budget Share for Leisure
β_{ih}	Marginal Budget Share for Commodity
$ibtr_i$	Indirect Business Tax Rate
sl	State and Local Government Proportions for Taxes
fed	Federal Government Proportions for Taxes
η	Labor Migration Elasticity of Respoonse

APPENDIX B

LINEAR EXPENDITURE SYSTEM

If a set of demand equations are assumed to be linear in all prices and income, and expressed in the expenditure form, then the set of demand functions can be written as

$$p_i q_i = c_i + \sum_{j=1}^{n} a_{ij} p_j + \beta_i y \qquad (i = 1, \ldots, n) \qquad \textbf{(A.1)}$$

where p_i and q_i are the price of and quantity demanded for the ith commodity, respectively, $p_i q_i$ is the expenditure on the ith commodity, c_i is the ith intercept, the a_{ij} are price parameters, β_i is the marginal budget share for the ith commodity, and y represents the consumer's income. A system of functions such as (A.1) for the n commodities is called a linear expenditure system (LES). Homogeneity of degree zero in prices and total expenditure can be preserved in any LES by setting all intercept terms to zero.

One of the commonly employed versions of the linear expenditure system is Stone's LES. Stone's LES imposes the general theoretical restrictions of classical demand theory to a general linear formulation of demand. Stone's LES is obtained from the constrained maximization of the Klein-Rubin utility function which is also called the Stone-Geary utility function. This utility function is of the form

$$U = \Sigma_i \beta_i \ln(Q_i - \gamma_i) \qquad \Sigma_i \beta_i = 1 \tag{A.2}$$

Maximization of equation (A.2) subject to the budget constraint yields the following demand equations:

$$Q_i = \gamma_i + \left(\frac{\beta_i}{P_i}\right)(Y - \Sigma_j P_j \gamma_j) \tag{A.3}$$

Thus the expenditure functions which constitute Stone's LES are

$$P_i Q_i = P_i \gamma_i + \beta_i (Y - \Sigma_j P_j \gamma_j) \qquad \Sigma_i \beta_i = 1 \tag{A.4}$$

The intuitive interpretation can be given to this expenditure functions. That is, the γ_i (if positive) are those quantities which the consumer perceives to be minimum requirements or subsistence minima. Given this interpretation, the expenditure on the ith commodity consists of the expenditure on the minimum required quantity of the ith commodity plus the proportion of the budget which is left over after the expenditure on all minimum requirement is accounted for. This proportion, β_i, are the marginal budget shares that determine the allocation of supernumerary income (i.e., expenditure above that required for purchasing the subsistence minima).

APPENDIX C

ESTIMATION OF ANGLER EXPENDITURES FOR MOUNTAIN FORK RIVER TROUT FISHERY TRIPS

In this appendix, angler expenditures spent in Mountain Fork River trout fishery are estimated by model sector and by origin of trip using the information provided in Choi (1993).

Aggregate angler expenditures estimated by Choi were $792,000 in 1990. Out of those expenditures, $655,000 (84.4%) were spent in the McCurtain County. However, the expenditures are not classified by origin of trip, that is, anglers from within the region and from outside the region. Aggregate angler expenditures by origin of trip were estimated using the indirect information from Choi. Table 5.6 in Choi presents the number of trips to the Mountain Fork River trout fishery by origin of trip which shows that 44.7% (3,791 trips) out of total trips (8,475 trips) were originated from McCurtain County and the remaining 55.3% (4,684 trips) were from out of the region. On the other hand, Table 4.9 in Choi provides percentage of the six different per trip expenditure levels. Since expenditures of the McCurtain County anglers are expected to be lower than those of outside anglers, it is assumed that the expenditure levels from the bottom up to 44.7% belong to the McCurtain County anglers. By interpolation, as shown in Table XXVII, new seven different expenditure levels were created to divide lower 44.7% of McCurtain County anglers and upper 55.3% of outside anglers. Average per trip expenditure by origin of trip were calculated by summing up weighted midrange value of each expenditure level. The average per trip expenditure was $11.25 for McCurtain County anglers while it was $130.73 for outside anglers. Each average per trip expenditure was multiplied by the numbers of trip by each origination group to result in aggregate expenditure. Those values are $42,650 for McCurtain County anglers and $612,350 for other location anglers.

The next step is to classify the aggregate expenditure by sector. This procedure is shown in Table XXVIII. Table 4.10 in Choi provides the proportions of angler expenditures by six categories, but without separate estimates for different origins of anglers. First of all, total aggregate expenditure ($655,000) was distributed into six categories according to the presented percentage. It is assumed that expenditure for lodging was occurred only by outside anglers. In other words, no anglers from McCurtain County spent their money for lodging. Assuming that for other categories, proportions of McCurtain County angler expenditures are equal to those in case of aggregate expenditures, the same proportion as aggregate expenditure (42650/655000=6.51%) was applied to aggregate expenditure for each category to get McCurtain County angler expenditure for each category. Those values were adjusted so that each category expenditure sums up to

TABLE XXVII

ESTIMATION OF AGGREGATE ANGLER EXPENDITURES BY ORIGIN OF TRIP

Origin of Trip	Expenditure per Trip ($)	(A) Midrange Expenditure ($)	Percent (%)	(B) Percent within Group (%)
Anglers from	0.01- 10.00	5.00	26.0	58.2
McCurtain	10.01- 20.00	15.00	10.7	23.9
County	20.01- 33.09	26.55	8.0	17.9
	Subtotal		44.7	100.0
Anglers from	33.10- 50.00	41.55	10.4	18.8
Other	50.01-100.00	75.00	15.0	27.1
Locations	100.01-200.00	150.00	19.3	34.9
	>200.00	262.02[a]	10.6	19.2
	Subtotal		55.3	100.0
	Total		100.0	

Origin of Trip	Expenditure per Trip ($)	A x B / 100 ($)	Number of Trips (No.)	Aggregate Expenditure ($)
Anglers from	0.01- 10.00	2.91		
McCurtain	10.01- 20.00	3.59		
County	20.01- 33.09	4.75		
	Subtotal	11.25	3,791	42,650
Anglers from	33.10- 50.00	7.81		
Other	50.01-100.00	20.34		
Locations	100.01-200.00	52.35		
	>200.00	50.22		
	Subtotal	130.73	4,684	612,350
	Total		8,475	655,000

a This midrange value was calculated so that aggregate angler expenditures from two different origins sum up to $655,000.

TABLE XXVIII

DISTRIBUTION OF ANGLER EXPENDITURES BY CATEGORY AND BY ORIGIN OF TRIP

Category	Percent (%)	Aggregate Expenditure ($)	McCurtain County		Other Locations ($)
			Before Adjusted ($)	After Adjusted ($)	
Lodging	26.7	174,885			174,885
Food & Beverage	27.9	182,745	11,900	16,234	166,511
Transportation	28.5	186,675	12,156	16,583	170,092
Purchased Items	16.2	106,110	6,909	9,426	96,684
Purchased Services	0.7	4,585	299	407	4,178
Others	0.0	0	0	0	0
Total	100.0	655,000	31,263	42,650	612,350

aggregate expenditure calculated in Table XXVII ($42,650). Outside angler expenditure for each category was obtained by subtracting those adjusted values from aggregate expenditure for each category.

Angler expenditures by category in terms of Choi's survey criteria should be transformed into aggregated sectors used in the model of this study. Categories of lodging, transportation, and purchased services are transformed into services sector in the model while categories of food and beverage, and purchased items are transformed into manufacturing sector in the model. It is noticed, however, that some proportion out of expenditures for food and beverage, and purchased items goes to other sectors than manufacturing since purchasers' prices paid by consumers include producers' prices plus intermediate margins such as transportation and trade margins. Scheppach (1972) provides the projections of 1970 and 1980 transportation and trade margins in the U.S. by industry. The 1980 margins of that study were employed for this analysis. The second column of Table XXIX represents the proportions out of purchasers' prices that go to producers, that is to say, purchasers' prices net of transportation and trade margins. Values of food and kindred products, and miscellaneous manufacturing industries in Scheppach's were applied to food and beverage, and purchased items categories in Choi's, respectively. Therefore, only 63.5% and 58.2% out of angler expenditures for food and beverage, and purchased items, respectively go to

TABLE XXIX

TRANSFORMATION OF EXPENDITURE CATEGORIES
INTO MODEL SECTORS

Category	Proportion of Produces' Prices (%)	Distribution of Expenditure by Model Sector (%)				
		AG	MIN	MANUF	SER	TOTAL
Lodging	100.0	0.0	0.0	0.0	100.0	100.0
Food & Beverage	63.5	0.0	0.0	63.5	36.5	100.0
Transportation	100.0	0.0	0.0	0.0	100.0	100.0
Purchased Items	58.2	0.0	0.0	58.2	41.8	100.0
Purchased Services	100.0	0.0	0.0	0.0	100.0	100.0

manufacturing sector and the remaining portions go to services sector. Those distribution coefficients are applied to expenditure for each category to obtain angler expenditures by model sector and by origin of trip. Table XXX is presented to show the expenditure distribution. McCurtain County anglers spent $15,795 and $26,855 for manufacturing and services sectors, respectively, whereas outside anglers spent $162,006 and $450,344 for corresponding sectors.

