ANALYSIS OF OKLAHOMA'S BOOM AND BUST ECONOMY BY MEANS OF A CGE MODEL

By

YOUNG-KON KOH

Bachelor of Science in Agriculture
Seoul National University
Seoul, Korea
1970

Master of Science
Oklahoma State Unviersity
Stillwater, Oklahoma
1989

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
July, 1991

ANALYSIS OF OKLAHOMA'S BOOM AND

BUST ECONOMY BY MEANS

OF A CGE MODEL

Thesis Approved:

Thesis Adviser

Dean of the Graduate College

ACKNOWLEDGEMENTS

First of all, I extend my deepest thanks to Dr. Dean F. Schreiner, my advisor, for his insight, guidance, encouragement, patience, and thoughtfulness during my four years of graduate program. I am grateful to the members of my advisory committee, Dr. Arthur L. Stoecker, Dr. Francis M. Epplin, Dr. Daryll E. Ray, Dr. Michael J. Applegate for their valuable advice, assistance, and suggestions. I also thank Dr. Larkin B. Warner, former member of the committee for his assistance and suggestions.

I sincerely thank Dr. James E. Osborn for his attention and financial support. Thanks are due to Dr. Michael D. Woods, Dr. Elton C. Li, Dr. Michael R. Dicks, Dr. Daniel S. Tilley, and Dr. James N. Trapp for their helpful comments and encouragements at various stages of my study. I appreciate the computer assistance of Mr. Brent Tweeten, Mr. David Cassel, Mr. Min Fah Teo, Mrs. Priscilla Milam; the painstaking typing by Mrs. Gloria Cook; and all of the personnel in the Department of Agricultural Economics.

I extend my sincere thanks to Dr. Kun-Whan Yoon and Mr. Ho-Sun Han, former and current President and Chairman of the National Agricultural Cooperative Federation (NACF) of Korea, for their encouragement and financial support for my master's program. Special thanks are due to Dr. Kee-Won Suh and Mr. Nai-Soo Lee, former Directors of the Research Department of the NACF, and Mr. Kyo-Un Kim for their encouragement and moral support. Without their encouragement I could have not decided to take my graduate program 17 years after the undergraduate program. I thank the nice friends in the Marketing Research Division of the NACF for all arrangements during my stay in Oklahoma. I also thank the Personnel Department and the Education Department of the NACF for their support for my study.

I am thankful to Dr. Su-Ki Kang and Dr. Kwang-shik Myoung for encouragement.

Thanks are due to my brother-in-law Mun-Soo Ghu, for his taking care of my household affairs back home during my stay in Oklahoma.

I thank my parents, brothers and sisters, for their prayers.

I thank my lovely daugher Hee-Young, and son Kang-il for their understanding and sacrifice. I believe that they will adjust themselves exceptionally well to a new environment they face back home as they did four years ago.

To my wife Young-Mi who has accepted all the hardships with joy, I dedicate this paper.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Table		Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Problem Statement

Oklahoma's Boom and Bust Trends

The "Boomer State" of Oklahoma enjoyed another round of booming in the 1970's and early 1980's associated with escalating oil and gas prices and a favorable economic environment for agriculture. According to the U.S. producer price index, crude petroleum price rose by about 590 percent and gas fuel price by 900 percent from 1970-82, whereas the overall producer price index increased by 162 percent. During the booming period of 1977-82, every sector in the State's economy showed a significantly higher growth rate than its national counterpart (Table I).

However, oil and gas prices began falling in 1982. By 1986, prices of those commodities were about 47 percent and 83 percent, respectively, of the peak levels of 1982. Agricultural commodity prices also showed a considerable decrease during the period. A 1982 based price index (1982 = 100) for overall agricultural commodities produced in the State was 89 by 1986. Production activities in Oklahoma began to shrink. The sectoral gross state product (GSP) growth rate of Oklahoma for the period 1982-86 was significantly lower than the national average, not only for the price declining sectors but also for all other sectors. Considering the inflation rate of 14.1 percent (GNP deflator),

TABLE I

OKLAHOMA GROSS STATE PRODUCT FOR SELECTED YEARS 1977 TO 1986 BY SECTOR WITH U.S. COMPARISONS FOR GROWTH RATES

Sector	Oklahoma State 1977	1982	1984	1986	OK 82/77	84/82	86/82	U.S. 82/77	84/82	86/82
	$mm (current)				%			%		
Agriculture	715	1799	1400	1687	251.6	77.8	93.8	152.6	100.8	99.2
Mining	2890	9690	7042	5183	335.3	72.7	53.5	263.4	90.3	72.1
Construction	1350	2290	2401	2132	169.6	104.8	93.1	143.9	121.7	140.4
Manufacturing	3669	6347	7423	7110	173.0	117.0	112.0	136.4	121.6	129.9
Tran/Com/Util[1/]	2215	4312	4951	5240	194.7	114.8	121.5	161.3	122.9	135.7
Trade	3991	7370	7824	7966	184.7	106.2	108.1	152.2	121.2	138.7
Fin/Ins/R.Estate[2/]	2837	5882	6541	6745	207.3	111.2	114.7	169.5	120.6	146.3
Service	2717	5281	6058	6644	194.4	114.7	125.8	181.9	125.0	150.5
Government	3203	5729	6437	7107	178.9	112.4	124.1	155.5	115.3	131.9
Gross State Product	23587	48700	50077	49814	206.5	102.8	102.3	158.6	119.4	135.0

1/ Transportation, communication, and public utilities.

2/ Finance, insurance, and real estate.

Source: Bureau of Economic Analysis, USDC, Current Business Survey, May 1988.

agriculture, mining, construction, manufacturing, and trade sectors recorded negative real growth during the four year period resulting in a negative growth rate for total GSP.

An important indicator reflecting overall economic environment for the State in general and factor market conditions in particular, is the population trend. From 1970-82, Oklahoma's population increased from about 2,559,000 to 3,233,000 representing a 26.3 percent increase compared with the national increase of 14.1 percent. However, during the four year period 1982-86 population increased 2.1 percent whereas U.S. population increased by 4.4 percent. Oklahoma population hit a peak of 3,312,000 in 1984 which is a lag of two years from the peak in energy prices.

The 1988 population was 3,242,000 or about 70,000 fewer than 1984. If the natural population growth rate for the State from 1984-88 was the same as for the U.S. (increase of 3.95 percent), the 70,000 decrease in absolute number implies about 200,000 net outmigration during the four year period. This contrasts to a net inmigration of 313,000 during 1970-82 based on similar calculations.

Faced with the "bust" after the "boom" the issue of industry and sector diversification was raised and gained wide support among politicians, economic planners, and consultants in the Boomer State (Penn). The idea was to lower the dependence of the State's economy on the traditional oil, gas, and agricultural commodities and thus reduce cyclical instabilities. The issue of sectoral structure, however, raises questions about factor market structure.

Factor-Product Market Interaction

Openness of regions, such as the state of Oklahoma, makes regional economies much more sensitive to exogenous shocks in commodity markets than exists for national economies from exogenous shocks in world markets. Shocks in commodity markets affect profitability of economic activities and influence the levels of regional output and demand for resources. Therefore, factor market prices depend on commodity market signals from outside the region and on interindustry relationships within the region. Because of relative immobility of resources compared to commodities, factor market prices, in turn, determine income levels of various population groups within the region in the short run and the direction of regional resource flows, especially population, in the long run.

Interaction between commodity and factor markets depends on interindustry linkages, factor substitution relationships in production processes, structure of consumption and trade, and structure of income determination and distribution. Income determination and distribution requires special attention because it affects resource flows between regions in the long run. For example, other things equal, the larger the proportion of capital income to total regional income, the lower the demand for residential activities. Similarly, if income is concentrated at higher income levels, demand for commodities would be reduced because of low income elasticities of demand (Cline).

In evaluating economy-wide impacts of an economic event, interindustry fixed price multiplier analysis has been widely used. Beginning about the mid 1980's, the traditional input-output multiplier model has been extended to a social accounting matrix (SAM) multiplier methodology to accommodate distributional effects in the analysis (Adelman and Robinson, 1986).

Fixed price multiplier analysis does not effectively capture the factor-product market interactions when price adjustments are involved because of the implicit assumption that quantities will adjust at fixed prices. Computable general equilibrium (CGE) models are an attractive alternative in modeling 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 including income determination and distribution under strategies of industry diversification.

Objectives and Hypothesis

A region's rural economy can not be considered as an isolated system independent of the rest of the region and the rest of the nation. A region's agricultural and rural development path is determined by the interactions between various interdependent markets. Endogenous prices and quantities in model structure is essential in analyzing horizontal and vertical market interactions. The horizontal market interactions include interactions between regions and the nation, sectors or commodities, and factors. Vertical market interactions are interactions between commodity and factor markets and are important in the process of income determination and distribution. An equilibrium model designed to capture horizontal and vertical interactions simultaneously, i.e., feedback effects of changes in equilibrium prices and quantities in one horizontal market to prices and quantities in another horizontal market, can be classified as general equilibrium.

The basic objective of this study is to construct a computable general equilibrium model for the State of Oklahoma that facilitates analysis of economic impacts of commodity market disturbances on factor markets. The model will emphasize multi-dimensional income distribution including functional, geographic, and size distribution. The main focus of analysis is to investigate the basic adjustment mechanisms of a regional economy and to identify the distributional impact of the "bust after the boom" in Oklahoma. The fundamental hypothesis of the study is that factor market structure is an important determinant in the behavior of a region's economy in response to external shocks, and thus a regional growth strategy of industrial diversification should be evaluated in relation to issues of income determination and distribution.

The specific objectives of this study include:

(1) To set up a social accounting matrix (SAM) for Oklahoma that allows analysis of the structure of the economic system and provides a data set for a computable general equilibrium (CGE) model. The process of constructing the SAM should also generate information on issues related to data sources and to reliability and consistency of data.

(2) To develop a SAM based regional CGE model incorporating alternative theoretical assumptions about labor market behavior.

(3) To identify differences in the impact estimates of a same shock estimated by fixed multiplier approach and by CGE approach.

(4) To conduct simulation experiments under alternative assumptions on labor market behavior and regional trade parameters, evaluate the general equilibrium results, identify distributional impacts, and draw policy implications.

The information derived by this study is expected to be useful in regional development policy formulation for the State of Oklahoma. It is also hoped that this study will contribute to the development and application of analytical frameworks, including general equilibrium models for regional analysis.

Organization of the Study

This dissertation consists of seven chapters. Following this introductory chapter, Chapter II is devoted to literature review on the issues of income determination and distribution and Chapter III describes the theoretical development and empirical applications of computable general equilibrium analysis. Structure of the computable general equilibrium model developed in this study is presented in Chapter IV with discussions on model assumptions. Chapter V reports the data sources and procedures followed for the empirical application in this study. Some of the data issues in building a regional level SAM and in using computer algorithms for model solution including processes for parameter calibration are discussed. Results of simulation experiments are presented and analyzed in Chapter VI. The last chapter, Chapter VII, discusses the limitations of the study, implications for policy formulation, and further research.

CHAPTER II

ISSUES ON INCOME DISTRIBUTION

The subject of income distribution covers a wide variety of issues from philosophical and ideological debates to detailed analyses of distributional impacts of specific policy or economic events. This chapter deals with some of those issues. It starts with a fundamental perspective on income distribution maintained by mainstream neoclassical economic theory. Discussions on some of the weaknesses of this approach are followed together with attempts to explain some of the reasons for skewed income distribution. The issue of efficiency-equity or growth-equity trade off is introduced.

Market Approaches to Income Distribution

Neoclassical Solution for Income Formation and Distribution

Neoclassical economic theory analyzes income formation and distribution as a market phenomenon. Income is determined in the factor market based on the transactions between buyers, profit maximizing producers, and sellers who are utility maximizing consumers. The theory begins with a set of axioms for utility maximization; completeness of ordering, transitivity, continuity, monotonicity and strict convexity. Each individual has his/her own tastes and preferences satisfying the above axioms. The production set is strictly convex. Market competition is perfect; full information for both sellers and buyers, full mobility of factors and commodities, sufficient smallness of sellers and buyers in both markets, and ability of instantaneous adjustment for both consumers and producers.

Based on these assumptions, the prices and quantities determined in the market will satisfy the Pareto efficient condition such that (1) the marginal rate of substitution between any pair of commodities will be the same for every consumer and equal to the inverse of the commodity price ratio (exchange optimum or efficiency in consumption); and (2) the marginal rate of factor substitution between any pair of factors will be the same for every production process (production optimum or efficiency in production) and equal to the inverse of the factor price ratio.

These Pareto efficient conditions can be derived by mathematical formulation. Suppose, for simplicity, an economy with two persons A and B; two goods, x and y; and two factors of labor, L, and capital, K. Resources of A and B are denoted by L^a, K^a and L^b, K^b. Therefore, the amount of resources available for production is $L = L^a + L^b$, and $K = K^a + K^b$. Production of x and y requires both labor and capital based on available technologies $x = x(L_x, K_x)$ and $y = y(L_x, K_y)$ where the subscripts indicate the use of factors. Let x^a, x^b and y^a, y^b be quantities consumed by each person.

Assume that A and B have the utility functions $U^a = U^a(x^a, y^a)$ and $U^b = U^b(x^b, y^b)$, respectively, and that the social welfare function is of the form $W = W(U^a, U^b)$ which is concave and continuously differentiable. Assuming that the objective of society is to maximize W, the maximization problem is:

Maximize $W(U^a, U^b)$

Subject to $x^a + x^b = x(L_x, K_x)$

$y^a = y^b = y(L_y, K_y)$

$L^a + L^b = L_x + L_y$

$$K^a + K^b = K_x + K_y$$

Note that the first two constraints define commodity market equilibrium conditions for goods x and y, and the remaining two are labor market and capital market equilibrium conditions. Setting up the Lagrangian and solving for the first order conditions.

$$V = W\{U^a(x^a, y^a), U^b(x^b, y^b)\}$$
$$+ P_x\{x(L_x, K_x) - x^a - x^b\} + P_y\{y(L_y, K_y) - y^a - y^b\}$$
$$+ w(L^a + L^b - L_x - L_y) + r(K^a + K^b - K_x - K_y)$$

$$\frac{\partial V}{\partial x^a} = \frac{\partial W}{\partial U^a}\frac{\partial U^a}{\partial x^a} - P_x = 0 \quad (2.1)$$

$$\frac{\partial V}{\partial y^a} = \frac{\partial W}{\partial U^a}\frac{\partial U^a}{\partial y^a} - P_y = 0 \quad (2.2)$$

$$\frac{\partial V}{\partial x^b} = \frac{\partial W}{\partial U^b}\frac{\partial U^b}{\partial x^b} - P_x = 0 \quad (2.3)$$

$$\frac{\partial V}{\partial y^b} = \frac{\partial W}{\partial U^b}\frac{\partial U^b}{\partial y^b} - P_y = 0 \quad (2.4)$$

$$\frac{\partial V}{\partial L_x} = P_x \frac{\partial x}{\partial L_x} - W = 0 \quad (2.5)$$

$$\frac{\partial V}{\partial K_x} = P_x \frac{\partial x}{\partial K_x} - r = 0 \quad (2.6)$$

$$\frac{\partial V}{\partial L_y} = P_y \frac{\partial y}{\partial L_y} - w = 0 \quad (2.7)$$

$$\frac{\partial V}{\partial K_y} = P_y \frac{\partial y}{\partial K_y} - r = 0 \quad (2.8)$$

where P_x, P_y, w, and r are shadow prices representing prices of x, y, labor, and capital, respectively. Observe that equations 2.1 through 2.4 are equivalent to utility maximizing condition for consumers if consumers ignore social welfare, i.e., marginal utility for society is equal to their own utility, or alternatively, if W is simply the summation of individual welfare. Observe also that equations 2.5 through 2.8 are profit maximizing conditions indicating that factor prices are equated with marginal value products of corresponding factors. Dividing equation 2.1 by 2.2 and 2.3 by 2.4 gives the exchange optimum, and dividing equation 2.5 by 2.6 and 2.7 by 2.8 gives the production optimum. Note that if conditions of exchange optimum and production optimum are met, the marginal rate of product transformation in production will be equal to the marginal rate of commodity substitution in consumption. This can be shown by dividing equation 2.5 by equation 2.7, and equating the result with the exchange optimum condition.

There will be no other solution for prices and quantities that can make someone better off without making anyone worse off. Moreover, assuming long term equilibrium in the neighborhood of which the production function exhibits constant returns to scale, i.e., the function is homogeneous of degree one, factor prices determined by marginal value products will exhaust all output according to Euler's Theorem implying that there is no economic profit.

Income distribution among the individuals will be determined by multiplying the market determined prices by quantities of factors sold in the market. In the two person economy above, incomes for A and B, Y^a and Y^b are:

$$Y^a = wL^a + rK^a$$

$$Y^b = wL^b + rK^b$$

Functional incomes for capital and labor are determined simultaneously as rK and wL, respectively. Assuming $K^b = 0$, which implies A is a capitalist and B is a laborer, the solution is still a Pareto optimum. Moreover, suppose $L^a = 0$, $K^a = 0$, i.e., individual A has nothing and individual B has everything. Still the solution is Pareto optimum, and thus welfare for the society is at maximum, implying that the solution is still valid for a society in which one has everything and all other members have nothing.

The question arises how the quantities of L^a, L^b, and K^a, K^b are determined. The answer is simple; the initial point of resource ownership is assumed to be given. Some of the theoretical and empirical approaches to answering this question are discussed below under reasons for skewed distribution. Other limitations of the Pareto efficient solution have been pointed out in relation to income distribution. They include market imperfections, externalities in consumption, and exogeniety and measurability of preferences.

Market Imperfections and Income Distribution

Any violation of the assumptions (including perfect information and full mobility of factors on which Pareto efficiency was constructed) will violate the "efficient" income distribution which distributes income in such a way that everybody in society receives as much as they contribute to the welfare of society. One of the representative examples of distorted income distribution is monopsony in a commodity market where at least one of the equations 2.5 through 2.8 is not satisfied.

If a factor market is under monopsony, the buyer faces an increasing, not horizontal, supply curve. Profit is maximized by equating marginal factor cost (MFC) with marginal value product (MVP) of the factor. The factor price will be determined based on the supply curve, not on marginal value product. The difference between MVP and factor price is net income transfer from seller to buyer. If the buyer of the factor is also a monopolist of his product market, there exists still more transfer. This monopsony in factor market and monopoly in output market is depicted in Figure 1. The vertical axis of Figure 1 measures the price of factor X, while the horizontal axis measures quantity. The equilibrium income that satisfies Pareto efficiency for sellers of factor X can be measured by the rectangular area OP_0EX_0, where X_0 is the amount of factor employed in the production process and P_0 represents the factor price. However, under factor market monopsony (product market is competitive), the amount of factor employed is X_1 and the price paid by the factor employer is P_1 while the MVP of X_1 is P_1' as a result of profit maximizing behavior of the factor employer. Further, if factor market monopsony and commodity market monopoly occur at the same time, the employer will equate marginal revenue product with marginal factor cost. The resulting income transfer from factor suppliers to employer is equal to $(P_3' - P_3)X_3$.

Externalities in Consumption

Note that the determinants of individual utility assumed above include only the level of one's own consumption. This result is not useful in deriving policy implications for society when individual welfare is not limited to own income and own consumption (Hochman). Utilities are generally interdependent among members in society, not independent. Consider again the two person economy. Suppose utility of A is determined not only by his own consumption but also by B's consumption (welfare). If $y^a > Y^b$ initially, and if with

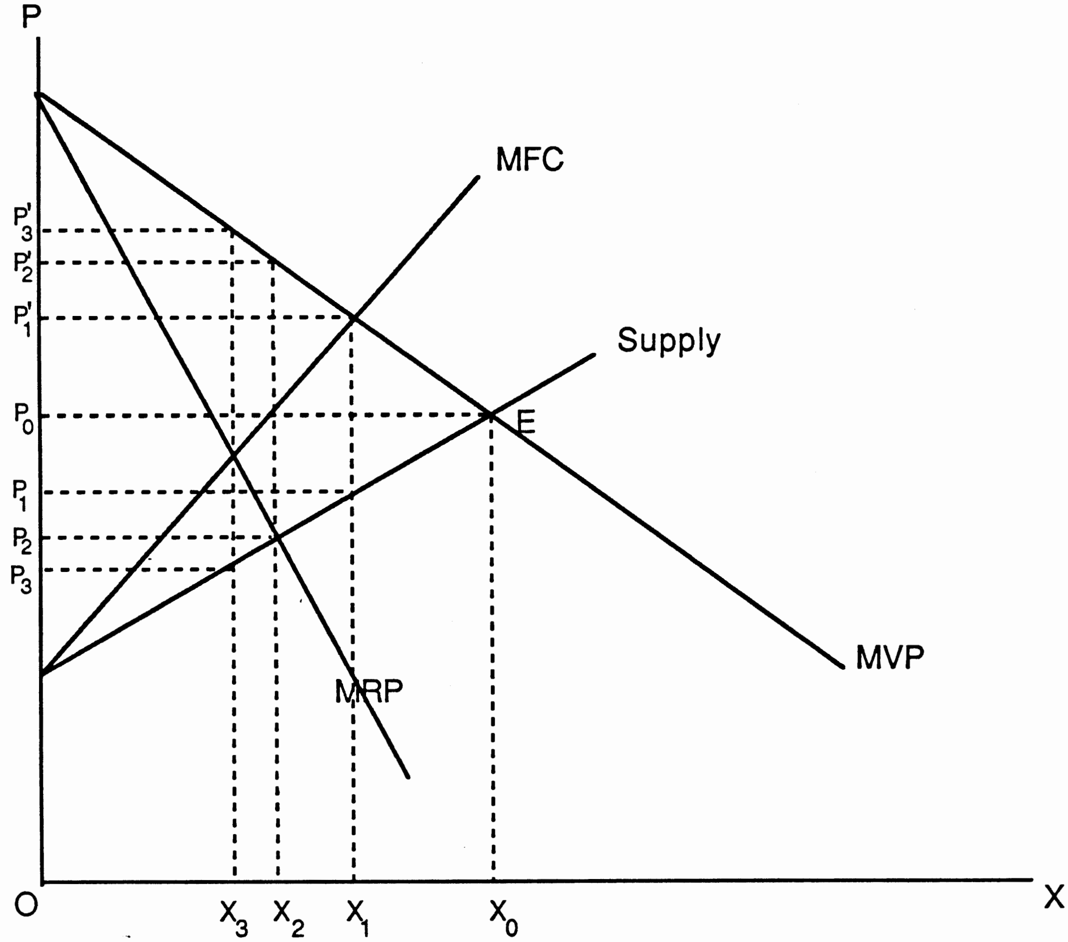

Figure 1. Result of Market Imperfection on Income Distribution

A's higher income the partial derivative of U^a with respect to U^b is greater than the partial derivative of U^a with respect to either x^a or y^a, then transfer of A's additional income will increase A's own utility as well as social welfare.

This utility dependence was also emphasized by Galbraith from the opposite direction:

> Who can say for sure that the deprivation which afflicts him with hunger is more painful than the deprivation which afflicts him with envy of his neighbor's new car? . . .And where a society is concerned, comparisons between marginal satisfactions when it is poor and those when it is affluent will involve not only the same individual at different times but different individuals at different times (Galbraith pp. 3-4).

The empirical evidence of the utility interdependence may be abundant in the area of consumer behavior as indicated by demonstration effect and conspicuous consumption. It was summarized by Robinson.

> In consequence of the disturbing leitmotif of Keynes's General Theory, namely that consumption needed reappraisal, the conceptual possibility that economic wants may be socially interdependent over wide ranges of satisfaction began to attract serious attention. It was given impressive empirical support by Duesenberry and Modigliani, whose inquiries suggested that the saving:consumption ratio is far more closely correlated with income rank in the community than with absolute level of real income (Robinson, 1961 p. 394).

Tinbergen argues that economics as a science cannot do without some elements originating from psychology because the concept of welfare is basically psychological. Further, he points out that welfare or happiness of human beings may not be effectively explained by economic terms. Research by Levy and Gutman indicate that the four determinants "good family life", "good health", "satisfaction with leisure", and "satisfaction with town life" explained 59 percent of the variance in happiness of 1,940 respondents from four major cities of Israel. On the contrary, the determinants of "sufficient income", "satisfaction with education", "good labor relations at work", which are more economic in character, explained 18 percent of the variance in happiness. Moreover, Tinbergen criticizes the concept of welfare or the welfare function used by economists as materialistic and consumption oriented (Tinbergen pp. 131-135)

Exogeniety and Measurability of Preferences

What determines the degree of, and shape of the utility dependence in a society? More fundamentally, how are individual welfare functions formed? Basically it is not considered to be relevant to economic science. The utility function may be formed by various social learning processes including family life, school education, churches, jobs, and everyday life. Traditionally, tastes and preferences are assumed to be exogenously given. However, Hahnel and Albert suggest endogenizing preferences. One of their welfare theorems states that neoclassical theory ignores the fact that present choice of consumption and work activities not only fulfills present preferences but also generates changes in future preferences. Neglecting changes in preferences systematically misestimates the welfare effects of economic choices. They argue that even with endogenizing preferences, the Pareto optimum is still an equilibrium of the competitive economy (Hahnel and Albert). This assertion implies that tastes and preferences of individuals and society, in part, depend upon public policy. The development and empirical application of this theoretical improvement opens new avenues for economic policy analysis, including income distribution.

However, the main issue of measurability of individual or social utility has not been resolved. Various methods have been applied to estimate the individual utility function in areas of risk analysis. In these approaches the determinant of utility is simply expected income.

The level of happiness indicated by utility, in general, is only a subjectively quantifiable magnitude. It is measurable, at most, ordinarily or cardinally, by the individual decision maker. This means interpersonal comparisons of individual utilities are meaningless in measuring utility of all or part of society. However, economists measure changes in the utility level of society, in part,by observing market phenomena since demand and supply schedules are aggregate reflections of individual utility. The concept of consumer surplus originating from Marshal has been widely used in welfare analysis. But the dichotomy of consumer and producer in classical welfare analysis limits its usefulness in distributional issues where interpersonal comparisons of utility change is the basic issue, whether utilities are interdependent or not.

This impossibility of utility estimation implies that any policy decision basically depends upon public decision makers collective representation of society. This representation is conditional upon the democratic process of voting without any distortions by rent seeking activities or political/economic seeking transfers (PESTs) as pointed out by Tullock (1967).

Non-Market Approaches To Income Distribution

Ladd emphasizes that efficiency is not a value free term. A certain criterion must be attached when the word efficiency is used. Different criteria and different constraints imposed on the system lead to different efficiency solutions. This seems relevant to the criteria suggested by Scherer in evaluating the performance of an economic system under the structure-conduct-performance paradigm. The four criteria suggested by Scherer are:

(1) Decision as to what, how much, and how to produce should be efficient in two respects: scarce resources should not be

> wasted . . . and . . . decisions must be responsive . . . to consumer demands.
>
> (2) The operations of producers should be progressive, taking advantage of opportunities opened by science and technology for . . . long run growth of per capita real income.
>
> (3) . . . should facilitate stable full employment of resources. especially of human resources . . .
>
> (4) The distribution of income should be equitable. Equity in economics . . . implies . . . that producers do not secure rewards far in excess of those needed to call forth the amount of service supplied . . . . (p. 3-4).

Others suggest similar criteria. In discussing the structure and control of the U.S. agricultural sector, Hildreth, Krause, and Nelson used criteria of (1) technological progressiveness, (2) magnitude and distribution of externalities, (3) efficiency, (4) values, and (5) income and power distribution.

Observe that the conventional efficiency concept is only one of the criteria, and that each criterion may be in severe conflict with real world decision making, both in the private and public sectors. Thus a basic value judgement is inevitable. Under the S-C-P (Structure-Conduct-Performance) paradigm, income determination and distribution is basically understood as a structural issue. There exists market failure as well as government failure. The conventional efficiency norm usually assumes, implicitly or explicitly, that government is a perfect instrument for correcting whatever market failures might be identified. Tullock (1967) asserts that the standard dead weight loss from monopolies and tariffs calculated according to classical welfare analysis is at best a lower bound estimate of actual costs to society. Rausser, Perloff, and Zusman state:

> Governments do what they do, in part, because they are lobbied or pressured into doing so. Pure transfers cost society nothing: but, for the people engaging in such transfers, they are like any other activity, and this, of course, means that large

> resources may be invested in attempting to make or prevent transfers (p. 12).

The concept of X-efficiency introduced by Leibenstein may be considered another limitation to the traditional Paretian type of efficiency. He lists various empirical results showing that welfare loss estimates due to the market imperfection is "ridiculously" small and emphasizes that nonallocative efficiency is much more important than allocative efficiency. The sources of nonallocative efficiency or X-efficiency are (1) incomplete labor contracts, (2) existence of non-market inputs such as management, (3) inability to know production functions completely, and (4) existence of tacit cooperation between competing firms because of interdependency and uncertainty.

From these viewpoints, determination and distribution of income is not only a market phenomenon. Other factors exist in determining income for individuals in society. The institutional economics integrates political and legal facets of social process into economic process. People hold and exercise power in decision making in society, and this is true for the operation of an economy which is characterized by a process of continuous transactions made through negotiation. Therefore, income formation and distribution is the result of choices made by various individuals who are acting through or in behalf of institutional power systems and reflecting various views concerning merits, incentives, worth, and entitlements (Tool).

Buchanan's view on exchange system is a similar perspective. In his Nobel Lecture, Buchanan classified exchange systems into market exchange and political exchange, and indicated that analysis of the market exchange system is not complete in explaining the workings of an economic system.

> Politics is a structure of complex exchange among individuals, a structure within which persons seek to secure collectively their own privately defined objectives that cannot be efficiently secured through simple market exchange. In the market people exchange applies for

> oranges; in politics, individuals exchange agreed-on shares in contributions toward the costs of that which is commonly desired . . . (Buchanan pp. 307-8).

Some of the direct and obvious examples of non-market determined incomes are downward stickiness of labor incomes, minimum wage rates, and agricultural incomes affected by government policies. Moreover, Thurow (1968) provides empirical estimates showing that capital receives higher renumeration than its marginal productivity. Tinbergen (1985) finds, based on regression analysis for the U.S. (1959 data) and Japan (1975 data), that estimates of marginal productivity of different labor categories greatly deviate from labor income. His findings for the U.S. include: managers receive 2.6 times the income calculated from marginal productivity, professionals and technicians receive 98 percent, white collar workers received 64 percent, and the marginal product of blue collar workers and farm workers are both negative. With some limitations in interpretation, he concludes that the reasons for such results, especially for negative marginal products, are basically institutional: employment as a reserve for a quick increase in future production and the influence of trade unions (Tinbergen 1985, pp. 7-17).

Other Dimensions of Income Distribution

Income distribution has multi-dimensional characteristics. Discussion so far has been mainly on functional distribution of income. Other dimensions include individual or size distribution, geographic or regional distribution, and international, racial, occupational, and sexual distribution (Bronfenbrenner).

Discussion of income distribution has concentrated on size distribution. Size distribution has become closely associated with the issue of income redistribution. Questions arise about the desirability of income redistribution, why distribution of income among individuals is highly skewed, what relationships exist between economic development and size distribution of income, and how the degree of distributional equality or inequality can be measured. Reviews of these income distribution issues follow.

Value Judgements and Income Distribution

In a capitalist system, policies designed to alter income distribution are often viewed as socialistic and harmful to efficiency maintained by free markets (O'Connell). Tullock (1984) argues that many believe income distribution is essentially a moral rather than a scientific issue and this has led to low levels of quantity and quality research. It seems to be true that the issue of income distribution usually involves a normative value judgement around the concept of "equality" or "fairness".

Three definitions of equitable income distribution discussed by Tinbergen (1985) indicate this inevitable situation. The first definition is completely based on the efficiency norm that equitable income distribution is characterized by equality between each person's income and their contribution to production. Secondly, a situation that allows income differences attributable to effort and scarcity of productive personality traits can be defined as equitable. Tinbergen's third definition equalizes welfare among individuals assuming extreme situations of scarcities that cause "scarcity rents" are eliminated by sufficient education and training. He argues that the elimination would be reached if for every job to be filled in society a person could be found whose productive personality traits are identical to traits required.

Note that the above statements on equity are concerned only with labor income. Equity discussions on capital income lead to further ideological issues. Personal attitude or philosophy toward the perception of the world and human affairs is involved, implicitly or explicitly, in some of the income distribution literature. This is particularly true when the problem of social justice enters the discussion. Different approaches based on different philosophical backgrounds can be summarized as: (1) egalitarians emphasize equal distribution, (2) libertarians emphasize contribution and merit in a free market, (3) socialists emphasize need, and (4) utilitarians emphasize a mixed criteria to attain maximum social welfare (Beauchamp).

Okun argues that people want more equality of income than is generated by the operation of markets. Evidence of this are the firm principles of equal distribution established in many social and political institutions such as one person one vote, one person one spouse, equal justice among all, universal freedom of speech and religion, and equal claims on public services. Rawls' theory of social justice is another example. His difference principle says that social primary goods, including liberty, income, and opportunity, should be distributed equally. However, inequalities are permitted if they are arranged for the greatest benefit of the least advantaged members of society. Both approaches, by Okun and Rawls, are based on egalitarian philosophy.

A position toward equal income distribution expressed in economic terminology is Lerner's theorem. Based on the assumptions of (1) the principle of diminishing marginal utility of income holds generally, (2) utilities of different individuals are commensurable and addable, and (3) utility functions do not exhibit interdependence, Lerner argues that ". . . If it is impossible, on any division of income, to discover which of any two individuals has a higher marginal utility of income, the probable value of total satisfaction is maximized by dividing income evenly. . ." (Lerner p.29).

Reasons For Skewed Income Distribution

About one hundred years ago, Pareto discovered his "simple empirical law'[1] of income distribution that income is skewed to the right and this skewness is stable (Staehle) even though individual abilities follow normal distributions.