Finally, information is necessary for McCurtain County angler expenditures by household income class. Table 4.25 in Choi presents distribution of sampled anglers by household income level, which is differently classified from the IMPLAN database of 1990. By interpolation, this distribution was adjusted to accord with the IMPLAN household income classification (Table XXXI). Then, assuming that the amount and pattern of angler expenditures for MFR trout fishery are same among different household groups, the distribution coefficients were applied to McCurtain County angler expenditures of Table XXX to result in sectoral expenditures of three different household income groups (Table XXXII). It is also assumed that distribution of McCurtain County anglers by household income level is the same as that of outside anglers.

TABLE XXX

DISTRIBUTION OF ANGLER EXPENDITURES BY MODEL SECTOR AND BY ORIGIN OF TRIP

Origin of Trip	Category	Distribution of Expenditure by Model Sector (%)				
		AG	MIN	MANUF	SER	TOTAL
McCurtain County						
	Lodging	0	0	0	0	0
	Food & Beverage	0	0	10,309	5,925	16,234
	Transportation	0	0	0	16,583	16,583
	Purchased Items	0	0	5,486	3,940	9,426
	Purchased Services	0	0	0	407	407
	Other	0	0	0	0	0
	Total	0	0	5,795	26,855	42,650
Other Locations						
	Lodging	0	0	0	174,885	174,885
	Food & Beverage	0	0	105,734	60,777	166,511
	Transportation	0	0	0	170,092	170,092
	Purchased Items	0	0	56,271	40,413	96,674
	Purchased Services	0	0	0	4,178	4,178
	Other	0	0	0	0	0
	Total	0	0	162,006	450,344	612,350

TABLE XXXI

DISTRIBUTION OF ANGLERS BY HOUSEHOLD INCOME LEVEL

From Choi's		Adjusted	
Income Level	Percent	Income Level	Percent
Under $15,000	12.5		
		Under $20,000	23.35
$15,000 - $24,999	21.7		
$25,000 - $34,999	18.5		
		$20,000 - $39,999	38.15
$35,000 - $44,999	17.6		
		$Over $40,000	38.60
$45,000 - $54,999	13.4		
Over $55,000	16.4		

TABLE XXXII

DISTRIBUTION OF MCCURTAIN COUNTY ANGLER EXPENDITURES BY HOUSEHOLD INCOME LEVEL

Sector	Household Income Group			
	Low	Medium	High	Total
Agriculture	0	0	0	0
Mining	0	0	0	0
Manufacturing	3,672	6,026	6,097	15,795
Services	6,244	10,245	10,366	26,855
Total	9,916	16,271	16,463	42,650

APPENDIX D

GAMS RPOGRAM LISTING FOR MODEL SOLUTION

This Appendix provides a listing of the GAMS program to solve the model applied to McCurtain County, Oklahoma (Chpater VI).

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***  CGE MODEL WITH 1990 DATA BASE, THOUSANDS OF DOLLARS ***
************  (MCCURTAIN COUNTY, OKLAHOMA)  ****************

$OFFSYMLIST OFFSYMXREF OFFUPPER

***************   SET DECLARATION   ******************

SETS

I  SECTORS
   /AG, MIN, MANUF, SER, TFR, TFE/

MK(I) MARKET GOODS
   /AG, MIN, MANUF, SER/

NM(I) N-MARKET GOODS
   /TFR, TFE/

CI(I) REGIONALLY CONSUMED GOODS
   /AG, MIN, MANUF, SER, TFR/

NMR(I) REGIONAL TF TRIPS
   /TFR/

NME(I) EXPORTED TF TRIPS
   /TFE/

F  FACTORS
   /LAB, CAP, LAND/

G  GOVERNMENTS
   /SLG, FEDG/

H   HOUSEHOLD GROUPS
   /LOW, MED, HIGH/;

ALIAS(I,J);
ALIAS(MK,ML);
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ALIAS(CJ,CI);

***************   PARAMETER DECLARATION      *********

PARAMETERS

* PARAMETERS FOR BASE YEAR

VA0(I)       VALUE ADDED
V0(J,I)      DEMAND FOR COMPOSITE INTERMEDIATE GOOD
TV0(I)       TOTAL DEMAND FOR COMPOSITE INTERMEDIATE GOOD
X0(I)        SECTORAL OUTPUT
T0(I)        LAND DEMAND
PT0(I)       RENTAL PRICE OF LAND
VM0(J,I)     DEMAND FOR IMPORTED INTERMEDIATE GOOD
VR0(J,I)     DEMAND FOR REGIONAL INTERMEDIATE GOOD
PM0(I)       IMPORT PRICE
PR0(I)       REGIONAL PRICE
TVM0(I)      TOTAL DEMAND FOR IMPORTED INTERMEDIATE GOOD
TVR0(I)      TOTAL DEMAND FOR REGIONAL INTERMEDIATE GOOD
L0(I)        LABOR DEMAND
K0(I)        CAPITAL DAMAND
PL0          WAGE RATE
PLROC0       WAGE RATE OF REST-OF-COUNTRY
PK0(I)       RENTAL PRICE OF CAPITAL
E0(I)        EXPORT OF REGIONAL PRODUCT
R0(I)        REGIONAL SUPPLY OF REGIONAL PRODUCT
PE0(I)       EXPORT PRICE
YL0          LABOR INCOME
LLHH0        LABOR EMPLOYED BY LOW INCOME HOUSEHOLD GROUP
LSLG0        LABOR EMPLOYED BY STATE AND LOCAL GOVERNMENT
LFEDG0       LABOR EMPLOYED BY FEDERAL GOVERNMENT
YK0          CAPITAL INCOME
YAGK0        AGRICULTURAL CAPITAL INCOME
YT0          LAND INCOME
YENT0        ENTERPRISE INCOME
TRSLG0(H)    STATE AND LOCAL GOVERNMENT TRANSFER TO HOUSEHOLD
TRFEDG0(H)   FEDERAL GOVERNMENT TRANSFER TO HOUSEHOLD
REMIT0(H)    REMITTANCE FROM OUTSIDE THE REGION TO HOUSEHOLD
YH0(H)       HOUSEHOLD INCOME
DYH0(H)      DISPOSABLE HOUSEHOLD INCOME
HSAV0(H)     HOUSEHOLD SAVING
HEXP0(H)     HOUSEHOLD EXPENDITURE
LS0(H)       LABOR SUPPLY BY HOUSEHOLD
TLS0         TOTAL LABOR SUPPLY
P0(I)        COMPOSITE PRICE
QM0(I,H)     DEMAND FOR IMPORTED CONSUMPTION GOOD
QR0(I,H)     DEMAND FOR REGIONAL CONSUMPTION GOOD
Q0(I,H)      DEMAND FOR COMPOSITE CONSUMPTION GOOD
TQM0(I)      TOTAL DEMAND FOR IMPORTED CONSUMPTION GOOD
TQR0(I)      TOTAL DEMAND FOR REGIONAL CONSUMPTION GOOD
TQ0(I)       TOTAL DEMAND FOR COMPOSITE CONSUMPTION GOOD
SLGR0        STATE AND LOCAL GOVERNMENT REVENUE
SLGEXP0      STATE AND LOCAL GOVERNMENT EXPENDITURE
SLGDM0(I)    STATE AND LOCAL GOV'T DEMAND FOR IMOPRTED GOOD
SLGDR0(I)    STATE AND LOCAL GOV'T DEMAND FRO REGIONAL GOOD
SLGD0(I)     STATE AND LOCAL GOV'T DEMAND FOR COMPOSITE GOOD
FEDGR0       FEDERAL GOVERNMENT REVENUE
FEDGEXP0     FEDERAL GOVERNMENT EXPENDITURE
FEDGDM0(I)   FEDERAL GOVERNMENT DEMAND FOR IMPORTED GOOD
FEDGDR0(I)   FEDERAL GOVERNMENT DEMAND FOR REGIONAL GOOD
FEDGD0(I)    FEDERAL GOVERNMENT DEMAND FOR COMPOSITE GOOD
SAV0         TOTAL SAVING
ROWSAV0      SAVING FROM REST-OF-WORLD
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INVDMO(I)    INVEST DEMAND FOR IMPORTED GOOD
INVDRO(I)    INVEST DEMAND FOR REGIONAL GOOD
INVDO(I)     INVEST DEMAND FOR COMPOSITE GOOD
INVO         TOTAL INVEST
KSO          SUPPLY OF CAPITAL
TSO          SUPPLY OF LAND
FTRYLABO     LABOR INCOME DISTRIBUTED TO HOUSEHOLDS
FTRYCAPO     CAPITAL INCOME DISTRIBUTED TO HOUSEHOLDS
FTRYLANDO    LAND INCOME DISTRIBUTED TO HOUSEHOLDS
ENTYO        ENTERPRISE INCOME DISTRIBUTED TO HOUSEHOLDS
SLGBORO      TRANSFER AND BORROWING OF STATE AND LOCAL GOV'T
FEDGBORO     TRANSFER AND BORROWING OF FEDERAL GOVERNMENT
MO           IMPORT
GSPO         GROSS STATE PRODUCT