Since then, various approaches have been suggested to explain discrepancies between normal ability distribution and skewed income distribution. Pigou conjectured that the reason for the discrepancy was due to a skewed distribution of inherited wealth and the existence of non-competing groups created by social, legal, and other barriers to labor mobility. A group of authors have suggested that individual categories of ability are distributed normally but that worker's productivity depends on the composite of all abilities. The composite ability follows lognormal distribution rather than normal distribution because of the multiplicability (not additivity) relationship between components (Mandelbrot). Friedman incorporated risk attitude into income distribution. If society is made up largely of risk averters (risk neutral) then rightward skewed (normal) income distribution will emerge.

However, the most widely used approach in explaining income distribution phenomenon is the human capital approach originated by Schultz and Mincer. Human capital theory perceives current earnings as returns to all past investments for education and training. Supporting empirical studies include Chiswick and Mincer. Mincer found that about half of total observed earnings differential can be attributed to schooling and postschooling investments. However, weaknesses of the human capital approach are pointed

---

1 Based on income tax data from different countries and periods, Pareto found that the upper bracket (above mode) of income is distributed following the formula; $\log N = \log A - a \log Y$ where N is the frequency distribution of persons having income equal to Y or more, A and "a" are parameters with the value of "a" approximately equal to 1.5 (Staehele).

out by Sahota and include: (1) it does not try to explain the sources of differentials in human investment; (2) schooling is merely a screening device to potential employers, so the persons selected in the screening process receive higher wages partly at the cost of others; and (3) it analyzes earnings rather than total income even though property income is more unequally distributed than earnings, and the relationship between property ownership and earnings is ignored.

Against the human capital approach, Jencks et. al, argue that neither cognitive talent nor educational attainment significantly alter income inequalities. Major determinants of economic success, apart from inheritance of property, are luck and peculiar competencies over which governments have no control. Therefore, education cannot achieve noneducational, i.e., economic, objectives.

Another contrasting approach emphasizes the effect of inheritance following the Cambridge tradition. The basic premise is that capital owners prolong their economic position by the chain effect of more savings - more accumulation - more capital income-more savings, etc. (Kaldor). Empirical evidence of Britain is inconclusive. Atkinson (1975) concludes that at least two-thirds of the wealth holders in Britain inherited a substantial amount of their wealth. According to Rubenstein, the self-made category of rich people in Britain rose from 12 percent over the 1900-1929 period to 31 percent in 1960. This approach claims different propensities to save out of incomes from different sources but this position is also prone to criticism in that it ignores human capital, and the model collapses when society has more than two classes. Other approaches exist including the life cycle approach that attributes inequalities in income in age effects and the random-walk approach that emphasizes luck and fortune.

Economic Growth and Income Distribution

Questions about the impact of economic development on income distribution, or income distribution on development have been raised. The conceptual approaches and empirical evidences are controversial even though Kuznets' U hypothesis claims wide support. Kuznets U hypothesis postulates that as countries move through various stages of development, inequality in income distribution first increases, and then after a certain level of development is reached, the inequality reduces. Based on cross section data for eighteen developing countries, Kuznets observed that the income share of the poorest group in those countries was comparable to that in the developed nations, but the income share of the richest group in developing countries was larger than that in the developed countries. He concluded that the impact of economic development on improvement in income distribution was the increasing income share for the middle class. The first reason for this phenomenon is that the savings rate is higher for the rich, and total assets and non-assets will grow more rapidly than for the poor. The second reason is because of the dual economic structure. The modern sector grows more rapidly than the traditional sector and this is at a higher income base for the population in the modern sector. Thus the income share of the population in that sector will increase initially. However, there will be an equalizing effect when the share of population in the modern sector increases above a certain level. In addition, there will be an equalizing effect from the growing political influence of the middle class.

Ahluwalia found evidence to support the Kuznets' U hypothesis based on an econometric test. Saith criticized Ahluwalia's regression results and concluded that the evidence did not support the hypothesis. However, Campano and Salvarote confirmed the hypothesis with the exception of the poorest 20 percent of the population. Adelman and Morris are doubtful of the U hypothesis and emphasize that, on the average, the primary effect of economic development is to increase inequality and it continues over a long period of time.

Hirschman also believes that inequalities among different classes, sectors, and regions tend to increase rapidly in early stages of economic growth, and this is possible because society has a substantial tolerance for increasing disparities. He emphasizes the tolerance level will vary not only across different countries with different social, historical , cultural, and institutional backgrounds, but also will vary over time in the course of economic development. His main assumption is that individual A's utility is a function of both current income and expected future income and the expected future income depends on changes in B's income. At early stages of economic development, increases in B's current income increases utility of A because it is regarded as a signal for increases in A's future income. However, if A realizes that the information was wrong or feels the B's improved income position indicates a worsening position for him, then society's tolerance will decrease sharply. It may lead to "development disaster" due to A's "indignation from gratification" as experienced by some of the developing nations.

However, it is impossible to estimate Hirschman's tolerance level and changes in the level for a particular society. The Kuznets U hypothesis does not give implications on how long it will take or what is the level of development for a country before a reversal of the income distribution trend occurs. Moreover, it is notable that the empirical studies on the U hypothesis do not reflect any of the social and economic structure of a particular country because the analyses are based on cross-country data.

The issue of equity-efficiency tradeoff has also received attention from economists. For the developed countries, consensus seems to be that more equality in distribution can be achieved only at the cost of efficiency. Feldstein found that the social security program in the U.S. reduced capital accumulation and distorted labor supply.

However, for the developing countries, contrasting views exist. According to Adelman and Morris, policies to achieve the maximum economic growth rate may be different from those policies most effective in improving income distribution. On the other hand, Ahluwalia concludes that the objectives of growth and equity may not be in conflict based on his cross-country analysis. However, he does not deny that increased investment in physical and human capital for poverty groups requires some sacrifice of aggregate output and increased costs to the high income groups. But he argues that this is a short run effect, and in the long run it may even benefit the upper income groups through "trickle up" effects of greater productivity and purchasing power.

The equity-growth tradeoff question was more systematically analyzed by Cline for six Latin countries. He analyzed the effect of redistribution from two aspects: effects on savings and effects on the composition of demand. He did not include the effects on productivity even though income redistribution may cause a positive effect on productivity for low income countries. Based on simulation experiments under alternative consumption functions, he concludes that the equity-growth trade off exists only minimally and with varying degrees across the countries studied. His empirical estimates of growth rate loss were one percent at the maximum, assuming these countries decreased the level of income inequality to that of Britain.

Williamson and Lindert analyzed the trend of income inequality in the U.S. since the late eighteenth century and concluded that the U.S. experience on a growth-equity trade-off is "very tenuous and pliable." They found that the periods of high (rising) inequality and high (rising) investment shares in the country were the periods in which per capita national income grew no faster than the twentieth century era of leveling of income, and slower capital accumulation. However, the more important factors they argue, are the sources of inequality and growth. In the nineteenth century, with fast growing labor supply and slow growing labor skills, considerable per capita income growth originated largely from capital accumulation and growth in inequality. But in the twentieth century, slower labor growth and faster growth in labor skills brought about the same per capita income growth with a decrease in income inequality for the U.S. In this regard, for developing countries with high population growth rates, family planning and technological progress seem to be important in achieving growth without increasing inequality.

Measures of Income Inequality

Measures of income inequality have been used to evaluate and compare income distributions between counties, between different time periods in the same country, between the results of alternative policies, and between different subgroups of the same population. Different measures of inequality may lead to different conclusions for the same distributional issue. An example is the regression result by Campano and Salvarote. They regressed income shares for the 40 percent and 20 percent lowest income groups against per capita income and the square of per capita income using cross country data. The estimated coefficients were found to support the Kuznets U hypothesis for the

40 percent but not for the 20 percent. This implies different measures of income inequality will lead to different conclusions both in empirical analysis and policy making.

The Lorenz curve or Gini concentration coefficient has been widely used as a summary measure representing income inequality. However, limitations of the measure have been pointed out. Morgan has emphasized that the Gini coefficient does not consider the income inequality caused by differences in age distribution. Paglin introduced a modified Gini coefficient incorporating age distribution and income differences by age group (age-Gini). Further modifications are suggested by Formby and Seaks. Another serious weakness is the ranking of different distributions of the Lorenz curve when the curves intersect. Moreover, the Gini coefficient is not invariant to the degree and number of income intervals in the grouped data (Sale). Theil has suggested a decomposable measure based upon the Lorenz curve, allowing the comparison of between group and within group inequality (Cowell).

Atkinson (1970) proposed an inequality aversion coefficient to incorporate the level of income equality preference. If the value is 0.5 - 1.0 this measure approximates the original Gini coefficient and if it approaches to zero it implies perfect equality. He concludes that the problem of intersecting Lorenz curves can be avoided in ranking different distributions if the inequality aversion coefficient value 1.5 - 2.0 is applied.

Nelson has suggested a different approach from the Lorenz-Gini type of measures. He proposes that the income ratio between the ninety-fifth and the fifth percentiles to be used as an inequality measure.

Most important in using inequality measures may be the value judgements associated with the measures. Basically, with the Lorenz-Gini related measures, an increase in incomes of the higher income classes with all other's income unchanged is interpreted as a worsening of the income distribution. Additionally, the Gini coefficient is not sensitive to changes in the income shares of the top and the bottom income classes, but sensitive to changes within the middle income classes. According to Nelson's measure, if the absolute income increase for the fifth percentile is less than for the ninety-fifth percentile, it results in no improvement in the income distribution. More seriously, both measures do not consider average income. If income for everyone increases by the same rate, the Gini coefficient will not change but the Nelson measure will indicate an increase in inequality.

For these reasons other statistical summary measures, including variance and coefficient of variation, are frequently used. However, these methods also have weaknesses and associated value judgements. Proportional increases in income for all individuals will increase inequality measured by variance, whereas the coefficient of variation is most sensitive to inequality of extreme values. Moreover, the variance does not satisfy Dalton's basic criterion as an inequality measure where inequality should increase when income is transferred from a poorer class to a richer class (Braun)[2]. In conclusion, the choice of the inequality measure in income distribution analysis may affect the policy implication. Therefore a multiple measure approach is useful in preventing possible bias.

Income Distribution, Economics, and General Equilibrium

Economists' attitude toward income distribution can be classified into two basic groups: the positivists and the normativists. The positivists approach

---

2 Braun ranked U.S. states' income inequality based on alternative measures. Oklahoma was ranked 41st using the Gini coefficient (higher rank means more equal distribution), 44th using the coefficient of variation, 40th to 45th using the Atkinson measure, and 36th using the Nelson measure (p. 401).

basically treats income determination and distribution as a market process and any decision to which value judgements are involved must be made by policy makers. More emphasis is given to the analysis of production efficiency in economic activities of society and less attention is paid to distributional aspects of the economic system.[3] Individual utilities or social welfare are not directly and objectively measurable, personal comparisons are meaningless.

According to the normativists approach, income distribution is not a pure market phenomenon: it depends, at least in part, on non-market processes. Moreover, it is difficult for an economist to sit in a completely value free seat. This may not be possible nor even desirable. Even though social welfare is not directly measurable, economists should contribute to the increase in the level of well-being of society. Less attention is paid to production efficiency and more emphasis is placed on the distribution of a given output.

However, it is true that whatever the economists position might be, modern governments in capitalist societies are engaged in various distributional activities, directly and indirectly. It is also true that decision made by policy makers through political processes are certainly influenced by free-market behavior.

It is believed that more meaningful information, to the public and thus for policy decision making, can be generated by simultaneous treatment of both production and distribution. There should be a balance in emphasis on production and distributions but with more emphasis on market processes than political processes in letting the public make final decision. In this regard, the general equilibrium approach is designed to trace out the impact of an

---

3 "Our primary problem is production. The common man or average family has a far greater stake in the size of our income than any possible distribution of income" (Henry C. Simons. Economic Policy for a Free Society. University of Chicago Press. 1948, p. 5. quoted in Bronfenbrenner).

exogenous shock to the market system and into the effects of distribution on production. In this dynamic world, a general equilibrium does not exist in any real sense, but with appropriate assumptions on both product and factor market behavior, information derived from a general equilibrium solution is helpful in interpreting the real world phenomenon. This study follows this line of approach.

CHAPTER III

FRAMEWORK OF GENERAL EQUILIBRIUM

General Equilibrium Defined

General equilibrium (GE) implies that all individual economic agents (and all subsets of the agents) in the system are in "equilibrium". To define "equilibrium" itself, assumptions are required for the behavior of agents and their initial conditions or constraints. An extremely simple conceptual GE model without production is the pure exchange model with two consumers and two goods represented by the Edgeworth box diagram (Figure 2). The behavioral assumption is utility maximization for the two agents and the constraint assumption is the amounts of goods each person owns initially which is represented by point O. GE for this exchange economy is the point E where the indifference curves for the two persons, I_A^* and I_B^*, are tangent to each other, where the offer curves originating from the initial point intersect with each other. GE prices are represented by the slope of the straight line, P^*P^*, tangent to both indifference curves. At this GE price ratio, exchanges are made between the two agents in such a way that the exchange brings about utility maximization for both with given initial amounts of goods to each. Under the convexity assumption for consumption sets, this equilibrium will be unique to the given setting. But this model doesn't have production activities.

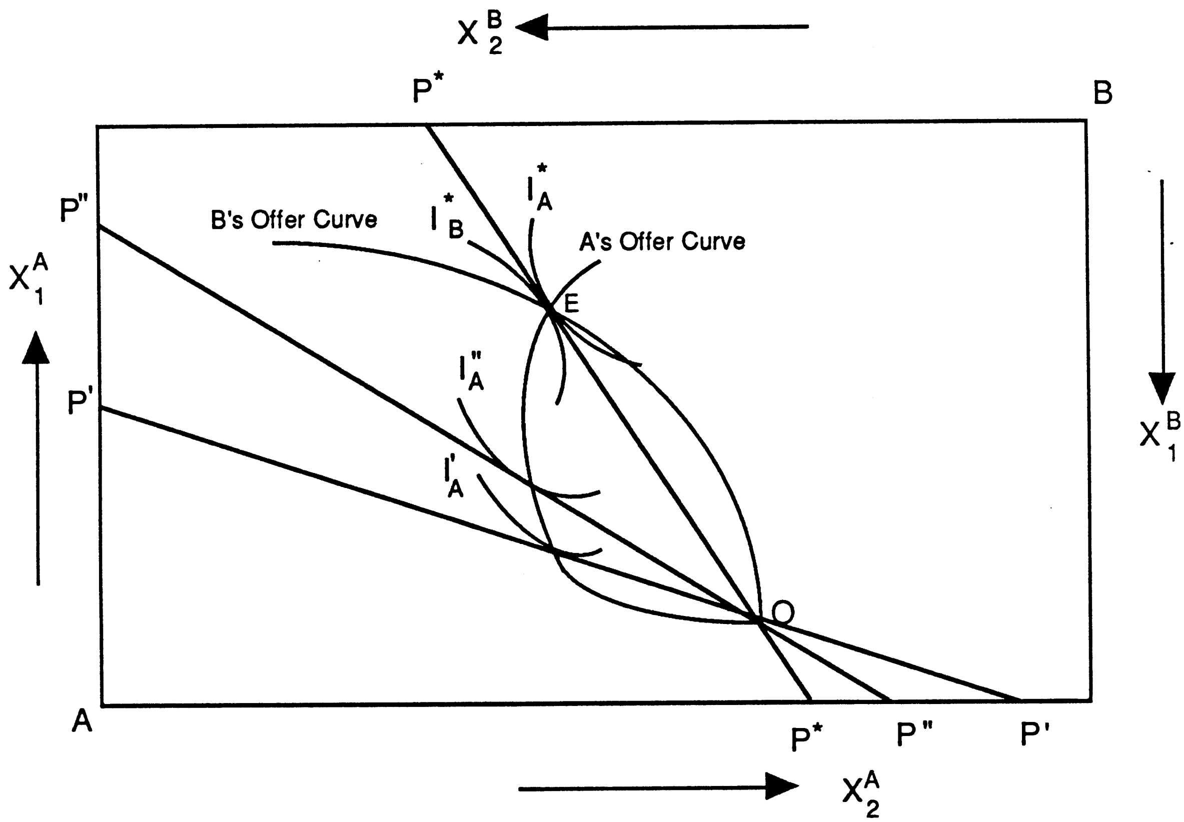

Figure 2: General Equilibrium Solution for Two Person, Two Good Economy

The Robinson Crusoe Economy (Varian) is another representation of GE with production in a world of one agent, two goods (consumption and leisure) and one input (labor) illustrated by Figure 3. In this setting, the one agent is both consumer and producer. In Figure 3, the distance $O\bar{L}$ represents the amount of labor available, out of which a part will be allocated as labor for production (measured by the distance from $\bar{L}$ in the direction to the origin), and the remaining part will be used as leisure. The vertical axis measures consumption (equal to production). A set of indifference curves between the two goods of leisure and consumption is I_1, I_2, and I^*. Assuming constant returns to labor, the straight line from $\bar{L}$ to C_3 represents the production function. Moreover, following the non-substitution theorem, the slope of the production function is also the real wage rate for determining equilibrium. The GE values for this economy are represented by the point E^*. The point E^* determines optimum values for all endogenous variables in the economy – prices of goods and factor, slope of $\bar{L}\,C_3$; optimum input use, $L^*\bar{L}$; optimum output, OC^*; and optimum consumption, OC^*; and optimum leisure, OL^*.