* PARAMETERS TO BE CALIBRATED

a0(I)
a(J,I)
alpha(I,F)
Ava(I)
RHOv(I)
DELTAv1(J,I)
DELTAv(J,I)
Av(J,I)
RHOj(I)
DELTAj1(I)
DELTAj(I)
Aj(I)
RHOx(I)
DELTAx1(I)
DELTAx(I)
Ax(I)
ktr
sstr
ttr
depr
l(H)
t(H)
e(H)
hhtr(H)
s(H)
RHOq(I)
DELTAq1(I,H)
DELTAq(I,H)
Aq(I,H)
slIBT
slSST
slKTT
slHHT
ibtr(I)
fedIBT
fedSST
fedKTT
fedHHT
RHOsl(I)
DELTAsl1(I)
DELTAsl(I)
Asl(I)
RHOfed(I)
DELTAfed1(I)
DELTAfed(I)
Afed(I)
RHOinv(I)
DELTAinv1(I)
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DELTAinv(I)
Ainv(I)
beta0(H)
beta(I,H)
gamma(I,H)
MAXHOURS0(H)
;


*********   DATA ASSIGNMENT   ***************

TABLE IOR(I,J)    INPUT-OUTPUT REGIONAL MATRIX
             AG      MIN       MANUF        SER      TFR       TFE
AG      810.570    0.020   37943.670    270.800
MIN       4.290    1.010      29.890     13.540
MANUF   243.460    0.580   31026.639   1911.150   15.795   162.006
SER    6380.760   70.300   36106.620  33185.071   26.855   450.344
;

TABLE IOM(I,J)    INPUT-OUTPUT IMPORT MATRIX
                  AG         MIN       MANUF         SER
AG         12711.536       0.116   85089.138     649.587
MIN           14.345       5.861      67.029      32.479
MANUF        814.072       3.366   69577.612    4584.413
SER        21335.727     407.977   80969.531   79603.411
;

TABLE VAD(I,F)    VALUE ADDED MATRIX
                 LAB         CAP        LAND
AG          4815.930    3727.500    6366.570
MIN          664.600     317.100
MANUF      96346.400   23826.500
SER       116736.200   46777.900
;

SCALAR LLHH0    LABOR USED BY LOW HH      /689.000/;
SCALAR LSLG0    LABOR USED BY SLGOVT      /37348.200/;
SCALAR LFEDG0    LABOR USED BY FEDGOVT     /5546.800/;

TABLE HHCONR(I,H)  HOUSEHOLD CONSUMPTION DEMAND FOR REGIONAL
                   GOODS
                 LOW         MED        HIGH
AG           327.000     219.100      61.800
MIN            0.500       0.200       0.100
MANUF       2017.628    2278.274     736.703
SER        44813.256   42868.655   13189.834
TFR            9.916      16.271      16.463
;

TABLE HHCONM(I,H)  HOUSEHOLD CONSUMPTION DEMAND FOR IMPORTED
                   GOODS
                 LOW         MED        HIGH
AG           332.100     248.900      71.100
MIN           16.800       6.000       1.900
MANUF      32970.700   29917.900    8257.900
SER        71545.800   57778.200   17176.300
;

TABLE GOVTCONR(I,G)  GOVERNMENT CONSUMPTION DEMAND FOR
                     REGIONAL GOODS
                 SLG        FEDG
AG            35.000
MIN            1.000
MANUF        183.100
SER         7944.600    4341.100
```

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;

TABLE GOVTCONM(I,G)   GOVERNMENT CONSUMPTION DEMAND FOR
                      IMPORTED GOODS
                SLG        FEDG
AG            44.100
MIN           23.200
MANUF       5549.600
SER         5023.100
;

TABLE FTRYDIST(H,F)   FACTOR INCOME DISTRIBUTION TO
                      HOUSEHOLDS
                LAB          CAP         LAND
LOW       44268.786       56.954      169.569
MED       93191.470      807.956     2405.532
HIGH      89559.159      931.745     2774.091
;

TABLE PARAMA(*,I)    BASE YEAR VALUES FOR INDUSTRY
              AG        MIN       MANUF           SER    TFR     TFE
XO      61693.26   1544.73 463452.329    300871.651  42.65  612.35
INVDRO     41.20      0.20   2882.100     55208.600
INVDMO     67.00      9.30   1477.100       641.600
MO      99213.57    176.91 153152.663    334481.646
EO      18993.10   1494.00 421994.894     56285.656         612.35
RO      42700.16     50.73  41457.435    244585.995  42.65
IBTO     1477.50     73.80   2469.300     17107.100
IBTSLGO 1105.61      55.22   1847.777     12801.243
IBTFEDGO 371.88      18.57    621.523      4305.857
PTO          1        1          1             1       1       1
PKO          1        1          1             1       1       1
PRO          1        1          1             1       1       1
PO           1        1          1             1       1       1
PMO          1        1          1             1       1       1
PEO          1        1          1             1       1       1
SIGMAv       1.42     0.5        3.55          2
SIGMAx       3.9      2.9        2.9           0.7
SIGMAq       1.42     0.5        3.55          2
SIGMAsl      1.42     0.5        3.55          2
SIGMAfed     1.42     0.5        3.55          2
SIGMAinv     1.42     0.5        3.55          2
;

TABLE ELASTY(I,H)    INCOME ELASTICITY OF FINAL CONSUMPTION
                LOW       MED       HIGH
AG             0.30      0.30      0.30
MIN            0.89      0.89      0.89
MANUF          1.06      1.06      1.06
SER            0.9854    0.9854    0.9854
TFR            0.082     0.082     0.082
;

TABLE PARAMB(F,*)    BASE YEAR VALUES FOR FACTORS
    WAGEO WAGEROCO  FTAXO FTAXSLO FTAXFEDO DEPRAGO  DEPRENTO
LAB     1       1  35127.71 5662.58 29465.12
CAP                 9928.31 3364.70  6563.61 1435.08 27304.778
LAND                1017.37  344.78   672.58
;

TABLE PARAMC(H,*)    BASE YEAR VALUES FOR HOUSEHOLD GROUPS
        HTAXO   HTAXSLO  HTAXFEDO     HSAVO    TRSLGO    TRFEDGO
LOW    5617.03  1013.87   4603.16  -6527.90   4215.16   54247.59
MED   14236.52  2569.69  11666.83   5510.91   2571.60   33095.63
HIGH  10020.36  1808.67   8211.68   7401.40    227.97    2934.01
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+           REMITO ENTYDISTO ELASTLY    FRISCH
LOW      39692.401  9161.356   -0.12     -1.8
MED       2668.933 18339.803   -0.18     -1.6
HIGH    -46176.127  6683.004   -0.24     -1.4
;

TABLE PARAMD(G,*)    BASE YEAR VALUES FOR GOVERNMENTS
             BORO    GOVTDMO   GOVTDRO
SLG      32592.468 10640.000 8163.700
FEDG     33664.297     0     4341.100
;

SCALAR YENTO   ENTERPRISE INCOME    /61488.941/;
SCALAR ROWSAVO   SAVING FROM ROW    /25202.828/;
SCALAR INVDMSUMO   INVEST DEMAND FOR IMPORTED GOODS
                   /2195.000/;
SCALAR eta   LABOR MIGRATION ELASTICITY OF RESPONSE
     /0.92/;

***************   ASSIGN PARAMETERS    ***************

VAO(I)=SUM(F,VAD(I,F));
VO(J,I)=IOR(J,I)+IOM(J,I);
TVO(I)=SUM(J,VO(I,J));
XO(I)=PARAMA("XO",I);
TO(I)=VAD(I,"LAND");
PTO(I)=PARAMA("PTO",I);
VMO(J,I)=IOM(J,I);
VRO(J,I)=IOR(J,I);
PMO(I)=PARAMA("PMO",I);
PRO(I)=PARAMA("PRO",I);
TVMO(I)=SUM(J,VMO(I,J));
TVRO(I)=SUM(J,VRO(I,J));
LO(I)=VAD(I,"LAB");
KO(I)=VAD(I,"CAP");
PLO=PARAMB("LAB","WAGEO");
PLROCO=PARAMB("LAB","WAGEROCO");
PKO(I)=PARAMA("PKO",I);
EO(I)=PARAMA("EO",I);
RO(I)=PARAMA("RO",I);
PEO(I)=PARAMA("PEO",I);
YLO=SUM(I,VAD(I,"LAB"))+LLHHO+LSLGO+LFEDGO;
LLHHO=LLHHO;
LSLGO=LSLGO;
LFEDGO=LFEDGO;
YKO=SUM(I,VAD(I,"CAP"));
YAGKO=VAD("AG","CAP");
YTO=SUM(I,VAD(I,"LAND"));
YENTO=YENTO;
TRSLGO(H)=PARAMC(H,"TRSLGO");
TRFEDGO(H)=PARAMC(H,"TRFEDGO");
REMITO(H)=PARAMC(H,"REMITO");
YHO(H)=SUM(F,FTRYDIST(H,F))+PARAMC(H,"ENTYDISTO")+TRSLGO(H)
         +TRFEDGO(H)+REMITO(H);
DYHO(H)=YHO(H)-PARAMC(H,"HTAXO");
HSAVO(H)=PARAMC(H,"HSAVO");
HEXPO("LOW")=DYHO("LOW")-HSAVO("LOW")-LLHHO;
HEXPO("MED")=DYHO("MED")-HSAVO("MED");
HEXPO("HIGH")=DYHO("HIGH")-HSAVO("HIGH");
FTRYLABO=SUM(H,FTRYDIST(H,"LAB"));
LSO(H)=(SUM(I,VAD(I,"LAB"))+LLHHO+LSLGO+LFEDGO)
          *FTRYDIST(H,"LAB")/FTRYLABO;
TLSO=SUM(H,LSO(H));
PO(I)=PARAMA("PO",I);
QMO(I,H)=HHCONM(I,H);
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QR0(I,H)=HHCONR(I,H);
Q0(I,H)=QM0(I,H)+QR0(I,H);
TQM0(I)=SUM(H,QM0(I,H));
TQR0(I)=SUM(H,QR0(I,H));
TQ0(I)=SUM(H,Q0(I,H));
SLGR0=SUM(I,PARAMA("IBTSLG0",I))+SUM(F,PARAMB(F,"FTAXSL0"))
+SUM(H,PARAMC(H,"HTAXSL0"))+PARAMD("SLG","BOR0");
SLGEXP0=PARAMD("SLG","GOVTDR0")+PARAMD("SLG","GOVTDM0")
        +SUM(H,PARAMC(H,"TRSLG0"))+LSLG0;
SLGDM0(I)=GOVTCONM(I,"SLG");
SLGDR0(I)=GOVTCONR(I,"SLG");
SLGD0(I)=SLGDM0(I)+SLGDR0(I);
FEDGR0=SUM(I,PARAMA("IBTFEDG0",I))+SUM(F,PARAMB(F,"FTAXFED0"
))+SUM(H,PARAMC(H,"HTAXFED0"))+PARAMD("FEDG","BOR0");
FEDGEXP0=PARAMD("FEDG","GOVTDR0")+PARAMD("FEDG","GOVTDM0")
        +SUM(H,PARAMC(H,"TRFEDG0"))+LFEDG0;
FEDGDM0(I)=GOVTCONM(I,"FEDG");
FEDGDR0(I)=GOVTCONR(I,"FEDG");
FEDGD0(I)=FEDGDM0(I)+FEDGDR0(I);
SAV0=PARAMB("CAP","DEPRAG0")+PARAMB("CAP","DEPRENT0")
        +SUM(H,PARAMC(H,"HSAV0"))+ROWSAV0;
ROWSAV0=ROWSAV0;
INVDM0(I)=PARAMA("INVDM0",I);
INVDR0(I)=PARAMA("INVDR0",I);
INVD0(I)=INVDM0(I)+INVDR0(I);
INV0=SUM(I,INVD0(I));
KS0(I)=VAD(I,"CAP");
TS0(I)=VAD(I,"LAND");
FTRYLAB0=SUM(H,FTRYDIST(H,"LAB"));
FTRYCAP0=SUM(H,FTRYDIST(H,"CAP"));
FTRYLAND0=SUM(H,FTRYDIST(H,"LAND"));
ENTY0=SUM(H,PARAMC(H,"ENTYDIST0"));
SLGBOR0=PARAMD("SLG","BOR0");
FEDGBOR0=PARAMD("FEDG","BOR0");