Notice that if the wage rate is the slope of $\bar{L}\,w_1$ or $\bar{L}\,w_2$, labor supply is the distance of $L_1\bar{L}$ or $L_2\bar{L}$, output is OC_1 or OC_2, consumption is OC_1' or OC_2', and the over-supply of product expressed by the distance $C_1'C_1$ or $C_2'C_2$.

Basic Structure of General Equilibrium Economy

A basic economic system with n commodities (denoted by a vector y) and m primary factors (vector x) is represented in Figure 4. Government and trade are not included in this basic structure. The number of producers and consumers is not specified. A set of firms produces n commodities combining m

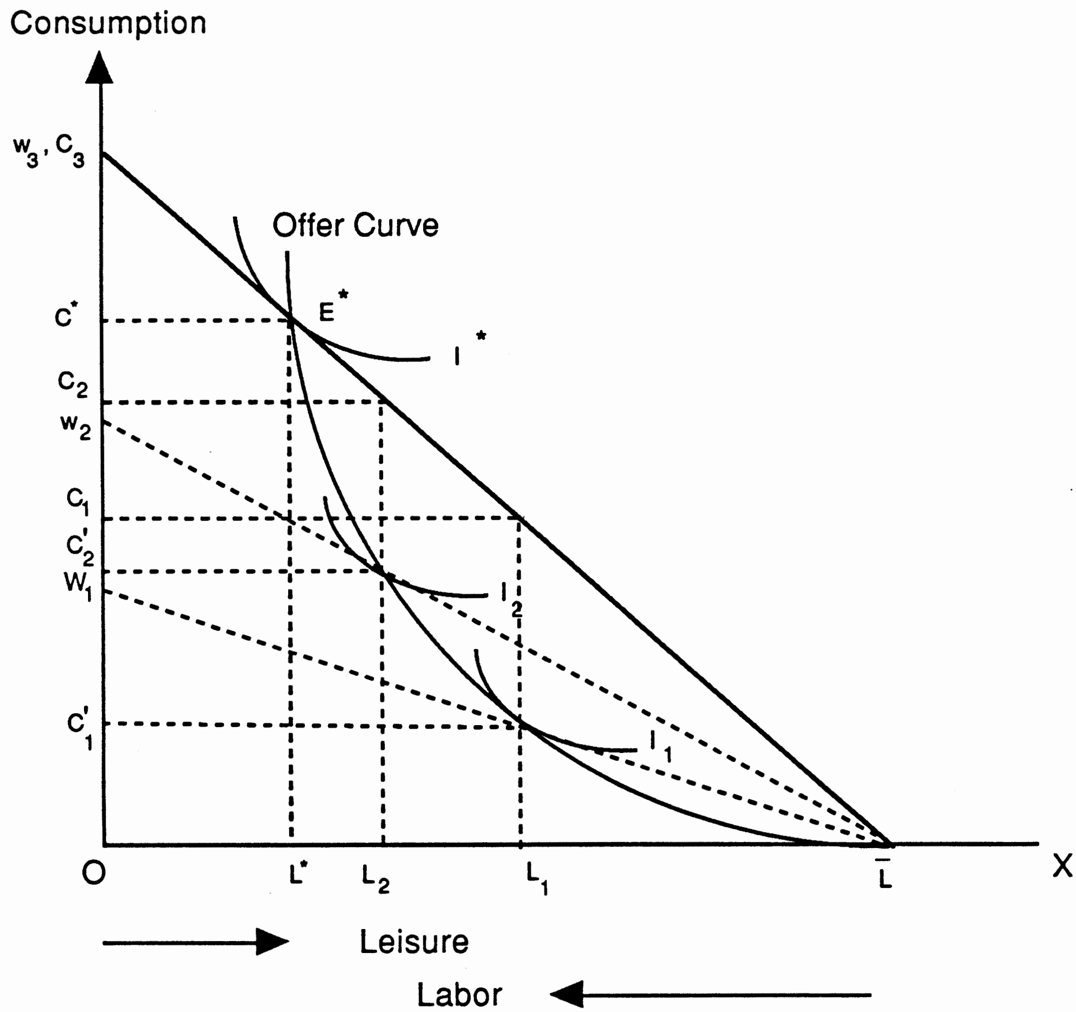

Figure 3: General Equilibrium Solution for Robinson Crusoe Economy

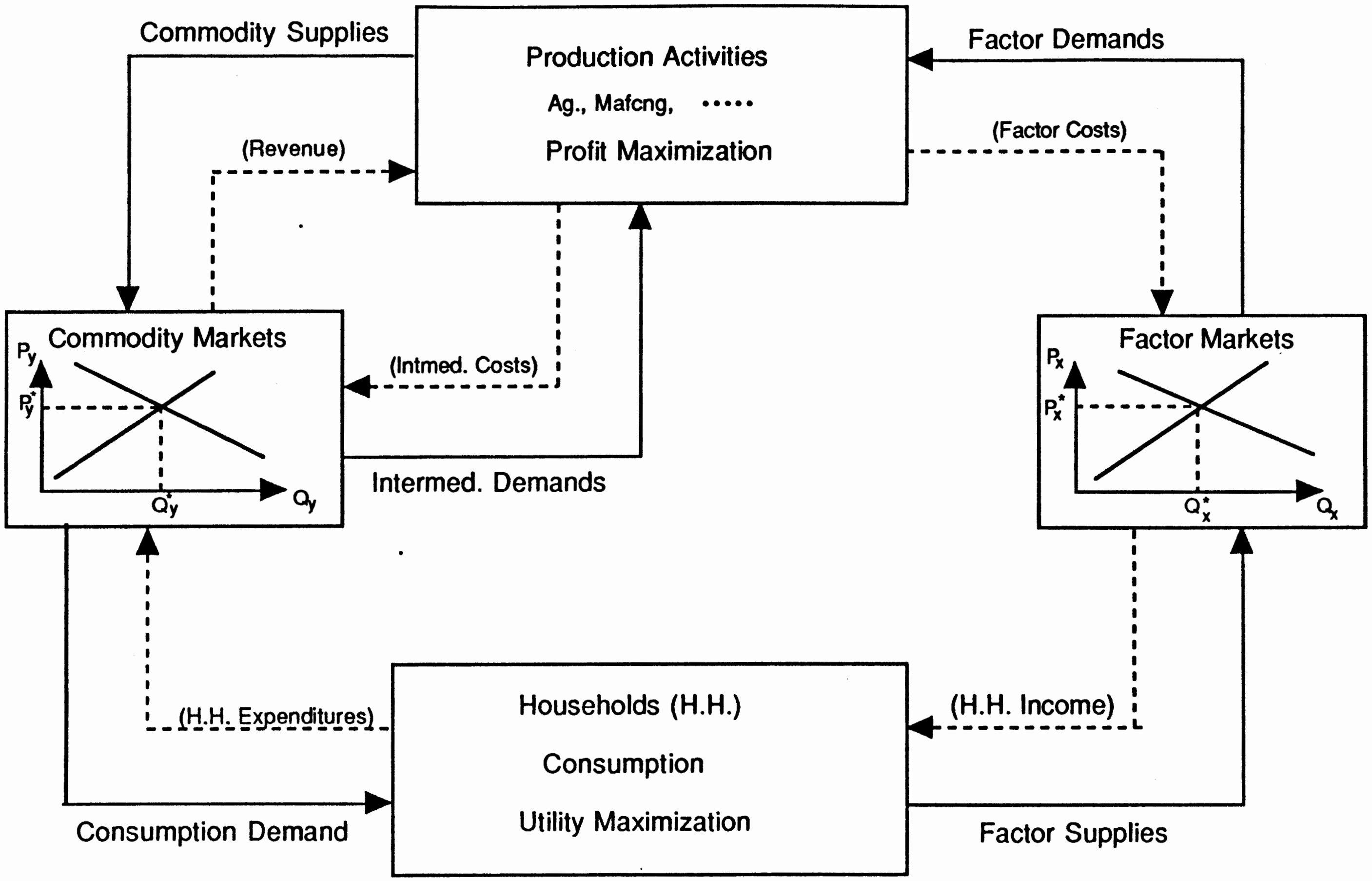

Figure 4. Basic General Equilibrium of an Economy

factors and n intermediate goods with given technology. Households consume n goods with given utility structure under the constraints imposed by incomes generated from selling factors of production they own. A total of n+m markets exist in the economy. Factor markets generate household incomes which are factor costs to firms. Commodity market prices determine household expenditures and revenues for the firms. The n+m equilibrium prices (denoted by vectors of P_y^* and P_x^*) that clear all markets with equilibrium quantities of Q_y^* and Q_x^* define the GE for the system.

The GE approach is Walarsian and is distinguished from a Keynsian macro economic model approach. Walarsian equilibrium is attained by the adjustment of the n+m relative prices such that all markets are cleared. No excess demand or supply exists in equilibrium. The Keynsian model, as usually employed, aggregates output into a single composite good with prices assumed fixed. The concern is with determination of the level of output at which aggregate demand and supply is in equilibrium for the commodity market. Hence, factor markets are not necessarily cleared allowing for some excess supply (Krauss and Johnson).

Ginsburgh and Robinson (1984) distinguish two broad families of empirical GE models; computable general equilibrium (CGE) models and activity general equilibrium (AGE) models. CGE models search for a price vector which clears all markets in the system specified by a set of behavioral rules for economic agents with given factor endowments and technology. Competitive markets are generally assumed. A solution vector that makes the excess demand function values for all commodities and all factors simultaneously equal to zero is considered the GE solution. The first order conditions for the economic agents' objective functions should be satisfied simultaneously, under the assumptions of well behaved production and utility functions. CGE models usually involve a number of nonlinear equations, but no inequality constraint or explicit objective function is required.

AGE models are cast in the format of mathematical programming with an explicit objective function to be optimized with a set of constraints (Ginsburgh and Robinson). A programming approach, as discussed in Hazel and Norton, maximizes the value of consumption or consumer surplus subject to various feasibility conditions specified by technology, resource availability, and marginal cost pricing. Under competitive markets, resources are fully employed and shadow prices for activities and resources are the GE commodity prices and factor returns.

Development of General Equilibrium Models

The concept of GE dates back to Adam Smith's invisible hand. However, a formal development of the GE model originated from Leon Walras, who formulated a mathematical model based on the idea of GE achieved by the invisible hand under competitive markets. A debate in the early twentieth century on allocative efficiency under socialism and capitalism centered around the feasibility of a centralized Pareto optimal allocation of resources (Whalley 1985). The proof of existence of a GE solution by Arrow and Arrow and Debreu in the 1950's opened the way to empirical GE models. The first operational GE model was developed by Leif Johansen in 1960 for the Norwegian economy. Wide applications of CGE models for various policy issues have been made during the last 15-20 years. Increased popularity of the CGE model in economic analysis was stimulated by the development of computer algorithms that have made numerical solutions easier and cheaper.

Shoven and Whalley (1984) provide a comparative analysis of 18 CGE models applied to tax and international trade policy. Devarjan, Lewis and Robinson list 48 references of empirical CGE models applied to 22 countries. Thorbecke, calling the CGE model the second generation consistency model compared with the fixed coefficient first generation consistency model, gives an in-depth evaluation of three early CGE models applied to developing countries. More recently, Decaluwe and Martens compared the basic structure of 73 empirical applications of CGE models for 26 developing countries, of which 67 applications were made in the 1980's indicating the rapid pace of growth in the literature. In the United States, CGE models have been applied for tax and trade policy evaluation since the early 80's (Shoven and Whalley). In 1990, a CGE model for the U.S. with emphasis on the agricultural sector was developed at the USDA (Robinson, Kilkenny, and Hanson). Hertel views the relatively recent appearance of CGE analysis in U.S. agricultural economics as a belated arrival.

Computable General Equilibrium

CGE models have been used in various areas of analysis including tax policy, trade policy, and energy policy. Generally, it is observed that tax and trade policy CGE models are more frequently used in developed countries. In developing countries, CGE models have been used for a wider range of issues from food policy to medium term or long term macro economic and micro economic issues. The reasons for this wider use in developing countries include (1) the lack of reliable time series data and thus an inability to apply econometric models, and (2) significant changes in policy regimes which call for models with structural changes (de Melo, 1988).

Because "general equilibrium" relies on basic characteristics of markets, the structure of CGE models used to evaluate different policies need not be too different. The differences come from the degree of elaboration in model specification for different components of the model including the level and manner of disaggregation for sectors, factors, and households. Moreover, most CGE models have some components of income distribution because consumption demand and savings are specified as functions of income, and income depends on the level of endogenous production.

Tax policy is the most widely applied area of research for CGE models. Following Harberger's (1962) two sector model for tax policy analysis, Shoven and Whalley (1972) analyzed effects of changes in capital income tax on labor income with two income groups (capital and labor). Additional applications of the CGE model have been made on tax related policy issues such as (1) changes in consumption tax, value added tax, and capital or labor taxes (Ballard et. al.); and (2) corporate tax cuts and increases in gasoline taxes (Goulder and Summers). The complexity of the model structure has increased considerably and includes some dynamics. For example, the model by Ballard et. al., has 12 income groups and 19 production sectors. In agricultural areas, Hertel and Tsigas (1988) have used a 1977 based U.S. CGE model to analyze impacts of eliminating the farm/nonfarm disparity in tax rates. Shoven and Whalley (1984) and Pereira provide surveys of the tax models.

Trade policy analysis is another widely applied area of CGE models. Trade focused models can be classified into multi-country models (Whalley, 1982; Manne and Preckel) and single country models (Dixon et. al., and Jeffrey and Urata). Basically these models are based on the Heckscher-Ohlin framework of trade theory.

One of the most comprehensive CGE models is for Australia with 114 commodities. The model, by Dixon et. al., shows that a 25 percent increase in all import tax rates will lead to a 0.21 percent decrease in total employment. The USDA/ERS CGE model of the U.S. developed by Robinson, Kilkenny, and Hanson (1990) was recently used in analyzing the impacts of alternative world trade environments on the U.S. agriculture (Hanson, Robinson, and Tokarick, 1990).

Regional CGE Models

Even though national CGE models are increasingly being used in diversified fields of economic analysis, regional applications are limited. Jones and Whalley (1985) have evaluated differential regional impacts of Canadian tariff policy with respect to U.S. - Canadian trade. By use of a two domestic region and three commodity interregional CGE model, they have concluded that unilateral abolition of Canadian tariffs will give negative welfare effects to Western Canada, and that only with restricted assumptions will there be a small gain in welfare for Eastern Canada. Harrigan and McGregor have analyzed the different general equilibrium results caused by alternative macro-economic closure rules by use of a one sector, two region model for Malaysia. Fisher and Despotakis have estimated the impacts of alternative energy taxes on the California economy by use of a regional CGE model. Morgan, Mutti, and Partridge have investigated how alternative tax policies affect inter-regional factor mobility in the U.S.

The main reasons for infrequent regional applications seem to be twofold. First, policy instruments available to regional governments are limited when compared with central governments. Price, monetary, trade, and income distribution policies are generally not applicable at the regional level. Thus the usefulness of the CGE model at the regional level is limited.

However, regional general equilibrium models can be used to evaluate impacts of central government policy or other exogenous shocks on specific regional economies. Because of differences in economic structure and factor endowments across regions, impacts of central government policies may vary significantly across regions. General equilibrium analysis is desirable when evaluating adjustments of regional economies through horizontal and vertical market interactions.

Second, regional CGE models lack appropriate data. As Dervis, de Melo, and Robinson have suggested constructing a consistent data base for an economy-wide model is a "nightmare." But the problem is more severe for regional models. For national models, income and input-output accounts are widely used as the data base for the production side. Consumer expenditure surveys, together with the national income accounts, are utilized as data sources for the demand side. These same data may be utilized for regional models but with more difficulties in the reconciliation process. However, many of the data problems in regional CGE modeling for the U.S. have been mitigated by the development of IMPLAN (IMpact Analysis for PLANning) and by the contributions of Rose, Stevens, and Davis.