M0(I)=PARAMA("M0",I);
GSP0=YL0+YK0+YT0+SUM(I,PARAMA("IBT0",I));

DISPLAY VA0,V0,TV0,X0,T0,PT0,VM0,VR0,PM0,PR0,TVM0,TVR0,L0,
        K0,PL0,PLROC0,PK0,E0,R0,PE0,YL0,LLHH0,LSLG0,LFEDG0,
        YK0,YAGK0,YT0,YENT0,TRSLG0,TRFEDG0,REMIT0,YH0,DYH0,
        HSAV0,HEXP0,LS0,TLS0,P0,QM0,QR0,Q0,TQM0,TQR0,TQ0,
        SLGR0,SLGEXP0,SLGDM0,SLGDR0,SLGD0,FEDGR0,FEDGEXP0,
        FEDGDM0,FEDGDR0,FEDGD0,SAV0,ROWSAV0,INVDM0,INVDR0,
        INVD0,INV0,KS0,TS0,FTRYLAB0,FTRYCAP0,FTRYLAND0,
        ENTY0,SLGBOR0,FEDGBOR0,M0,GSP0;


***************   CALIBRATION   **********************

a0(I)=VA0(I)/X0(I);
a(J,I)=V0(J,I)/X0(I);
alpha(MK,"CAP")=VAD(MK,"CAP")/VA0(MK);
alpha(MK,"LAND")=VAD(MK,"LAND")/VA0(MK);
alpha(MK,"LAB")=1-alpha(MK,"CAP")-alpha(MK,"LAND");
Ava(MK)=VA0(MK)/PROD(F,VAD(MK,F)**alpha(MK,F));
RHOv(MK)=1-1/PARAMA("SIGMAv",MK);
DELTAv1(ML,MK)=(VR0(ML,MK)/VM0(ML,MK))**(1-RHOv(ML))*(PR0(ML
          )/PM0(ML));
DELTAv(ML,MK)=1/(1+DELTAv1(ML,MK));
Av(ML,MK)=V0(ML,MK)/(DELTAv(ML,MK)*VM0(ML,MK)**RHOv(ML)+(1-D
ELTAv(ML,MK))*VR0(ML,MK)**RHOv(ML))**(1/RHOv(ML));
RHOx(MK)=1+1/PARAMA("SIGMAx",MK);
DELTAx1(MK)=(R0(MK)/E0(MK))**(1-RHOx(MK))*(PR0(MK)/PE0(MK));
DELTAx(MK)=1/(1+DELTAx1(MK));
Ax(MK)=X0(MK)/(DELTAx(MK)*E0(MK)**RHOx(MK)+(1-DELTAx(MK))
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      *RO(MK)**RHOx(MK))**(1/RHOx(MK));
ktr=PARAMB("CAP","FTAXO")/YKO;
sstr=PARAMB("LAB","FTAXO")/YLO;
ttr=PARAMB("LAND","FTAXO")/YTO;
depr=PARAMB("CAP","DEPRAGO")/VAD("AG","CAP");
l("LOW")=FTRYDIST("LOW","LAB")/FTRYLABO;
l("MED")=FTRYDIST("MED","LAB")/FTRYLABO;
l("HIGH")=1-l("LOW")-l("MED");
t("LOW")=(FTRYDIST("LOW","LAND")+FTRYDIST("LOW","CAP"))
         /(FTRYLANDO+FTRYCAPO);
t("MED")=(FTRYDIST("MED","LAND")+FTRYDIST("MED","CAP"))
         /(FTRYLANDO+FTRYCAPO);
t("HIGH")=1-t("LOW")-t("MED");
e("LOW")=PARAMC("LOW","ENTYDISTO")/ENTYO;
e("MED")=PARAMC("MED","ENTYDISTO")/ENTYO;
e("HIGH")=1-e("LOW")-e("MED");
hhtr(H)=PARAMC(H,"HTAXO")/YHO(H);
s(H)=PARAMC(H,"HSAVO")/YHO(H);
RHOq(MK)=1-1/PARAMA("SIGMAq",MK);
DELTAq1(MK,H)=(QRO(MK,H)/QMO(MK,H))**(1-RHOq(MK))*(PRO(MK)/
               PMO(MK));
DELTAq(MK,H)=1/(1+DELTAq1(MK,H));
Aq(MK,H)=QO(MK,H)/(DELTAq(MK,H)*QMO(MK,H)**RHOq(MK)+(1-
         DELTAq(MK,H))*QRO(MK,H)**RHOq(MK))**(1/RHOq(MK));
slIBT=PARAMA("IBTSLGO","AG")/PARAMA("IBTO","AG");
slSST=PARAMB("LAB","FTAXSLO")/PARAMB("LAB","FTAXO");
slKTT=PARAMB("CAP","FTAXSLO")/PARAMB("CAP","FTAXO");
slHHT=PARAMC("LOW","HTAXSLO")/PARAMC("LOW","HTAXO");
ibtr(I)=PARAMA("IBTO",I)/(PRO(I)*XO(I));
fedIBT=1-slIBT;
fedSST=1-slSST;
fedKTT=1-slKTT;
fedHHT=1-slHHT;
RHOsl(MK)=1-1/PARAMA("SIGMAsl",MK);
DELTAsl1(MK)=(SLGDRO(MK)/SLGDMO(MK))**(1-RHOsl(MK))*(PRO(MK)
             /PMO(MK));
DELTAsl(MK)=1/(1+DELTAsl1(MK));
Asl(MK)=SLGDO(MK)/(DELTAsl(MK)*SLGDMO(MK)**RHOsl(MK)+(1-
        DELTAsl(MK))*SLGDRO(MK)**RHOsl(MK))**(1/RHOsl(MK));
RHOinv(MK)=1-1/PARAMA("SIGMAinv",MK);
DELTAinv1(MK)=(INVDRO(MK)/INVDMO(MK))**(1-RHOinv(MK))*(PRO(
               MK)/PMO(MK));
DELTAinv(MK)=1/(1+DELTAinv1(MK));
Ainv(MK)=INVDO(MK)/(DELTAinv(MK)*INVDMO(MK)**RHOinv(MK)+(1-
         DELTAinv(MK))*INVDRO(MK)**RHOinv(MK))**
         (1/RHOinv(MK));
beta0(H)=PLO*LSO(H)*PARAMC(H,"ELASTLY")/(PLO*LSO(H)*PARAMC
         (H,"ELASTLY")-HEXPO(H));
beta(CI,H)=ELASTY(CI,H)*(1-beta0(H))*PO(CI)*QO(CI,H)/HEXPO
           (H);
gamma(CI,H)=QO(CI,H)+(beta(CI,H)/PO(CI))*(HEXPO(H)/PARAMC
            (H,"FRISCH"));
MAXHOURSO(H)=LSO(H)+(beta0(H)/PLO)*(HEXPO(H)-SUM(CI,PO(CI)*
           gamma(CI,H)))/(1-beta0(H));

DISPLAY  a0,a,alpha,Ava,RHOv,DELTAv1,DELTAv,Av,RHOx,
         DELTAx1,DELTAx,Ax,ktr,sstr,ttr,depr,l,t,e,hhtr,
         s,RHOq,DELTAq1,DELTAq,Aq,slIBT,slSST,slKTT,slHHT,
         ibtr,fedIBT,fedSST,fedKTT,fedHHT,RHOsl,DELTAsl1,
         DELTAsl,Asl,RHOinv,DELTAinv1,DELTAinv,Ainv,beta0,
         beta,gamma,MAXHOURSO;

***************   VARIABLE DECLARATION   *************

* ENDOGENOUS VARIABLES
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VARIABLES

Z	OBJECTIVE FUNCTION VALUE
VA(I)	VALUE ADDED
V(J,I)	DEMAND FOR COMPOSITE INTERMEDIATE GOOD
X(I)	SECTORAL OUTPUT
PN(I)	NET PRICE
LAND(I)	LAND DEMAND
PT(I)	RENTAL PRICE OF LAND
VM(J,I)	DEMAND FOR IMPORTED INTERMEDIATE GOOD
VR(J,I)	DEMAND FOR REGIONAL INTERMEDIATE GOOD
PR(I)	REGIONAL PRICE
TVM(I)	TOTAL DEMAND FOR IMPORTED INTERMEDIATE GOOD
TVR(I)	TOTAL DEMAND FOR REGIONAL INTERMEDIATE GOOD
TV(I)	TOTAL DEMAND FOR COMPOSITE INTERMEDIATE GOOD
LAB(I)	LABOR DEMAND
CAP(I)	CAPITAL DAMAND
PL	WAGE RATE
PK(I)	RENTAL PRICE OF CAPITAL
EXP(I)	EXPORT OF REGIONAL PRODUCT
R(I)	REGIONAL SUPPLY OF REGIONAL PRODUCT
YL	LABOR INCOME
AYL	ADJUSTED LABOR INCOME
YK	CAPITAL INCOME
YAGK	AGRICULTURAL CAPITAL INCOME
YT	LAND INCOME
YENT	ENTERPRISE INCOME
YH(H)	HOUSEHOLD INCOME
DYH(H)	DISPOSABLE HOUSEHOLD INCOME
HSAV(H)	HOUSEHOLD SAVING
HEXP(H)	HOUSEHOLD EXPENDITURE
AHEXP(H)	ADJUSTED HOUSEHOLD EXPENDITURE
LS(H)	LABOR SUPPLY BY HOUSEHOLD
ALS(H)	ADJUSTED LABOR SUPPLY BY HOUSEHOLD
P(I)	COMPOSITE PRICE
LMIG	LABOR MIGRATION
Q(I,H)	DEMAND FOR COMPOSITE CONSUMPTION GOOD
QM(I,H)	DEMAND FOR IMPORTED CONSUMPTION GOOD
QR(I,H)	DEMAND FOR REGIONAL CONSUMPTION GOOD
ADQ(I,H)	ADJUSTED DEMAND FOR COMPOSITE CONSUMPTION GOOD
AQM(I,H)	ADJUSTED DEMAND FOR IMPORTED CONSUMPTION GOOD
AQR(I,H)	ADJUSTED DEMAND FOR REGIONAL CONSUMPTION GOOD
TQM(I)	TOTAL DEMAND FOR IMPORTED CONSUMPTION GOOD
TQR(I)	TOTAL DEMAND FOR REGIONAL CONSUMPTION GOOD
TQ(I)	TOTAL DEMAND FOR COMPOSITE CONSUMPTION GOOD
SLGR	STATE AND LOCAL GOVERNMENT REVENUE
SLGBORO	TRANSFER AND BORROWING OF STATE AND LOCAL GOV'T
SLGEXP	STATE AND LOCAL GOVERNMENT EXPENDITURE
SLGDM(I)	STATE AND LOCAL GOV'T DEMAND FOR IMOPRTED GOOD
SLGDR(I)	STATE AND LOCAL GOV'T DEMAND FRO REGIONAL GOOD
FEDGR	FEDERAL GOVERNMENT REVENUE
FEDGBORO	TRANSFER AND BORROWING OF FEDERAL GOVERNMENT
FEDGEXP	FEDERAL GOVERNMENT EXPENDITURE
FEDGDM(I)	FEDERAL GOVERNMENT DEMAND FOR IMPORTED GOOD
FEDGDR(I)	FEDERAL GOVERNMENT DEMAND FOR REGIONAL GOOD
SAV	TOTAL SAVING
ROWSAV	SAVING FROM REST-OF-WORLD
INV	TOTAL INVEST
INVDM(I)	INVEST DEMAND FOR IMPORTED GOOD
INVDR(I)	INVEST DEMAND FOR REGIONAL GOOD
M	IMPORT
CV(H)	COMPENSATING VARIATION
EV(H)	EQUIVALENT VARIATION
TCV	TOTAL COMPENSATING VARIATION