Regional Adjustment Mechanisms

The basic structure of regional CGE model for this study is represented in Figure 5. Variables in rectangles are exogenous while those in ovals are endogenous. Arrows show the direction of flow of causal relationships. The plus (+) or minus (-) signs indicate how the affected variable moves relative to

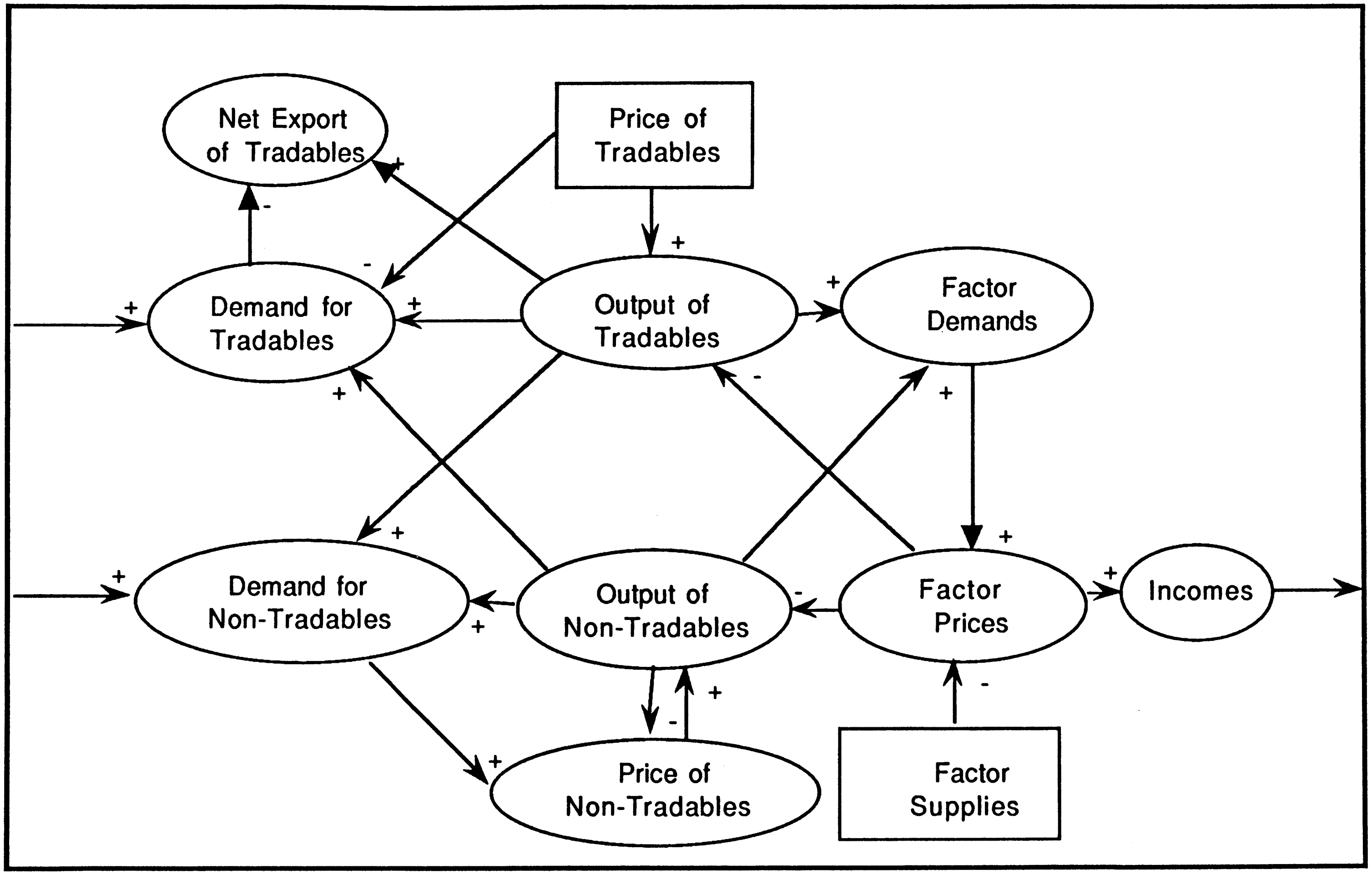

Figure 5. Causal Relationships Between Selected Variables of a Regional Economy

the causal variable. In other words, the plus sign indicates that the partial derivative of the affected variable with respect to the causal variable is positive.

A regional economy is assumed to produce and consume two distinct groups of commodities with respect to the rest of the world; tradables and non-tradables. Most commodities produced by the agriculture, mining, and manufacturing sectors are tradables. Outputs of construction, wholesale, retail, and service sectors are relatively close to non-tradables. The dimensions of the two vector variables sum to n reflecting an n-commodity space. Prices of tradables are exogenous while the prices of non-tradables are determined by the interaction of supply and demand within the region.

Suppose the price of a tradable commodity increases as a result of government policy. The initial first round effect is positive on production and negative on consumption of the commodity. But inter-industry relationships, and interdependencies between factor and commodity markets are important in analyzing the multidimensional income distribution effects of the commodity policy. Initially, stimulated production of the commodity shifts factor demands (land, capital, and labor with various types of skills) and the demands for both tradables and non-tradables for intermediate use. Factor prices rise with limited inter-regional factor mobility in the short run. Increases in factor prices imply negative feedback effects on production of both groups of commodities, and positive effects on regional incomes. Changes in factor prices influence income distribution and consumption demand for commodities. This change in commodity demands will affect production activities again. As part of this process, tax revenues for governments are determined with given tax rates (not included in the figure for simplicity). The magnitude of all changes depends on the corresponding elasticities.

Under the assumption of smallness of a region relative to the national economy, demand functions for tradables are perfectly elastic (otherwise downward sloping demand curves can be incorporated in the model). Changes in regional output do not affect national prices of tradables. Therefore the level of production in the region has no feedback effect on own price for tradable commodities, but it plays a significant role in the determination of factor prices and prices of non-tradables. For non-tradables, prices are endogenous to the regional economic system. Prices adjust to eliminate the excess demand for non-tradables in contrast to the market clearing by adjustment in trade for tradable commodities. This type of adjustment mechanism requires price differentials for non-tradables and factors between regions. Mobility of resources will reduce price differentials in the longer time horizon.

The assumptions on tradables and non-tradables are relaxed in model specification by introducing the concept of composite goods, which incorporates sectorwise elasticities of substitution between imported goods and regionally produced goods.

Social Accounting Matrix (SAM) and CGE Model

For CGE modeling, the Social Accounting Matrix (SAM) is utilized as a basic data framework. A SAM is a snapshot description of an economy representing the full circular flow of commodities and money during a certain time period i.e., the base year. It has the same accounts for columns and rows implying that a SAM is always square. Entries read down a column are expenditures by the column heading account to each of the corresponding row heading accounts, i.e., an entry in i'th row and j'th column represents amount of money paid by j'th column account to i'th row account. Therefore, the row sum and the column sum of each account is always the same. In this way, a SAM provides consistent information on overall structure of an economy by organizing data on production, income, and consumption in the base year.

In constructing a CGE model, it is considered that the economic system represented by the SAM is in general equilibrium. A CGE model is a system of equations representing theoretically consistent economic relationships between variables, and can reproduce the base year SAM with values for the exogenous variables prevailing in the base year. In this sense, the basic structure of a CGE model depends on the structure of the SAM.

The Schematic SAM set up for this study is presented in Figure 6. It has nine economic sectors; factors characterized by five types of labor, one type of land, and one type of capital; three geographic institutions represented as urban, rural agriculture, and rural non-agriculture; three household accounts categorized by low, medium, and high income classes; a government account; a condensed capital account; and a rest-of-world account.

The aggregated SAM used in this study is for the base year 1982. This base year is selected simply because of data availability. The latest IMPLAN data available until late 1990 was for the base year 1982. The selection of the base year is critical to SAM based CGE models because it determines the structural coefficients in the model. The year 1982 for Oklahoma was a peak of the economic boom as discussed in Chapter I. Therefore, the model results may be inappropriate to policy analysis for ordinary economic conditions. However, it is believed that information generated by the 1982 based model is useful in understanding the behavior of the overall economic system in Oklahoma. More detailed discussion on the construction of the SAM is presented in Chapter V.

	Sectors 1 • • • • • n	Factors 1 • • • S,land,capital	Institutions 1 • • • • T	Households 1 • • • • H	Government Account	Capital Accounts	Rest of World	Total
Sectors	Input-Output Table			Household Consumption Demand	Government Demand	Investment Demand	Commodity Exports	Commodity Demand
Factors	Value Added Matrix						Net Factor Payment Flows	Factor Income
Institutions		Institutional Income Distirubion			Transfer to Institutions			Institutional Income
Households			Household Income Distribution	Inter-Household Transfer Income Matrix	Transfer to Households			Household Income
Government Account	Indirect Taxes	Factor Taxes		Household Taxes				Government Revenue
Capital Accounts			Institutional Savings	Household Savings	Government Savings		Financial Net Inflow	Total Savings
Rest of World	Imports				Financial Net Outflow	Financial Net Outflow		Total Financial Outflow
Total	Commodity Supply	Factor Expenditure	Institutional Expenditure	Household Expenditure	Government Expenditure	Use of Savings	Total Financial Inflow	

Figure 6. Structure of the Oklahoma SAM.

CHAPTER IV

MODEL SPECIFICATION AND ASSUMPTIONS

The structure of applied general equilibrium models is basically similar with differences between models in the degree of complexity and emphasis on the policy issue in question (Shoven and Whalley, 1984). This is not surprising because the usual assumptions behind the models most often include competitive markets with full information, and profit or utility maximization behavior of economic agents. Based on these assumptions, the models are structured to allow prices of outputs and inputs to adjust until equilibria in all markets are attained. Such micro-foundations in a multi-sectoral framework are quite standard and well accepted especially for static analysis (Dewatripont and Michel). The model which follows is a variant of that developed by Dervis, de Melo, and Robinson.

Production

Consider a multi-sectoral economic system. Each of n production sectors produces only one homogeneous commodity using intermediate and primary inputs. A sector is an aggregation of many producers but the sector is treated as a single firm in the model. Technology used in each sector does not allow substitution between intermediate and primary factors nor between intermediate inputs produced by different sectors.

However, input substitution is possible among primary factors of labor, capital, and land. There exists only one type of capital and one type of land but s types of labor skill categories where substitution among different labor skills is allowed in the production processes of each sector. The incorporation of input substitution in production together with commodity substitution in consumption is the basic departure of CGE models from traditional input-output or fixed price multiplier analysis.

Thus the production function is described in a three stage process. First, the relationship between intermediate and primary inputs is described by a Leontief production function:

$$X_i = \min\left(\frac{INT_{ij}}{a_{ij}}, \frac{VAD_i}{v_i}\right) \qquad (4\text{-}1)$$

where X_i = industry output of sector i

INT_{ij} = amount of commodity j used in industry i

a_{ij} = direct requirement of commodity j to produce one unit of output in industry i,

VAD_i = value added in industry i, and

v_i = value added per unit of output in industry i.

This specification implies that the sectoral output X_i can be measured either by the level of intermediate goods used or value added, because the profit maximizing behavior will provide the equality represented in equation (4-2):

$$\frac{INT_{ij}}{a_{ij}} = \frac{VAD_i}{v_i} = X_i \qquad (4\text{-}2)$$

The coefficients of a_{ij} and v_i together determine the first level of production technology. With fixed values for those parameters, the model is basically characterized as static.

The next stage of modeling production technology is to describe substitutability between primary factors of labor, capital, and land, and finally the substitution among different labor skill categories. Note that no substitutability between intermediate inputs is embodied in the above equations.

Let value added and labor aggregation for sector i be represented by equations (4-3) and (4-4), respectively:

$$VAD_i = g_i(AGGLAB, CAP, LND) \tag{4-3}$$

$$AGGLAB = h_i(LAB_1, LAB_2, \ldots, LAB_s) \tag{4-4}$$

Value added has arguments of aggregated labor, capital, and land, whereas labor aggregation is a function of different labor skills. Combining equations (4-3) and (4-4) gives:

$$VAD_i = g_i[h_i(LAB_1, \ldots, LAB_s), CAP, LND] \tag{4-5}$$

With a specific functional form for equation (4-5), the value added function is completely defined and consequently the production function is complete with the support of equation (4-2).

In applied CGE models, constant elasticity of substitution (CES) or Cobb-Douglas functions are widely used to represent production technology. Out of 73 models studied by Decaluw'e and Martens, 59 models adopted either the Cobb-Douglas or CES type of production function. The CES function is useful because it does not impose the unitary elasticity of substitution of the Cobb-Douglas function. But the CES function requires an additional parameter of elasticity of substitution which can not be calibrated from the SAM. Furthermore, CES functions are most useful when there are no more than two factors in the model. The Oklahoma model uses Cobb-Douglas production functions.

Based on equations (4-2) and (4-5), output in sector i is:

$$X_i = \theta_i (\prod_s LAB_{is}^{\alpha_{is}}) CAP_i^{\alpha_{ik}} LND_i^{\alpha_{il}} \tag{4-6}$$

Note that the production function shift parameter θ_i reflects the combined effects of equations (4-4) and (4-5). It is inversely related to the value added coefficient v_i in equation (4-2) implying smaller v_i leads to larger θ_i. Even though the functional form of equation (4-6) is typically Cobb-Douglas, two types of isoquants exist within the production system.

In the first stage, isoquants for intermediate inputs and primary factors are represented by panel (a) of Figure 7. In the second stage, the relationship between different intermediate inputs and between different primary factors are modeled as panel (a) and panel (b), respectively. Finally, panel (b) represents isoquants that relate labor skill categories to each other.

Determining Production Function Parameters

It is assumed that each production sector exhibits constant returns to scale at the competitive equilibrium. Thus the production function specified in equation (4-6) is homogeneous of degree one in primary factors. Parameter values of the production function are determined by use of the homogeneity property.

The number of parameters, under the configuration of equation (4-6), is the same as the number of primary factors plus the number of labor categories. One of the parameters is a shift parameter and the others are partial elasticities of production.

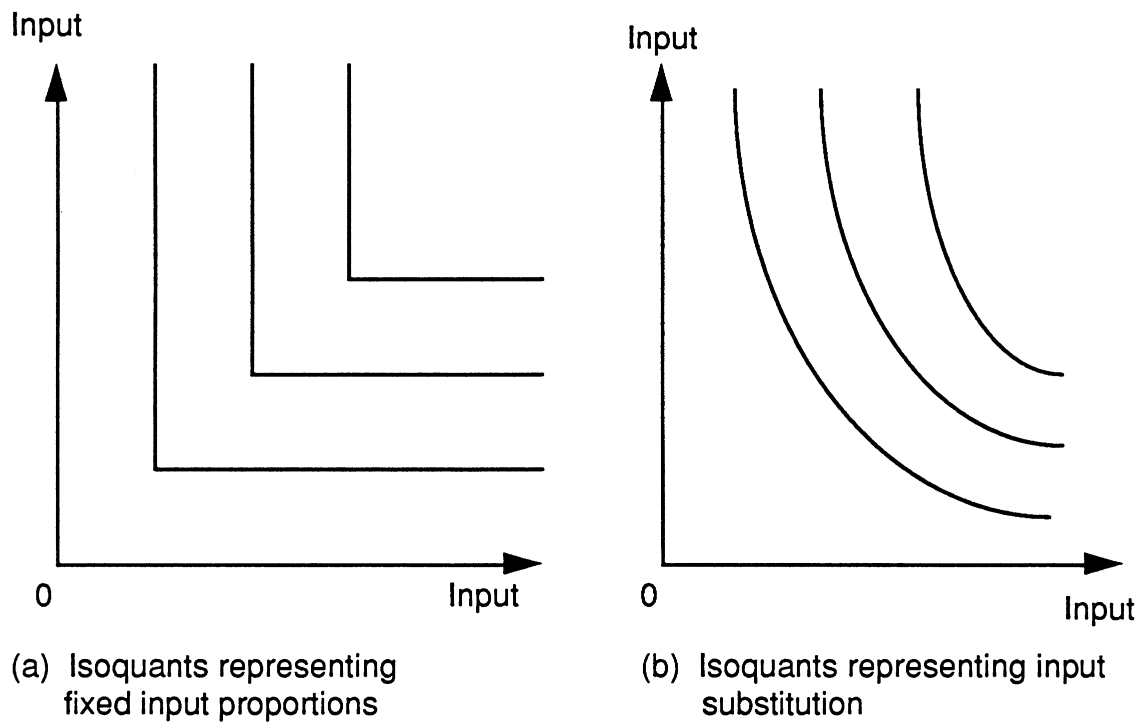

Figure 7. Two types of isoquants used in production function specification.

Consider a constant returns to scale production function:

$$y = f(x_1, x_2, \ldots, x_n) \tag{4-7}$$

where y denotes output and the x_i are inputs. If y is homogeneous of degree one, and if price of each x_i, Px_i, equals it's value of marginal product then the sum of the partial elasticities for all inputs will sum to one by Euler's theorem:

$$\sum_i \left(\frac{\partial y}{\partial x_i} \frac{x_i}{y} \right) = 1 \tag{4-8}$$

First order conditions for competitive production holds that the marginal product of each input should be equal to the ratio of input to output price at equilibrium:

$$\frac{\partial y}{\partial x_i} = \frac{P_{x_i}}{Py} \tag{4-9}$$

Substitution of equation (4-9) into equation (4-8) yields;

$$\sum_i \frac{P_{x_i} x_i}{P_y\, y} = 1 \tag{4-10}$$

Equation (4-8) and (4-10) imply that the partial elasticity of each input in the Cobb-Douglas production function is equal to the share of the output going to the corresponding input.

Therefore, the parameter values for the exponents in equation (4-6) are derived from the value added matrix in the SAM. Given these parameter values, θ_i can be calculated using the base year values for the variables in the equation.

Output Price

Even though the production function was specified such that there is only one firm in each sector, prices of inputs and outputs are given to the firm because of the assumed competitive markets. Firms in each sector are price takers, they can buy inputs and sell outputs as much as they want at given prices. No resource constraints exist to the individual firm.