```
TEV          TOTAL EQUIVALENT VARIATION
GSP          GROSS STATE PRODUCT
ADJ          ADJUSTMENT FACTOR
SLACK1(I)    SLACK VARIABLE 1
SLACK2(I)    SLACK VARIABLE 2



* VARIABLES AS INDEX WITH 1990=1.000

IVA(I)
IX(I)
ILAND(I)
IPT(I)
IVM(J,I)
IVR(J,I)
IPR(I)
ILAB(I)
ICAP(I)
IPL
IPK(I)
IEXP(I)
IR(I)
IYL
IYK
IYT
IYH(H)
IDYH(H)
IHSAV(H)
IHEXP(H)
ILS(H)
IP(I)
IQ(I,H)
IQM(I,H)
IQR(I,H)
IM(I)
IGSP

POSITIVE VARIABLE   SLACK1, SLACK2;


***************   EQUATION DECLARATION   *************

* MODEL EQUATIONS

EQUATIONS

EQZ                OBJECTIVE FUNCTION
VAdemand(MK)       DEMAND FOR VALUE ADDED USE
Vdemand(j,i)       DEMAND FOR INTERMEDIATE USE
VAprod(MK)         VALUE ADDED PRODUCTION FUNCTION
NETprice(MK)       NET PRICE
LABdemand(MK)      LABOR DEMAND
CAPdemand(MK)      CAPITAL DEMAND
LANDdemand(MK)     LAND DEMAND
Vces(ML,MK)        CES FUNCTION FOR INTERMEDIATE DEMAND
TVdemand(i)        TOTAL DEMAND FOR INTERMEDIATE DEMAND
TVRdemand(i)       TOTAL DEMAND FOR REGIONAL INTERMEDIATE DEMAND
TVMdemand(i)       TOTAL DEMAND FOR IMPORTED INTERMEDIATE DEMAND
VRdemand(ML,MK)    DEMAND FOR REGIONAL INTERMEDIATE GOOD
VRdemTF(j,NM)      DEMAND FOR REGIONAL INTERMEDIATE GOOD
VMdemTF(j,NM)      DEMAND FOR IMPORTED INTERMEDIATE GOOD
Xcet(MK)           CET FUNCTION FOR REGIONAL PRODUCT
Rsupply(MK)        REGIONAL SUPPLY OF REGIONAL PRODUCT
```

EXPortTFR(NMR)	EXPORT OF REGIONAL PRODUCT
RsupplyTFR(NMR)	REGIONAL SUPPLY OF REGIONAL PRODUCT
EXPortTFE(NME)	EXPORT OF REGIONAL PRODUCT
RsupplyTFE(NME)	REGIONAL SUPPLY OF REGIONAL PRODUCT
YLincome	LABOR INCOME
AYLincome	ADJUSTED LABOR INCOME
YKincome	CAPITAL INCOME
YAGKincome	AGRICULTURAL CAPITAL INCOME
YTincome	LAND INCOME
YENTincome	ENTERPRISE INCOME
YHincome(h)	HOUSEHOLD INCOME
DHYincome(h)	DISPOSABLE HOUSEHOLD INCOME
HSAVings(h)	HOUSEHOLD SAVING
HEXPendLOW	HOUSEHOLD EXPENDITURE
HEXPendMED	HOUSEHOLD EXPENDITURE
HEXPendHI	HOUSEHOLD EXPENDITURE
AHEXPendLO	ADJUSTED HOUSEHOLD EXPENDITURE
AHEXPendME	ADJUSTED HOUSEHOLD EXPENDITURE
AHEXPendHI	ADJUSTED HOUSEHOLD EXPENDITURE
LSupply(h)	LABOR SUPPLY
ALSupply(h)	ADJUSTED LABOR SUPPLY
LMIGration	LABOR MIGRATION
Qdemand(ci,h)	CONSUMPTION DEMAND FOR COMPOSITE GOOD
AQdemand(ci,h)	ADJUSTED Qdemand
QdemTFE(NME,H)	CONSUMPTION DEMAND FOR COMPOSITE GOOD
TQdemand(i)	TOTAL OF Qdemand
Qces(MK,h)	CES FUNCTION OF CONSUMPTION
QRdemand(MK,h)	CONSUMPTION DEMAND FOR REGIONAL GOOD
AQRdemand(ci,h)	ADJUSTED QRdemand
AQMdemand(ci,h)	ADJUSTED QMdemand
QRdemTFR(NMR,H)	CONSUMPTION DEMAND FOR REGIONAL GOOD
QMdemTFR(NMR,H)	CONSUMPTION DEMAND FOR IMPORTED GOOD
TQRdemand(i)	TOTAL OF QRdemand
TQMdemand(i)	TOTAL OF QMdemand
SLGRevenue	STATE AND LOCAL GOV'T REVENUE
SLGEXPend	STATE AND LOCAL GOV'T EXPENDITURE
SLGDemand(MK)	STATE AND LOCAL GOV'T COMPOSITE DEMAND
SLGDces(MK)	CES FOR STATE AND LOCAL GOV'T DEMAND
SLGDRdem(MK)	STATE AND LOCAL GOV'T REGIONA DEMAND
FEDGRev	FEDERAL GOV'T REVENUE
FEDGEXPend	FEDERAL GOV'T EXPENDITURE
FEDGDemand(MK)	FEDERAL GOV'T COMPOSITE DEMAND
FEDGDRdem(MK)	FEDERAL GOV'T REGIONAL DEMAND
FEDGDMdem(MK)	FEDERAL GOV'T IMPORT DEMAND
SAVings	TOTAL SAVING
INVest	TOTAL INVESTMENT
INVDemand(MK)	COMPOSITE INVEST DEMAND
INVDces(MK)	CES FOR INVEST DEMAND
INVDRdem(MK)	REGIONAL INVEST DEMAND
Mimports(MK)	IMPORT
Price(MK)	COMPOSITE PRICE
PriceTF(NM)	COMPOSITE PRICE
COMMequil(MK)	EQUILIBRIUM FOR COMMODITY MARKET
TFRequil(NMR)	EQUILIBRIUM FOR NONMARKET GOOD
TFEequil(NME)	EQUILIBRIUM FOR NONMARKET GOOD
Lequil	EQUILIBRIUM FOR LABOR MARKET
Kequil(MK)	EQUILIBRIUM FOR CAPITAL MARKET
Tequil(MK)	EQUILIBRIUM FOR LAND MARKET
SLGequil	EQUILIBRIUM FOR STATE AND LOCAL GOV'T
FEDGequil	EQUILIBRIUM FOR FEDERAL GOV'T
CAPequil	EQUILIBRIUM FOR CAPITAL ACCOUNT
CVwelfare(h)	COMPENSATING VARIATION
EVwelfare(h)	EQUIVALENT VARIATION
TCVwelfare	TOTAL COMPENSATING VARIATION
TEVwelfare	TOTAL EQUIVALENT VARIATION

```
GSProduct        GROSS STATE PRODUCT
ADJust           ADJUSTMENT FACTOR

* EQUATIONS FOR CALCULATION OF INDEX WITH 1990=1.000

EIVA(I)
EIX(I)
EILANDAG
EIPT(I)
EIVM(J,I)
EIPR(I)
EILAB(I)
EICAP(I)
EIPL
EIPK(I)
EIEXP(I)
EIR(I)
EIYL
EIYK
EIYT
EIYH(H)
EIDYH(H)
EIHSAV(H)
EIHEXP(H)
EILS(H)
EIP(I)
EIQ(I,H)
EIQM(I,H)
EIQR(I,H)
EIM(I)
EIGSP
;