Output prices are expressed as regional prices which are the prices of commodities produced in the region, and they are different from exogenous national prices.

For small and completely open regions, most commodity prices are exogenous. However, there are three possibilities where it is more appropriate to treat commodity prices endogenously: (1) existence of nontradable commodities, (2) highly specialized regional production, and (3) existence of product differentiation between regions. The first means a change in output in the region influences the regional price only and there exists a commodity price differential between the region and the rest of the nation. The second case suggests that the national price is affected by the regional output thus implying the small region assumption does not fit for the commodity. The last case causes the "cross hauling" (export and import occurs at the same time for the same commodity group) in regional trade which will be discussed in relation to import demand.

Due to the existence of the cross hauling, material inputs used by a firm are composed of imported and regionally produced goods. Therefore input prices are expressed as composite good prices weighted by the sum of regional output prices and imported good prices (which will be discussed later).

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

$$NPX_i = RP_i - \sum_j a_{ij} P_j - idtx_i RP_i \qquad (4\text{-}11)$$

where NPX_i = net price of commodity i

RP_i = regional price of commodity i produced in the region

P_j = composite good price of commodity j

$idtx_i$ = indirect tax rate for sector i.

Under Walrasian general equilibrium framework, relative prices are assumed to be the only force that determines the flow of commodities and factors.

Therefore, all prices are expressed in terms of relative value with respect to a base year price of 1, whether they are exogenized or endogenized prices.

Intermediate Inputs

The Leontief input-output technology assumed in equation (4-2) determines demand for intermediate input i ($INTD_i$):

$$INTD_i = \sum_j a_{ij} X_j \qquad (4\text{-}12)$$

The coefficients a_{ij} are derived from the transpose of the use matrix in the SAM such that $\sum_j a_{ij} = 1$ for all i. Because the transposed use matrix has production sectors as rows and commodities as columns, $INTD_i$ in equation (4-12) expresses the sum of the demand for commodity i by all production sectors.

Factor Markets

Labor Demand and Wage Rate

With given production technology and value added prices, primary input demand is determined by profit maximizing behavior for each production sector. The profit function for sector i is defined as:

$$PRFT_i = NPX_i X_i - \sum_s (WAGE_s LAB_{is})$$

$$- LNDRNT_i LND_i - CAPRNT_i CAP_i \qquad (4\text{-}13)$$

where $WAGE_s$ = wage rate for labor skill category s

$LNDRNT_i$ = rental price of land used in sector i

$CAPRNT_i$ = rental price of capital stock used in sector i.

Notice that the wage rate in the above equation implies inter-sectoral labor mobility. Thus wage for each labor skill category must be equalized across the production sectors. Take the first derivative of the profit function with respect to each labor skill and set it's value equal to zero for the local maximum. Solving the first order conditions gives demand for labor skill s by industry i:

$$NPX_i \frac{\partial X_i}{\partial LAB_{is}} = WAGE_s \tag{4-14}$$

or specifically

$$LAB_{is} = \alpha_{is} NPX_i \, X_i / WAGE_s \tag{4-15}$$

Aggregate demand for labor skill s is the sum of the demand by all industries:

$$LAB_s = \sum_i LAB_{is} \tag{4-16}$$

With the endogenously determined labor demand, the labor market equilibrium condition is specified as:

$$\sum_i LAB_{is} - \overline{LAB}_s = 0 \tag{4-17}$$

where $\overline{LAB}_s$ is exogenous supply of labor skill s. A key assumption of the above approach is that full employment is always attained by the adjustment of wage rate with the perfectly inelastic labor supply for a given time period.

In contrast to the above neoclassical closure rule, wage rate can be treated exogenously following the Keynsian closure rule. In this case, labor supply is endogenized and the model simulation will show the level of unemployment. Equations (4-18) and (4-19) can be used as labor market specifications following the Keynsian approach:

$$LAB_{is} = \sum_{i} \alpha_{is} \; NPX_i \, X_i \, / \, \overline{WAGE_s} \tag{4-18}$$

$$UNEMP_s = \overline{LAB}_s - \sum_{i} LAB_{is} \tag{4-19}$$

where $UNEMP_s$ indicates the unemployment level for labor skill s.

Another approach is to incorporate the efficiency wage hypothesis into the model. According to this hypothesis, the labor market can be classified into two parts: primary and secondary labor markets. The former market is for unskilled labor, and the latter market is for skilled labor. The efficiency wage hypothesis states that the primary labor market receives positive utility from shirking. Employers need to bear supervising cost to prevent shirking. If unemployment exists, utility of those workers from shirking will be reduced. Therefore profit maximizing employers pay wages higher than the marginal revenue product for labor in an effort to minimize supervisory cost or to discourage shirking. With a wage rate above the marginal product, unemployment can be created at equilibrium. Labor market equilibrium with unemployment created by an efficiency wage rate is used as a worker discipline device (Shapiro and Stiglitz; and Akerlof and Yellen).

For these labor markets, the Keynsian closure rule seems appropriate and consistent with real world situations where the government regulated minimum wage rate and unionized employment contracts bring about labor market equilibrium but with unemployment in the primary labor market. On the other hand, the neoclassical approach may be followed for secondary labor markets assuming that the wage-productivity relationship is weak and that a market clearing wage rate prevails.

There is no clear-cut theoretical justification or agreement on the choice between the neoclassical and Keynsian approach, and thus it largely depends on the modeler's "general view of the world" (Dewatripont and Michel). The current model for Oklahoma fallows a mixture of the two, i.e., the neoclassical labor market closure for skilled labor, and Keynsian for unskilled labor. However, this result will be compared with the results from the former two approaches.

Land Market

Demand for land and capital can be derived in the same manner as labor demand. Equation (4-20) represents a specific demand function for land by industry i (LND_i):

$$LND_i = \alpha_{il} \, NPX_i \, X_i / LNDRNT_i \qquad (4\text{-}20)$$

Assuming that land is "mobile" across production sectors, the rental price of land will be the same in each sector. The current study assumes that land is used only in agricultural production. Thus the production function parameter α_{il} is zero for the non-agricultural sectors. The market clearing equilibrium condition is given by:

$$\sum_i LND_i - \overline{LND} = 0 \qquad (4\text{-}21)$$

where $\overline{LND}$ denotes the region specific fixed supply of land.

Capital Market

Equalizing marginal value product of capital with rental price of capital stock for each production sector maximizes profit. Let $CAPRNT_i$ be rental price of capital stock in sector i. Demand for capital in the model is specified by:

$$CAP_i - \alpha_{ik} NPX_i X_i / CAPRNT_i = 0 \qquad (4\text{-}22)$$

Market equilibrium conditions in the model may differ depending on the assumption about sectoral mobility of capital stock. Two extreme assumptions are perfect mobility and complete immobility represented by equations (4-23) and (4-24), respectively, where $\overline{CAP}$ is total capital stock for the economy and $\overline{CAP_i}$ is capital stock in sector i, both exogenously given:

$$\overline{CAP} - \sum_i CAP_i = 0 \qquad (4\text{-}23)$$

$$CAP_i - \overline{CAP_i} = 0 \qquad (4\text{-}24)$$

The assumption on capital mobility depends on the length of time allowed for the system to attain a new equilibrium after an external shock. Thus region specific but inter-sectoral capital mobility in equation (4-23) may be used for evaluating a policy impact when a relatively longer time period is required for adjustment. The sector specific capital market represented in equation (4-24) may be relevant otherwise. The current Oklahoma model follows the second approach.

Another approach may be useful with respect to mobility when the model has several subcategories of capital. For example, suppose there are two categories of capital stock; agricultural and non-agricultural. And further assume that the former is mobile only among sub-sectors producing agricultural products, and the latter among non-agricultural sub-sectors. Let AGCAP and NAGCAP be demand for agricultural capital and non-agricultural capital, respectively. Then the demand functions are:

$$AGCAP = \sum_i (agk_i \, CAP_i) \tag{4-25}$$

$$NAGCAP = \sum_i (nagk_i \, CAP_i). \tag{4-26}$$

Note that agk_i and $nagk_i$ are elements of the summation vector. For example, agk_i are 1's for agricultural sectors and 0's for nonagricultural sectors.

With fixed amounts for both categories of capital stock, equilibrium conditions can be specified as the following:

$$AGCAP - \overline{AGCAP} = 0 \tag{4-27}$$

$$NAGCAP - \overline{NAGCAP} = 0. \tag{4-28}$$

Income Determination and Distribution

Functional Income Determination

Functional incomes for the resources in Oklahoma are derived from two sources: regional production activities and out of region activities. Some workers in the region may be employed by producers located outside the region. Some resources from out of the region may be used in regional production.

Capturing region specific resources and activities is important in relation to the feedback effect from consumption to production. This is true especially when the region under concern is small and interregional resource flow and consumption demand must be investigated in relation to central place theory.[1]

Because of data availability and the large size of the region, the current Oklahoma model ignores this type of interregional resource use. Consideration is paid only to labor income generated from outside the region and is regarded as fixed at the base year level. Therefore, the assumption for this treatment is that only regional resources are used in regional production, but there exists a fixed amount of labor income transferred from outside the region.

As indicated by factor market equilibrium conditions, functional income is determined by the endogenous factor prices and exogenous endowments. Let income for labor skill s be denoted by $YLAB_s$, transfer income by $TRLABY_s$, and total labor income by TOTYLAB:

$$YLAB_s = WAGE_s \, LAB_s + TRLABY_s \tag{4-29}$$

$$TOTYLAB = \sum_s YLAB_s \tag{4-30}$$

Similarly land income, YLND, is determined by rental price of land multiplied by quantity of land used by all industries:

$$YLND = \sum_i LND_i \, LNDRNT \tag{4-31}$$

Capital income, YCAP, is treated as the residual of total revenue net of intermediate cost and indirect tax and minus payments for labor and land:

$$YCAP = \sum_i NPX_i \, X_i - \sum_s (YLAB_s - TRLABY_s) - YLND \tag{4-32}$$

---

1 For central place theory see Flood and Schreiner, and Marshall.

If competitive equilibrium exists, the economic profit must be zero. Therefore, by Euler's theorem, the result of equation (4-32) must be identical to that of equation (4-33) because the production function is homogeneous of degree one, and $CAPRNT_i$ represents marginal productivity of capital employed by sector i:

$$YCAP = \sum_i CAP_i \, CAPRNT_i \tag{4-33}$$

Institutional and Household Income Distribution

Functional income is determined by factor demand, based on production technology and profit maximizing behavior, and factor endowment. However, institutional and household income is determined by the ownership of those factors by each institution and household group. Sector and geographic institutions are defined for this study and include agriculture, rural nonagriculture, and urban.

It is impossible, however, to know how much labor by skill, land, and capital stock are owned by each institution. Nonetheless, it may be considered that institutional income distribution presented in the benchmark SAM represents the structure of factor ownership in the region. With the assumption that ownership structure remains unchanged in the short run, factor income (row sum of factor account) can be translated into institutional income, and then institutional income can be translated into household income. For example, institutional income distribution coefficients are derived from the base year SAM by dividing each element of the institutional income distribution matrix by its column sum. These coefficients represent the share of each factor income distributed across the institution. Similarly, household income distribution coefficients are derived and used to allocate the institutional income (row sum of institutional accounts) across the household income group.

Based on the above approach, institutional income is determined by the sum of factor income plus government transfer to each institution. Incomes from each factor are reduced by any corresponding factor tax. Depreciation and retained earnings are subtracted from capital income.

Institutional income is defined as:

$$YINST_t = \sum_s b_{ts} \, YLAB_s \, (1\text{-}sstx_s) + w_t \, YCAP \, (1 - ktx - dprt)$$

$$+ z_t \, YLND \, (1\text{-}ltx) + TRINST_t \qquad (4\text{-}34)$$

where $YINST_t$ is institutional income; b_{ts}, w_t, and z_t are institutional income distribution coefficients for labor, capital, and land income, respectively. Notice that they are partitioned matrices of the whole income distribution coefficient matrix where $sstx_s$, ktx, and ltx denote the tax rate for social security payments, capital income tax and land income tax; dprt is the rate of depreciation and retained earnings; and $TRINST_t$ denotes exogenous transfers from government.

Household income is derived from three sources: distribution from institutional income, transfer from government, and interhousehold transfers. The former two are treated as taxable income and the latter is added to calculate disposable income:

$$TXHHY_h = \sum_t d_{ht} \, YINST_t + TRGHH_h \qquad (4\text{-}35)$$

$$HHY_h = TXHHY_h \, (1 - hhtx_h) + TRHHR_h \qquad (4\text{-}36)$$

where $TXHHY_h$ = taxable income of household group h

d_{ht} = household income distribution coefficients which map institutional income onto household income

$TRGHH_h$ = exogenous government payment to household group h

HHY_h = disposable income to household group h

$hhtx_h$ = income tax rate to household group h

$TRHHR_h$ = interhousehold transfer income (row sum of inter-household income matrix of the SAM).

Government Revenue and Household Saving

Government revenue is the sum of the various taxes; indirect tax, social security tax, capital income tax, land income tax, and household income tax. Notice that federal, state, and local governments are aggregated into one single account. Government revenue, YGVT, is:

$$YGVT = \sum_i idtxRP_iX_i + \sum_s sstx_s YLAB_s + ktxYCAP + ltx\,YLND + \sum_h hhtx_h\, TXHHY_h \qquad (4\text{-}37)$$

For household saving, it is assumed that each household group saves a fixed proportion of its disposable income for future consumption. Therefore, the marginal savings rate equals the average savings rate in the short run.

The savings rate is to be calibrated from the SAM as a proportion of saving out of total income rather than disposable income:

$$HHSAV_h = mps_h\,(TXHHY_h + TRHHR_h) \qquad (4\text{-}38)$$

Given the savings, the household expenditure for commodity consumption, HHE_h, is simply the residual; disposable income less savings and inter-household transfers:

$$HHE_h = HHY_h - HHSAV_h - TRHHC_h \tag{4-39}$$

where $TRHHC_h$ is a column sum of the interhousehold transfer matrix.

Commodity Markets

Consumer Demand

Consumer demand functions are derived from utility theory. The fundamental basis of utility theory is that if consumer preferences satisfy the axioms of complete ordering, transitivity, continuity, and strong monotonicity then there exists a single valued continuous utility function that represents those preferences (Varian). Further, diminishing marginal rate of substitution is assumed such that the second derivative of the utility function with respect to consumption is negative.

Due to the ordinal character of describing preferences, any function which is monotonically increasing at a decreasing rate can be used as the utility function. Hence, any strictly increasing transformation of a utility function is also regarded as a utility function representing exactly the same preferences.

In this study, the Stone-Geary utility function that leads to a linear expenditure system is used. The demand system derived from the Stone-Geary utility function satisfies the general properties required; homogeneity of degree zero in all prices and income, symmetry of the cross-substitution effects, adding up condition, and negativity of direct substitution effect. Commodity demand functions used in this model are derived below.

Consider a Cobb-Douglas type utility function which describes utility level determined by the quantity of each good consumed above some fixed minimum level:

$$U_h = \prod_i (D_{ih} - \gamma_{ih})^{\beta_{ih}} \tag{4-40}$$

where, U_h = utility level of household group h

D_{ih} = amount of commodity i consumed by household group h, and

γ_{ih} and β_{ih} are parameters.

Notice the restrictions on the parameters: $0 \leq \gamma_{ih} \leq D_{ih}$ because γ_{ih} is a minimum level of consumption and β_{ih} is non-negative to satisfy the properties of the utility function. Stone-Geary utility function is derived following log-transformation of the above equation:

$$U_h = \sum_i \beta_{ih} \log (D_{ih} - \gamma_{ih}) \tag{4-41}$$

Given a fixed amount of income that can be allocated to consumption, HHE_h, household group h faces the following constrained maximization problem:

Maximize $U_h(D_{ih})$

Subject to $HHE_h - \sum_i P_i D_{ih} = 0$

The first order conditions for the corresponding Lagrangian will yield:

$$\frac{\beta_{ih}}{D_{ih} - \gamma_{ih}} = \lambda_h P_i \tag{4-42}$$

$$\sum_i P_i D_{ih} - HHE_h = 0 \tag{4-43}$$

Solving equation (4-42) for β_{ih}, summing β_{ih} across i=1, . . ., n, and solving for the Lagrangian multipliers yields:

$$\lambda_h = 1/(HHE_h - \sum_i P_i \gamma_{ih}) \tag{4-44}$$

Substitution of (4-44) into (4-42) yields:

$$P_i D_{ih} = P_i \gamma_{ih} + \beta_{ih} (HHE_h - \sum_j P_j \gamma_{jh}) \tag{4-45}$$

Note that the term $P_i D_{ih}$ represents the expenditure on commodity i by household group h and β_{ih} is known to be the corresponding marginal expenditure share. The first derivative of the expenditure function with respect to total expenditure (HHE_h) is β_{ih}. Dividing through the above equation by P_i gives the linear expenditure system (LES) expressed as:

$$D_{ih} = \gamma_{ih} + \frac{\beta_{ih}}{P_i} (HHE_h - \sum_j P_j \gamma_{jh}) \tag{4-46}$$

To compute the consumption demand using equation (4-46) values are needed for γ_{ih} and β_{ih} in addition to data on prices and total consumption expenditure by each household group. However, γ_{ih} is not directly estimated from empirical data. Marginal budget shares β_{ih} can not be calculated from only one period data set for the base year. With a full set of expenditure elasticities and a single own or cross price elasticity, equation (4-46) could be completely implemented by use of the Frisch parameter (Pyles).