***************   EQUATION ASSIGNMENT   **************

*  MODEL EQUATIONS

EQZ..               Z=E=SUM(MK,SLACK1(MK)+SLACK2(MK));
VAdemand(MK)..      VA(MK)+SLACK1(MK)-SLACK2(MK)=E=
                    a0(MK)*X(MK);
Vdemand(j,i)..      V(J,I)=E=a(J,I)*X(I);
VAprod(MK)..        VA(MK)=E=Ava(MK)*LAB(MK)**alpha(MK,"LAB")
                          *CAP(MK)**alpha(MK,"CAP")
                          *LAND(MK)**alpha(MK,"LAND");
NETprice(MK)..      PN(MK)=E=PR(MK)-SUM(ML,A(ML,MK)*P(ML))
                    -ibtr(MK)*PR(MK);
LABdemand(MK)..     LAB(MK)=E=alpha(MK,"LAB")*PN(MK)*X(MK)/PL;
CAPdemand(MK)..     CAP(MK)=E=alpha(MK,"CAP")*PN(MK)*X(MK)/
                    PK(MK);
LANDdemand(MK)..    LAND(MK)=E=alpha(MK,"LAND")*PN(MK)*X(MK)/
                    PT(MK);
Vces(ml,mk)..       V(ml,mk)=E=Av(ml,mk)*(DELTAv(ml,mk)*VM
                    (ml,mk)**RHOv(ml)+(1-DELTAv(ml,mk))*VR
                    (ml,mk)**RHOv(ml))**(1/RHOv(ml));
TVdemand(i)..       TV(I)=E=SUM(J,V(I,J));
VRdemand(ml,mk)..   VR(ml,mk)=E=VM(ml,mk)*((1-DELTAv(ml,mk))
                    /DELTAv(ml,mk)*PM0(ml)/PR(ml))**
                    (1/(1-RHOv(ml)));
VRdemTF(J,nm)..     VR(J,nm)=E=V(J,nm);
VMdemTF(J,nm)..     VM(J,nm)=E=0;
TVRdemand(i)..      TVR(I)=E=SUM(J,VR(I,J));
TVMdemand(i)..      TVM(I)=E=SUM(J,VM(I,J));
Xcet(mk)..          X(mk)=E=Ax(mk)*(DELTAx(mk)*EXP(mk
                    )**RHOx(mk)+(1-DELTAx(mk))*R(mk)**
                    RHOx(mk))**(1/RHOx(mk));
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Rsupply(mk)..        R(mk)=E=EXP(mk)*((1-DELTAx(mk))/DELTAx(mk)
                     *PE0(mk)/PR(mk))**(1/(1-RHOx(mk)));
EXPortTFR(NMR)..     EXP(NMR)=E=0;
RsupplyTFR(NMR)..    R(NMR)=E=X(NMR);
EXPortTFE(NME)..     EXP(NME)=E=E0(NME)*P(NME)**0.5775;
RsupplyTFE(NME)..    R(NME)=E=0;
YLincome..           YL=E=PL*SUM(MK,LAB(MK))+PL*
                     (LLHH0+LSLG0+LFEDG0);
AYLincome..          AYL=E=YL/ADJ;
YKincome..           YK=E=SUM(MK,PK(MK)*CAP(MK));
YAGKincome..         YAGK=E=PK("AG")*CAP("AG");
YTincome..           YT=E=SUM(MK,PT(MK)*LAND(MK));
YENTincome..         YENT=E=(YK-YAGK)*(1-ktr);
YHincome(h)..        YH(H)=E=l(H)*YL*(1-sstr)+t(H)*(YAGK*
                     (1-ktr-depr)+YT*(1-ttr))+e(H)*(YENT-depr*
                     (YK-YAGK))+TRSLG0(H)+TRFEDG0(H)+REMIT0(H);
DHYincome(h)..       DYH(H)=E=YH(H)*(1-hhtr(H));
HSAVings(h)..        HSAV(H)=E=s(H)*YH(H);
HEXPendLOW..         HEXP("LOW")=E=DYH("LOW")-HSAV("LOW")
                     -LLHH0;
HEXPendMED..         HEXP("MED")=E=DYH("MED")-HSAV("MED");
HEXPendHI..          HEXP("HIGH")=E=DYH("HIGH")-HSAV("HIGH");
AHEXPendLO..         AHEXP("LOW")=E=ADJ*HEXP("LOW");
AHEXPendME..         AHEXP("MED")=E=ADJ*HEXP("MED");
AHEXPendHI..         AHEXP("HIGH")=E=ADJ*HEXP("HIGH");
LSupply(h)..         LS(H)=E=MAXHOURS0(H)-(beta0(H)/PL)*
                     ((AHEXP(H)-SUM(CI,P(CI)*gamma(CI,H)))/
                     (1-beta0(H)));
ALSupply(h)..        ALS(H)=E=LS(H)/ADJ;
LMIGration..         LMIG=E=eta*(SUM(MK,L0(MK))+LLHH0+LSLG0
                     +LFEDG0)*LOG(PL/PLROC0);
Qdemand(Ci,h)..      Q(CI,H)=E=gamma(CI,H)+(beta(CI,H)/
                     (1-beta0(H))*P(CI)))*AHEXP(H)-SUM(CJ,P(CJ)
                     *gamma(CJ,H)));
AQdemand(Ci,h)..     ADQ(CI,H)=E=Q(CI,H)/ADJ;
QdemTFE(NME,H)..     Q(NME,H)=E=0;
TQdemand(i)..        TQ(I)=E=SUM(H,Q(I,H));
Qces(mk,h)..         Q(mk,H)=E=Aq(mk,H)*(DELTAq(mk,H)*QM(mk,H)
                     **RHOq(mk)+(1-DELTAq(mk,H))*QR(mk,H)**
                     RHOq(mk))**(1/RHOq(mk));
QRdemand(mk,h)..     QR(mk,H)=E=QM(mk,H)*((1-DELTAq(mk,H))
                     /DELTAq(mk,H)*PM0(mk)/PR(mk))**(1/
                     (1-RHOq(mk)));
QRdemTFR(NMR,H)..    QR(NMR,H)=E=Q(NMR,H);
QMdemTFR(NMR,H)..    QM(NMR,H)=E=0;
AQMdemand(Ci,h)..    AQM(CI,H)=E=QM(CI,H)/ADJ;
AQRdemand(Ci,h)..    AQR(CI,H)=E=QR(CI,H)/ADJ;
TQRdemand(i)..       TQR(I)=E=SUM(H,QR(I,H));
TQMdemand(i)..       TQM(I)=E=SUM(H,QM(I,H));
SLGRevenue..         SLGR=E=slIBT*(SUM(MK,ibtr(MK)*PR(MK)
                     *X(MK)))+slSST*(sstr*YL)+slKTT*(ktr*YK+
                     ttr*YT)+slHHT*(SUM(H,hhtr(H)*YH(H)))+
                     SLGBOR;
SLGEXPend..          SLGEXP=E=SUM(MK,P(MK)*SLGD(MK))+SUM(H,
                     TRSLG0(H))+PL*LSLG0;
SLGDemand(MK)..      SLGD(MK)=E=SLGD0(MK);
SLGDces(mk)..        SLGD(mk)=E=Asl(mk)*(DELTAsl(mk)*SLGDM(mk)
                     **RHOsl(mk)+(1-DELTAsl(mk))*SLGDR(mk)**
                     RHOsl(mk))**(1/RHOsl(mk));
SLGDRdem(mk)..       SLGDR(mk)=E=SLGDM(mk)*((1-DELTAsl(mk))/
                     DELTAsl(mk)*PM0(mk)/PR(mk))**(1/(1-
                     RHOsl(mk)));
FEDGRev..            FEDGR=E=fedIBT*(SUM(MK,ibtr(MK)*PR(MK)
                     *X(MK)))+fedSST*(sstr*YL)+fedKTT*(ktr*YK+
                     ttr*YT)+fedHHT*(SUM(H,hhtr(H)*YH(H)))
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                        +FEDGBOR;
FEDGEXPend..            FEDGEXP=E=SUM(MK,P(MK)*FEDGD(MK))
                        +SUM(H,TRFEDGO(H))+PL*LFEDGO;
FEDGDemand(MK)..        FEDGD(MK)=E=FEDGDO(MK);
FEDGDRdem(MK)..         FEDGDR(MK)=E=FEDGDRO(MK);
FEDGDMdem(MK)..         FEDGDM(MK)=E=FEDGDMO(MK);
SAVings..               SAV=E=SUM(H,HSAV(H))+depr*YK+ROWSAV;
INVest..                INV=E=SUM(MK,P(MK)*INVD(MK));
INVDemand(MK)..         INVD(MK)=E=INVDO(MK);
INVDces(mk)..           INVD(mk)=E=Ainv(mk)*(DELTAinv(mk)*
                        INVDM(mk)**RHOinv(mk)+(1-DELTAinv(mk))*
                        INVDR(mk)**RHOinv(mk))**(1/RHOinv(mk));
INVDRdem(mk)..          INVDR(mk)=E=INVDM(mk)*((1-DELTAinv(mk))/
                        DELTAinv(mk)*PMO(mk)/PR(mk))**(1/
                        (1-RHOinv(mk)));
Mimports(MK)..          M(MK)=E=TVM(MK)+TQM(MK)+SLGDM(MK)+
                        FEDGDM(MK)+INVDM(MK);
Price(MK)..             P(MK)=E=(PR(MK)*R(MK)+PMO(MK)*M(MK))
                        /(R(MK)+M(MK));
PriceTF(NM)..           P(NM)=E=SUM(MK,P(MK)*V(MK,NM))
                        /SUM(MK,V(MK,NM));
COMMequil(MK)..         X(MK)+M(MK)=E=TV(MK)+TQ(MK)+SLGD(MK)
                        +FEDGD(MK)+INVD(MK)+EXP(MK);
TFRequil(NMR)..         X(NMR)=E=TQ(NMR);
TFEequil(NME)..         X(NME)=E=EXP(NME);
Lequil..                SUM(MK,LAB(MK))+LLHHO+LSLGO+LFEDGO=E=
                        SUM(H,LS(H))+LMIG;
Kequil(MK)..            CAP(MK)=E=KSO(MK);
Tequil(MK)..            LAND(MK)=E=TSO(MK);
SLGequil..              SLGR=E=SLGEXP;
FEDGequil..             FEDGR=E=FEDGEXP;
CAPequil..              SAV=E=INV;
CVwelfare(h)..          CV(H)=E=(1/(1-beta0(H)))*((AHEXP(H)-SUM(CJ,
                        P(CJ)*gamma(CJ,H)))-(ADJ*HEXPO(H)-SUM(CJ,
                        PO(CJ)*gamma(CJ,H)))*PROD(CI,(P(CI)/PO
                        (CI))**beta(CI,H))*(PL/PLO)**beta0(H));
EVwelfare(h)..          EV(H)=E=(1/(1-beta0(H)))*((AHEXP(H)-SUM(CJ,
                        P(CJ)*gamma(CJ,H)))*PROD(CI,(PO(CI)/P(CI))
                        **beta(CI,H))*(PLO/PL)**beta0(H)-(ADJ*HEXPO
                        (H)-SUM(CJ,PO(CJ)*gamma(CJ,H))));
TCVwelfare..            TCV=E=SUM(H,CV(H));
TEVwelfare..            TEV=E=SUM(H,EV(H));
GSProduct..             GSP=E=YL+YK+YT+SUM(I,ibtr(I)*X(I));
ADJust..                ADJ=E=(TLSO+LMIG)/TLSO;