Under the situation where such information is not available, a simplified version of the Stone-Geary LES can be applied (Robinson, Kilkenny, and Hanson).

Rearranging equation (4-46) yields:

$$\gamma_{ih} - \frac{\beta_{ih}}{P_i} \sum_j P_j \gamma_{jh} = \frac{HHE_h}{P_i} \left(\frac{P_i D_{ih}}{HHE_h} - \beta_{ih} \right) \tag{4-47}$$

The term $P_i D_{ih} / HHE_h$ is the share of expenditure on commodity i by household group h. If it is assumed that the average budget share equals the marginal budget share β_{ih}, the result is:

$$\beta_{ih} = \frac{P_i D_{ih}}{HHE_h} \tag{4-48}$$

$$\gamma_{ih} - \frac{\beta_{ih}}{P_i} \sum_j P_j \gamma_{jh} = 0 \tag{4-49}$$

Because $0 < \beta_{ih} < 1$, the value of γ is zero for each commodity and household.

From equation (4-46), the demand for good i by household group h reduces to equation (4-50):

$$D_{ih} = \beta_{ih} HHE_h / P_i \tag{4-50}$$

Substituting equation (4-39) for HHE_h we have commodity demand in terms of prices and income defined by equation (4-51):

$$D_i = \sum_h \beta_{ih} (HHY_h - HHSAV_h - TRHHC_h) / P_i \tag{4-51}$$

The coefficients β_{ih} are readily available from the benchmark SAM. Even though the above equation is used in the current study, the assumption behind equation (4-50) is somewhat unrealistic because it implies that income elasticities of expenditure for all commodities are unity. Although the result is not appropriate for dynamic analysis, the assumption does not pose a serious problem for a comparative static analysis because different expenditure patterns for different household groups are embodied in the model.

Government Demand and Investment Demand

Demand for commodities by the government in this study is treated as exogenous in contrast to the endogenous treatment of government revenue. The model allows policy simulations with respect to alternative government expenditure patterns.

Investment demand for commodities is also exogenous to the system because the basic purpose of the current study is to evaluate the short run impact of disturbances in commodity market prices on factor markets.

If the purpose is to evaluate the effect of changes in investment for a sector (e.g. investment by sector of destination), investment needs to be converted into commodity demands (by sector of origin). The general approach for the conversion is to use a capital composition matrix. (See Dervis, de Melo, and Robinson).

Import Demand and Composite Price

Conventional trade theory assumes homogeneity of commodities across imported and domestically produced goods. Therefore, imported goods are perfect substitutes for domestic goods. This approach leads to highly specialized regional production. The equilibrium solution for small open regions indicates that regions produce commodities in which they have comparative advantage under the assumption of infinite elasticity of substitution.

To allow regional production of commodities with comparative disadvantage, another extreme assumption is made that imported goods are perfect complements of regionally produced goods. However, this zero substitution elasticity implies either (1) the price ratio between imported and regionally produced goods is constant for all commodities or (2) whatever the relative price might be, the rate of change in quantity demanded is equal for both goods. Consequently, the region will import a fixed percent of total quantity demanded for each commodity.

A more realistic approach is to assume that the elasticity of substitution between imported and domestic products is greater than zero but less than infinity following Armington (1969). The basic concept of the Armington model was originally developed to evaluate international trade. A commodity traded between n different countries must be treated as n different goods due to the heterogeneity in commodity characteristics. It is impossible to define commodities representing all attributes of each good traded. This assumption is more relevant than the other two extreme cases because of the generally observed cross-hauling, i.e., import and export of the same commodity at the same time, both internationally and regionally. With highly aggregated commodity or production activities, the Armington approach is particularly appropriate and widely used in CGE models.

Following the Armington approach, the concept of composite goods is introduced. Commodities in the regional market are treated as a mix of imported and regional products. The quantity of composite good demanded in the regional market is described by the following CES trade aggregation function:

$$Q_i = \psi_i \left[\delta_i MQ_i^{-\rho_i} + (1-\delta_i) RQ_i^{-\rho_i} \right]^{-\frac{1}{\rho_i}} \tag{4-52}$$

where Q_i = composite commodity demanded

MQ_i = imported commodities demanded

RQ_i = regional products demanded

ψ_i = constant shift parameter

δ_i = share parameter

ρ_i = parameter associated with elasticity of substitution.

The trade elasticity of substitution between imported and domestically produced goods (σ_i) is represented by $1/(1+\rho_i)$.

Given equation (4-52), buyers in the regional market are faced with the following optimization problem:

Maximize $Q_i\,(MQ_i, RQ_i)$

Subject to $P_iQ_i - PM_i\,MQ_i - RP_i\,RQ_i = 0$

where P_i = price of composite goods

PM_i = exogenous price of imported goods i.e., national price.

Setting up the Lagrangian for this constrained maximization problem, and solving for the first order conditions results in the following import demand equation as a function of relative price and elasticity of substitution:

$$MQ_i = RQ_i \left(\frac{RP_i}{PM_i}\right)^{\frac{1}{1+\rho_i}} \left(\frac{\delta_i}{1-\delta_i}\right)^{\frac{1}{1+\rho_i}} \tag{4-53}$$

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

$$P_i = [RP_i\,RQ_i + PM_i\,MQ_i] \,/\, Q_i \tag{4-54}$$

Notice that national prices (PM_i) are exogenous to a small region so that these prices are applied to all imported goods. In contrast, the regional prices (RP_i)

are endogenous except for the sectors to which commodity market shocks are given. In sectors with exogenous RP_i, only quantities are allowed to adjust to attain the market equilibrium.

For implementation of the import demand function, the share parameter δ_i and the shift parameter ψ_i are calculated from benchmark SAM data with extraneous estimates for the elasticity of substitution. However, the elasticity estimates are seldom available, especially at the regional level. Therefore, sensitivity analyses are conducted to find a set of reasonable values for σ_i (and thus ρ_i) by assigning alternative values for the parameters and evaluating the model's performance.

In this process, the parameter values are not completely arbitrary because one can make use of the properties of the CES function according to the characteristics of commodity groups. It is fairly reasonable to assume that substitution is relatively easy for tradables, but not perfect. For a given Q_i the demand for imports and regional products depend on the relative price, and an interior solution is most likely. However, if import price were extremely high then import demand would be close to zero. Therefore indifference curves are expected to be convex to the origin but cut both axes. This implies that $1 < \sigma_i$ or $-1 < \rho_i < 0$. Notice that if ρ_i is close to negative one, then σ_i approaches infinity and the indifference curves become straight lines so that a corner solution is most likely.

On the other hand, for non-tradables, substitution is assumed possible but only to a limited degree. The relative price change does affect the demand, but there exists, for a given Q_i, minimum levels of consumption for commodities from both sources. Indifference curves are convex to the origin and are asymptotic to these minimum quantities determined by:

$$MQ_i = \left[\left(\frac{Q_i}{\psi_i}\right)^{-\rho_i} / \delta_i\right]^{-\frac{1}{\rho_i}}$$

and

$$RQ_i = \left[\left(\frac{Q_i}{\psi_i}\right)^{-\rho_i} / (1-\delta_i)\right]^{-\frac{1}{\rho_i}}$$

To satisfy this property, it is required that $0 < \sigma_i < 1$ or $0 < \rho_i < \infty$ (see Henderson and Quandt, pp 112 - 113). Notice that the indifference curves become right angled as the value for ρ_i increases implying that substitution becomes more difficult.

<u>Export Demand and Commodity Market Equilibrium</u>

For a small region, the demand for regional products outside the region may be assumed to be perfectly elastic under the condition that no product differentiation exists. However, for the same reasons discussed in import demand, a region can not export commodities as much as it wants at a given price. This is true even for the tradable goods because of the existence of non-price competition between regions.

The current study assumes downward sloping export demand functions with constant price elasticity and different treatments for different commodity groups. For commodities with an exogenous price shock, there is no own price effect on exports. Exports of these sectors will be determined endogenously only by the change in supply. Therefore, it is required to set RP_i at PM_i for these sectors to endogenize exports:

$$RP_i = PM_i \qquad (4\text{-}55)$$

Notice that PM_i is exogenous national price. Endogenous export demand for the rest of the sectors is a function of regional price and defined by:

$$EXQ_i = EXQB_i \, RP_i^{e_i} \qquad (4\text{-}56)$$

where EXQ_i = endogenous exports of commodity i

$EXQB_i$ = base year exports

e_i = price elasticity of exports.

At the regional level, price elasticity data are not available. However, it is fairly reasonable to assume that the export demand would be relatively elastic for tradable goods, and relatively inelastic for non-tradables. Under this situation, the model will be simulated based on alternative elasticity assumptions. This sensitivity analysis seems to be useful to generate information for industry diversification policy.

Regional output must be equal to the sum of regional use and exports:

$$X_i = RQ_i + EXQ_i \qquad (4\text{-}57)$$

The commodity market equilibrium condition is given by:

$$X_i + MQ_i = D_i + GVTD_i + INVD_i + INTD_i + EXQ_i \qquad (4\text{-}58)$$

where $GVTD_i$ and $INVD_i$ are government demand and investment demand which are exogenously determined.

State Aggregates

Gross State Product

GSP is estimated by before tax factor income generated from the production activities of the region plus indirect tax:

$$GSP = \sum_{s}(YLAB_{s} - TRLABY_{s}) + YCAP + YLND + \sum_{i} idtx_{i}X_{i} \qquad (4\text{-}59)$$

Financial Flows

For a national model, the balance of payments is related to the exchange rate using one of two basic approaches. If the balance of payments is exogenized then the exchange rate would be endogenized. If the exchange rate is exogenized then foreign savings will determine the balance of payments. However, no exchange rate enters into the financial flows between a region and the rest of the nation. This study treats net financial flows endogenously with endogenous saving and exogenous investment.

Financial flows are measured by two accounts in the SAM; capital and rest-of-world (ROW). For the capital account two channels of financial flows are observed; government and private. Any difference between government revenue and government expenditure measures the financial flows through the government channel. Because the government account comprises all government agencies (federal, state, and local), any government surplus (deficit) can be considered as money withdrawn from (injected into) the regional economic system, and thus it is a net financial out (in) flow. Similarly, if savings exceed investment, it is a net outflow or vise versa.

Total net financial flow FINFL is determined by summing trade balance components, capital account components, and government account components:

$$\begin{aligned} FINFL = & \sum_i P_i GVTD_i + \sum_t TRINST + \sum_h TRGHH - YGVT \\ & + \sum_i RP_i EXQ_i - \sum_i PM_i MQ_i \\ & + \sum_i P_i INVD_i - dprt\, YCAP - \sum_h HHSAV_h \end{aligned} \qquad (4\text{-}59)$$

Summary

The CGE model for Oklahoma has been fully specified. Distinct characteristics of the CGE model are that macro variables are derived from micro economics. Utility theory, production theory, and market equilibrium theory are the basis of the CGE model. If all prices are endogenous, one additional equation for price normalization (or numeraire) is required. This is not needed for the current model because there is at least one exogenous price. This exogenous price will serve as numeraire. Rather strong assumptions are associated with the model specification not only because of the special characteristics of the CGE approach but also because of data limitations at the regional level. Data related issues will be discussed in the next chapter.

The complete list of equations, endogenous and exogenous variables, and parameters are given in Appendix A.

CHAPTER V

DATA AND PROCEDURES

Several steps are involved in the empirical implementation of the model in this study. The first step is to construct the regional social accounting matrix (SAM). Because of limited data and a lack of consistency among certain data sets, most of the time required for this study was devoted to this step. The second step is to determine the parameters for the regional computable general equilibrium model (CGE). All of the parameters, with a few exceptions, are calibrated from the base year SAM in an ex-post fashion. However, in some cases parameter values are determined first and the real variable values for the bench mark SAM are "guesstimated" based on these initial parameters. The third step is transforming the model into a computer program and obtaining the base solution which is the exact reproduction of the base SAM. The last step is performing the simulation experiments with the model based on selected exogenous variables together with appropriate sensitivity tests.

Constructing the Regional Social Accounting Matrix (SAM)

In constructing the regional SAM based on published data, some of the values in the SAM had to be subjectively "guesstimated". This is true even for the national SAMs, especially when the structure of the SAM is focused on income distribution. A set of guidelines, however, were established when "guesstimation" was inevitable. If regional data are unavailable or if multiple data sets are inconsistent, the guidelines are: (1) adopt or make approximations from available national data; (2) determine aggregate values first and then progress to disaggregation using the aggregate values as control totals; and (3) final values must balance for all accounts in the SAM. Procedures and data sources are presented below for the current study.

IMPLAN as Data Base

Major submatrices of the SAM including the Use Matrix and Final Demands - household demand, government demand, investment demand, and exports and imports - are derived from IMPLAN (IMpact Analysis for PLANning) developed by the USDA. Other parts of the SAM are constructed by organizing data from various sources including the Census Bureau of the U.S. Department of Commerce and Rose, Stevens, and Davis on income distribution.

IMPLAN is an input-output data base available in microcomputer software form. This study used micro IMPLAN release 89-03 (version 2.0) containing 1982 data.[5] IMPLAN permits construction of regional input-output accounts with 528 sector detail for a single county or combination of counties of the U.S.

Fundamental characteristics of the IMPLAN data base are centered on the assumption of U.S. production technology and the estimation of regional purchase coefficients. The basic assumption used in the construction of IMPLAN data base is that production technology is homogeneous across all regions of the U.S. for all sectors. This assumption allows the generation of regional input-output tables from the national table with extraneous estimates of regional industry output. For example, the regional Make Matrix is generated by multiplying regional total industry output (extraneous data) by the national

---

5 A new version of IMPLAN containing 1985 updates became available in early 1991.

byproduct matrix. The regional Use Matrix is derived by dividing each column element of the national Absorption Matrix by regional total industry output.

The key parameter used to estimate interregional commodity flow is the regional purchase coefficient (RPC) which represents the proportion of locally produced commodities (net commodity supply) used to meet local demand (regional commodity demand). For the tradable commodities (IMPLAN sectors 1-445), the RPCs are estimated by use of a regression analysis using the Multiregional Input-Output Accounts (MRIOA) data provided by the U.S. Department of Human Services, while the RPCs for the remaining sectors are "observed" based on the MRIOA data. (Alward et. al. pp.G.1-G.4). Incorporating these RPCs into the above regional input-output matrices, IMPLAN generates detailed data on production, intermediate demand, consumption, investment, exports and imports for each of 528 sectors with limited additional extraneous data. Extraneous estimates used include gross regional final demand, government demand, foreign trade, and inventory changes (Alward et. al.).

The overall accuracy of IMPLAN can not be directly tested without survey data. Alward et. al. conclude the discussion on data accuracy by stating:

> two points should be made and appropriately stressed: first, the IMPLAN 2.0 data base makes optimal use of available published information and revised techniques for developing non-survey regional economic data bases; second, the data in IMPLAN 2.0 are absolutely accurate at least in an aggregate sense, in that they are consistent with all published 1982 totals at national and regional level (pp.J.4-J.5).

However, some unrealistic values were found in the process of constructing the SAM for this study. The RPCs for IMPLAN sectors 462 (recreational related retail trade), 463 (other retail trade), and 491 (eating and drinking places) were zero for Oklahoma. Total industry output for sector 461 (other wholesale trade) was extremely low. Modifications were made to these data by using IMPLAN's software editing option that allows incorporating user supplied information into the existing data set. For this study, average RPCs for neighboring states (Texas, Arkansas, Missouri and Kansas) were used as RPCs for the above sectors in Oklahoma. Modification for the low industry output of sector 461 was made following the method suggested in IMPLAN News (Issue No. 1, p.2).

With these modifications the input-output accounts were constructed and the report tables were generated for the state of Oklahoma. Detailed procedures for modifications to the original data bases and the construction of accounts are provided in Alward et. al.

Sector Aggregation

Sectoral aggregation is one of the initial steps for generating regional accounts using IMPLAN and requires careful consideration. Basically, sectoral aggregation depends on the objectives of the study, computational expense, and availability of data (Miller and Blair). For conventional input-output multiplier analysis, the latter two issues are relatively unimportant because the data are already available through IMPLAN and the processes of matrix inversion and report writing do not represent significant costs. However, from the viewpoint of CGE modeling using a SAM constructed from IMPLAN data, all three issues should be carefully considered.

The first issue is a theoretical one common to most multisector analyses. Consideration should be given to aggregation of sectors which have similar production and demand functions not only in terms of functional forms and parameter values but also in terms of related factor ownership distribution and geographical industry location with respect to factor and output markets. This should reduce aggregation bias associated with input demand, income generation, and output demand. However, selecting a sector aggregation based on similarity in production technology does not guarantee similarity in other aspects of modeling or analysis of study objectives.