* EQUATIONS FOR CALCULATION OF INDEX WITH 1990=1.000

EIVA(mk)..              IVA(mk)=E=VA(mk)/VAO(mk);
EIX(I)..                IX(I)=E=X(I)/XO(I);
EILANDAG..              ILAND("AG")=E=LAND("AG")/TO("AG");
EIPT(I)..               IPT(I)=E=PT(I)/PTO(I);
EIVM(ml,mk)..           IVM(ml,mk)=E=VM(ml,mk)/VMO(ml,mk);
EIPR(I)..               IPR(I)=E=PR(I)/PRO(I);
EILAB(mk)..             ILAB(mk)=E=LAB(mk)/LO(mk);
EICAP(mk)..             ICAP(mk)=E=CAP(mk)/KO(mk);
EIPL..                  IPL=E=PL/PLO;
EIPK(I)..               IPK(I)=E=PK(I)/PKO(I);
EIEXP(mk)..             IEXP(mk)=E=EXP(mk)/EO(mk);
EIR(mk)..               IR(mk)=E=R(mk)/RO(mk);
EIYL..                  IYL=E=YL/YLO;
EIYK..                  IYK=E=YK/YKO;
EIYT..                  IYT=E=YT/YTO;
EIYH(H)..               IYH(H)=E=YH(H)/YHO(H);
EIDYH(H)..              IDYH(H)=E=DYH(H)/DYHO(H);
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EIHSAV(H)..         IHSAV(H)=E=HSAV(H)/HSAVO(H);
EIHEXP(H)..         IHEXP(H)=E=HEXP(H)/HEXPO(H);
EILS(H)..           ILS(H)=E=ALS(H)/LSO(H);
EIP(I)..            IP(I)=E=P(I)/PO(I);
EIQ(mk,H)..         IQ(mk,H)=E=ADQ(mk,H)/QO(mk,H);
EIQM(mk,H)..        IQM(mk,H)=E=AQM(mk,H)/QMO(mk,H);
EIQR(mk,H)..        IQR(mk,H)=E=AQR(mk,H)/QRO(mk,H);
EIM(mk)..           IM(mk)=E=M(mk)/MO(mk);
EIGSP..             IGSP=E=GSP/GSPO;


***************     INITIALIZATION     ******************

VA.L(I)=VAO(I);
V.L(J,I)=VO(J,I);
X.L(I)=XO(I);
LAND.L(I)=TO(I);
PT.L(I)=PTO(I);
QR.L(I,H)=QRO(I,H);
VM.L(J,I)=VMO(J,I);
VR.L(J,I)=VRO(J,I);
PR.L(I)=PRO(I);
TVM.L(I)=TVMO(I);
TVR.L(I)=TVRO(I);
TV.L(I)=TVO(I);
LAB.L(I)=LO(I);
CAP.L(I)=KO(I);
PL.L=PLO;
PK.L(I)=PKO(I);
EXP.L(I)=EO(I);
R.L(I)=RO(I);
YL.L=YLO;
YK.L=YKO;
YAGK.L=YAGKO;
YT.L=YTO;
YENT.L=YENTO;
YH.L(H)=YHO(H);
DYH.L(H)=DYHO(H);
HSAV.L(H)=HSAVO(H);
HEXP.L(H)=HEXPO(H);
ADJ.L=1;
LS.L(H)=LSO(H);
P.L(I)=PO(I);
Q.L(I,H)=QO(I,H);
QM.L(I,H)=QMO(I,H);
TQ.L(I)=TQO(I);
TQM.L(I)=TQMO(I);
TQR.L(I)=TQRO(I);
SLGR.L=SLGRO;
SLGBOR.L=SLGBORO;
SLGEXP.L=SLGEXPO;
SLGD.L(I)=SLGDO(I);
SLGDM.L(I)=SLGDMO(I);
SLGDR.L(I)=SLGDRO(I);
FEDGR.L=FEDGRO;
FEDGBOR.L=FEDGBORO;
FEDGEXP.L=FEDGEXPO;
FEDGD.L(I)=FEDGDO(I);
FEDGDM.L(I)=FEDGDMO(I);
FEDGDR.L(I)=FEDGDRO(I);
SAV.L=SAVO;
ROWSAV.L=ROWSAVO;
INV.L=INVO;
INVD.L(I)=INVDO(I);
INVDM.L(I)=INVDMO(I);
INVDR.L(I)=INVDRO(I);
M.L(I)=MO(I);
GSP.L=GSPO;

OPTIONS ITERLIM=1000, LIMROW=0, LIMCOL=0;


******   MODEL DEFINITION AND SOLVE STATEMENT   ******

MODEL OK90CGE /ALL/;
SOLVE OK90CGE MINIMIZING Z USING NLP;


*********   SOLUTION DISPLAY STATEMENT   *************

* SOLUTION VALUES OF ENDOGENOUS VARIABLES

DISPLAY   Z.L, VA.L, V.L, X.L, LAND.L,  PT.L,
   VM.L, VR.L, PR.L, TVM.L, TVR.L, TV.L, LAB.L, CAP.L,
   PL.L, PK.L, EXP.L, R.L, YL.L, YK.L, YAGK.L, YT.L, YENT.L,
   YH.L, DYH.L, HSAV.L, HEXP.L, LS.L, P.L, Q.L, QM.L, QR.L,
   TQM.L, TQR.L, TQ.L, SLGR.L, SLGBOR.L, SLGEXP.L, FEDGR.L,
   FEDGBOR.L, FEDGEXP.L, SAV.L, ROWSAV.L, INV.L, M.L, SLGD.L,
   SLGDR.L, SLGDM.L, FEDGD.L, FEDGDR.L, FEDGDM.L, INVD.L, INVDR.L,
   INVDM.L, LMIG.L, CV.L, EV.L, TCV.L, TEV.L, GSP.L, ADJ.L, AYL.L,
   AHEXP.L, ALS.L, ADQ.L, AQM.L, AQR.L;
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* SOLUTION VALUES OF INDEX

DISPLAY  IVA.L, IX.L, ILAND.L, IPT.L,IVM.L, IPR.L, ILAB.L,
   ICAP.L,IPL.L, IPK.L, IEXP.L, IR.L,IYH.L, IDYH.L, IHSAV.L, IHEXP.L,
   ILS.L, IP.L, IQ.L, IQM.L,IQR.L,IM.L, IGSP.L;


*********   THE END OF PROGRAM   ************
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VITA

Han-Sung Lee

Candidate for the Degree of

Doctor of Philosophy

Thesis: WELFARE MEASURES OF RURAL DEVELOPMENT: A REGIONAL GENERAL EQUILIBRIUM ANALYSIS INCLUDING NON-MARKET GOODS

Biographical:

Personal Data: Born in Seoul, Korea, October 17, 1959, the son of Mr. Yong-Ho Lee and Mrs. Man-Rye Lee (Park). Married to Hye-Young Lee (Park) on February 10, 1987.

Education: Graduated from Han-Sung High School, Seoul, Korea in February, 1978; received Bachelor of Science degree in Agronomy from Seoul National University, Seoul, Korea in February, 1982; received Master of Science degree in Agricultural Economics from Seoul National University, Seoul, Korea in February, 1984; completed requirements for the Doctor of Philosophy Degree at Oklahoma State University in December, 1993.

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