The issues of computational expense and data availability are closely related to the structure of the SAM and the degree of complexity in the CGE model to be constructed. Because CGE models generally contain non-linear equations, the number of parameters increases multiplicatively as the number of sectors increases. Hence, iterative solution methods are generally employed and one must carefully consider the degree of sectoral disaggregation.

This study aggregates the 528 IMPLAN sectors into nine sectors as shown in the SAM. Basically, the sector aggregation followed in this study is for providing a general purpose CGE model rather than a problem specific model. The IMPLAN sector aggregation is provided in Appendix ~~5~~B.

Manufacturing is disaggregated into rural resource based activities and all other. The former includes food processing, textile related products, wood and timber products, paper products, and printing and publishing. All other manufacturing activity is aggregated into the second manufacturing sector. For an analysis focused on industry diversification policy a different aggregation scheme may be preferred. For example, a sectoring of durable and nondurable, or an aggregation of input sectors for the petroleum/gas mining and processing sectors would be more preferable. The service sector in this study includes all levels of government - federal, state and local. If regional (local) policy making is the main purpose of the analysis, this treatment is inappropriate in that the federal government should be separated from state and local government. In addition, disaggregation of the service sector into several subcategories may be desirable to generate more useful information on labor markets and income distribution. In analyzing the impact of an exogenous energy price shock, aggregation of petroleum refining with petroleum/gas mining would give better results because these prices tend to move together.

Establishing Income Aggregates

Factor Income Distribution

Factor income distribution is summarized by the value added matrix in the SAM, which has factor accounts as row headings and production sectors as column headings. Factor accounts include five labor categories, one capital category, and one land category. Labor skill categories are an aggregation of job classifications as used by the U.S. population census (see Table II). The value added matrix shows the use of factors in each production sector. Construction of the value added matrix was based on data from IMPLAN and Rose, Stevens, and Davis. IMPLAN provides total value added by each production activity under the categories of employee compensation, indirect taxes, proprietary income, and other property income which includes corporate income, rental income, and interest payments (IMPLAN report number 403-7.0). IMPLAN total value added is 47,387 million dollars (Table III). This compares to 48,700 million dollars of GSP estimated by the BEA (1988) which is less than a three percent difference from IMPLAN data.[6]

The components of value added given by IMPLAN do not exactly match the factor account assignments used in this study. Therefore, following GSP accounting convention, employee compensation and proprietary income were

---

6 Significant differences were found between sector value added given by IMPLAN and sector GSP given by the BEA even though the totals were comparable. This may be due to differences in aggregation schemes and other data treatments. This study follows IMPLAN results for purposes of maintaining consistency with other accounts.

TABLE II

CATEGORIES OF LABOR SKILLS

Labor Category in SAM	Classifications in the Census
1	Managerial and Professional Specialty Occupations - Executive, administrative, and managerial occupations - Professional specialty occupations
2	Technical, Sales, and Administrative Support Occupations - Technicians and related support occupations - Sales occupations - Administrative support occupations including clerical
3	Service Occupations - Private household occupations - Protective service occupations - Other service occupations
4	Farming, Forestry, and Fishing Occupations
5	Precision Production, Crafts, and Repair Occupations Operators, Fabricators, and Laborers - Machine operators, assemblers, and inspectors - Transportation and material moving occupations - Handlers, equipment cleaners, helpers, and laborers

Source: U.S.D.C., Bureau of Census. 1980 Census of population.

TABLE III

VALUE ADDED BY SECTORS AND BY FACTOR COMPONENTS, OKLAHOMA, 1982

Sector	Employee Compensation	Indirect Business Taxes	Proprietor Income	Other Property Income	Total Value Added
	-million dollars-				
Agriculture	230.0	72.5	373.4	161.9	837.9
Mining	2372.0	1500.8	747.7	5845.0	10465.5
Construction	2005.9	70.8	126.4	87.0	2290.1
Manufacturing[1]	682	26.4	7.4	268.1	984.0
Manufacturing[2]	3974.4	424.2	2.4	1030.7	5431.7
Comm/Tran/P.Util	1829.4	350.4	59.0	2195.5	4435.2
Trade	3424.1	1062.4	194.0	758.2	5438.6
Fin/Ins/R.Estate	1262.4	908.7	-23.4	3587.5	5735.2
Services	9083.1	187.2	639.9	1858.8	11768.9
TOTAL	24863.2	4603.4	2126.9	15793.6	47387.0

Source: IMPLAN 1989-3 version 2.0.

added together and regarded as contribution by labor. This treatment raises the question of whether distribution of proprietary income is similar to labor income distribution by income classes. However, it is difficult to identify the exact amount of labor income contained in proprietary income. Moreover, the total amount of proprietary income was about 4.5 percent of total value added in 1982, or about 8.6 percent of total employee compensation. Assuming that half of proprietary income is labor income by allocating all of proprietary income to labor income gives an overestimation of labor income by less than five percent. But under the same assumption, underestimation of property income is by 13 percent. Other property income given by IMPLAN was allocated as capital income.

Value added by the agricultural sector was treated differently. Total value added given by IMPLAN is allocated across labor, capital, and land. Assuming constant returns to scale, factor share analysis could be used in the allocation process. Several such empirical approaches are found in the literature (Ruttan and Stout, Melichar). This study, however, did not perform an independent factor share analysis, but adopted the USDA/ERS CGE model factor shares developed by Robinson, Kilkenny, and Hanson. These factor shares are: labor (23.94%), capital (33.94%), and land (42.11%).

After determining the value added by aggregate labor for each sector, the aggregate value was allocated across the different labor skills based on the "U.S. wage and salary income distribution matrix" given by Rose, Stevens, and Davis. The wage and salary distribution matrix shows the amount of wage and salary income from 41 industrial sectors distributed across 59 job categories in the U.S. for the year 1982.

This treatment is based on the assumption of homogeneous technology across the nation, and that the wage and salary structure in Oklahoma is identical to the national average. Moreover, it assumes that non-wage and salary distribution such as medical and educational expenses or other non-cash compensations follow wage and salary distribution.

Institutional Income Distribution

Factor income estimated by row-sum of the value added matrix is mapped onto an institutional income distribution matrix. This matrix shows the amount of income received by each institution from each factor. The current Oklahoma SAM has three geographical institution categories: urban, rural agriculture, and rural non-agriculture. The definitions of urban and rural used in this study are identical to the metropolitan statistical area (MSA) and non-MSA delineations.[7] All establishments located in Oklahoma counties which belong to the MSA are considered as urban institutions. The MSAs are designated by the Department of Commerce. Currently, there are three MSAs in the state of Oklahoma; Oklahoma City MSA, Tulsa MSA, and Lawton MSA. In addition, Sequoyah county is included in the Fort Smith MSA, Arkansas. The Oklahoma City MSA covers the six counties of Oklahoma, Canadian, Cleveland, Pottawatomie, McClain, and Logan; the Tulsa MSA includes the five counties of Tulsa, Osage, Creek, Rogers, and Wagoner; and the Lawton MSA is composed of Commanche county. This study considers the twelve (excluding Sequoyah) counties included in the three MSAs as urban area.[8]

To construct the institutional income distribution matrix, two separate input-output models are generated using IMPLAN; one for the regions

7 In general, an MSA is a county or group of contiguous counties which contain at least one city of 50,000 or more inhabitants, or "twin cities" with a combined population of at least 50,000.

8 The word urban area has peculiar definition in Population Census. According to the 1980 census, urban areas are roughly defined as places of 2,500 or more residents that are incorporated as cities, villages, boroughs, and towns.

consisting of the twelve SMA counties and one for the rest of the counties. Value added matrices for each model were constructed using the methods discussed above. However, total labor income was adjusted by the amount of earnings generated outside of the corresponding region. This adjustment was based on USDC (1989) personal income data.

The USDC provides aggregate personal income data for each county, which includes information on earnings by place of work and adjustment for residence. The adjustment for residence is the amount of earnings generated outside the region by persons in the region (if the value is positive). The flow of labor earnings between the MSA and non-MSA regions is given in Table IV and shows that net income generated by rural county residents working in Oklahoma MSA counties was 596 million dollars in 1982. For urban Oklahoma industries, value added by labor from outside the MSA was 434 million dollars. Residents working outside of the state of Oklahoma, had labor earnings of 162 million dollars in 1982.

Value added matrices for the urban and rural input-output models with adjustments of labor income for place of residence is directly related to the institutional income distribution matrix for the SAM. However, additional adjustments were required for factor taxes and undistributed income (depreciation and retained earnings). With these adjustments the values in the institutional income distribution matrix are incomes distributed to households.

Factor tax rates were first approximated using various data sources and then the tax amounts were calculated based on the tax rates. Uniform tax rates were applied for social security taxes. For a refined treatment, actual taxes collected (federal, state, and local) should be used rather than using approximated tax rates. According to the personal income data (BEA 1989), personal contribution to social insurance was 5.4 percent of earnings in 1982

TABLE IV

EARNINGS ADJUSTMENT FOR RESIDENCE
IN OKLAHOMA, 1976-1987

Year	STATE	URBAN	RURAL
	--------------	-million dollars-	--------------
1976	173	-96	269
1977	148	-148	296
1978	145	-204	349
1979	160	-287	447
1980	166	-367	533
1981	188	-420	608
1982	162	-434	596
1983	198	-390	588
1984	226	-393	619
1985	258	-395	653
1986	311	-382	694
1987	313	-378	691

Source: USDC., Bureau of Economic Analysis. (1989). Regional Information System (Computer Printout).

for Oklahoma. Assuming that the employers contribution is equivalent to the personal contribution, a 10.8 percent social security tax rate was applied for the Oklahoma SAM.[9] The rate of depreciation and retained earnings is assumed to be 52.3 percent of total capital income. For the USDA/ERS model the rate was 38.5 percent (Robinson, Kilkenny and Hanson). However, reconciliation is required between distributed capital income and aggregate capital income received by households given by the USDC (1989) personal income data series. The capital tax rate was adopted from the USDA/ERS model. The land tax was calculated based on information in Jones and Barnard.

After these adjustments were made, transposing the adjusted row sums of the value added matrix for urban counties gave the first row of the institutional income distribution matrix. The second and the third row of the matrix was derived by transposing the first column and row sums of the rest of the value added matrix for rural counties. Notice an additional assumption is associated with the allocation of out-of-region income, and is that employment distribution outside the region is identical to employment distribution inside the region.

Household Income Distribution

The institutional income distribution matrix was mapped onto household income class size distribution after subtracting factor taxes, depreciation, and institutional savings. Households were classified into three income class sizes following IMPLAN; low income households with less than 10,000 dollars of income excluding inter-household transfer; medium income households with 10,000-29,999 dollars; and high income households with income not less than 30,000 dollars. Notice that this household income distribution matrix is the

---

9 USDA/ERS CGE model for the U.S., applies 14.1 percent (Robinson, Kilkenny, and Hanson 1990); Adelman and Robinson (1986) applied 13 percent for their 1982 SAM for the U. S.

intersection point of factor income (or value added) and size distribution, and thus it connects production and consumption. This is because profit maximizing behavior determines the factor income distribution and size distribution is consistent with consumption and savings reflecting utility maximizing behavior of households.

Several steps were followed in constructing the household income distribution matrix. First, aggregate income (excluding inter-household transfer) for each household group was determined. Second, aggregate consumption expenditures and government transfers to households were allocated across the household groups. Third, using a savings rate, a household tax rate, and the U.S. total income distribution matrix given by Rose, Stevens, and Davis, the household income distribution matrix was constructed in the process of balancing the SAM as a whole.

Aggregate Income By Income Class

Difficulties in the empirical analysis of size distribution arise basically from the lack of reliable data, because differences in the definition of income in different data sources, and because of a persistent tendency to under-report incomes. Income data sources in the U.S. include (1) personal income published by the Bureau of Economic Analysis, Department of Commerce; (2) money income published by the Bureau of Census, Department of Commerce; and (3) income reported by the Internal Revenue Service, Department of Treasury. In addition, publications from the Department of Agriculture include income for the agricultural sector and the Consumer Expenditure Survey published by the Bureau of Labor Statistics, Department of Labor includes information on household income. However, the most widely used data source in the analysis of size distribution is money income published by the Bureau of Census.

The income definition used in the CPS (Current Population Survey) by the Bureau of Census is "money income". It includes all income received by persons in the form of money. The definition covers money wages and salary; net income from farm and nonfarm self employment; interest and dividend income from savings and investment; public and private transfer payments including social security, pensions, alimony etc.; and net rental income. However, the concept of money income does not include non-cash income such as food stamps, health benefits, value of home consumed farm products, gifts, lump-sum inheritances, or insurance payments. Using the money income definition, the Bureau of Census publishes various reports on size distribution of income by households, families, persons, job categories, races, and family types based on the complete census or on a sample survey.[10]

However the definition of money income is not appropriate for social accounting for economic analysis. The concept of "personal income" used in GNP accounting is more preferable because it includes non-money income and under-reporting is less of a problem.[11] Annual personal income is published by the BEA for states and counties but information on size distribution is not included in the series.

Another difficulty in constructing the household income distribution matrix is that money income at the state level is not published annually. It is available for the population census year of 1980. The data format is the number of households which belong to nine income classes, as shown in Table V. State-

---

[10] Complete census is conducted decennially, and annual data is published based on sample survey of CPS. The CPS sample comprises 59,000 interviewed observations since 1981.

[11] In GNP accounting personal income (PY) is defined by; PY=GNP - Depreciation - Indirect Tax - Corporate Profit - Social Security Tax + Transfer Receipts + Net Interest Income + Dividends.

wise aggregate income by income class is not reported. Therefore, a set of assumptions was required to approximate aggregate income for the three household income groups of Oklahoma for the SAM benchmark year (1982) based on the 1980 census data. It was assumed that (1) personal income (net of government and interhousehold transfer) distribution was identical to money income distribution; (2) money income distribution in 1982 was identical to that in 1980; and (3) income growth for each person from 1980-82 was the same as personal income growth for the State. A cumulative distribution function of households was fitted using the Weibul distribution and based on least squares method using a non-linear programming algorithm.[12] The estimated CDF is:

$$F(x) = 1 - \exp(-(x/21643)^{1.381})$$

where, x = income in dollars (1980)

F(x) = fraction of households with income less than or equal to x.

A Kolmogorof-Smirnof goodness of fit test was conducted to determine if the use of a Weibul distribution is appropriate. The null hypothesis, that the distribution is not Weibul, was rejected for an alpha level of five percent.

Based on the above assumptions and the estimated CDF, aggregate personal income was allocated to the three household groups. Multiplying the CDF by the total number of households yields the number of households belonging to any desired income range. Multiplying this result by the corresponding income level and summing over the income range gives the aggregate income for that income range. Estimated CDFs for household and aggregate income are presented in Table V. Notice that the shares of low,

---

12 To test the reliability of this approach, the same method was used to estimate aggregate income for each of the income classes for the U.S. based on data available for both 1980 and 1982. Estimated values were comparable to actual values. Bartels, C.P.A. (1977) considers the Weibul distribution an appropriate functional form in modeling income distribution.

TABLE V

CUMULATIVE DISTRIBUTION FUNCTIONS OF HOUSEHOLDS AND AGGREGATE INCOME BY INCOME CLASSES, OKLAHOMA, 1980, 1982

Income Class (current $)	1980				1982	
	No. of Households[1] (1000)	Actual CDF of Households[1]	Estmtd CDF of Households	Estmtd CDF of Aggregate Income	Estmtd CDF of Households	Estmtd CDF of Aggregate Income
5000 or less	180.3	0.1612	0.1540	0.0231	0.1131	0.0133
5000-7499	104.7	0.2548	0.2489	0.0552	0.1857	0.0323
7500-9999	97.0	0.3415	0.3423	0.0994	0.2597	0.0597
10000-14999	185.5	0.5075	0.5118	0.2135	0.4023	0.1346
15000-19999	158.9	0.6495	0.6500	0.3436	0.5293	0.2280
20000-24999	130.6	0.7663	0.7561	0.4723	0.6367	0.3295
25000-30000	NA	NA	0.8341	0.5879	0.7246	0.4311
25000-34999	149.5	0.9000	0.8896	0.6851	0.7934	0.5264
35000-49999	73.3	0.9656	0.9708	0.8656	0.9209	0.7476
50000 or more	38.5	1.0000	1.0000	1.0000	1.0000	1.0000

[1] USDC, Bureau of Census, 1980 Census of Population.

medium, and high income households are about 26, 46, and 28 percent of the total while their income shares are six, 37, and 57 percent, respectively.

Aggregate Consumption and Transfer Income

IMPLAN gives household consumption by commodity and income class. However, IMPLAN estimates of consumption by low and medium income households appear to be high while estimates for high income households appear to be low compared to results of the Consumer Expenditure Survey (CES) by the Bureau of Labor Statistics, and compared to other data on income shares, household shares, and savings ratios. Because the Consumer Expenditure Survey covers only urban consumers, the data for the State cannot be directly compared with the CES results. However, aggregate consumption shares by household income group can be approximated using results of the CES. Two types of expenditure shares were calculated: expenditure shares with and without insurance and pension payments (or expenditures). This study adopted the latter because insurance and pension payments are considered as savings. Comparisons of consumption and income shares from different data sources and the results selected for this study are presented in Table VI. Total consumption for the State and commodity composition of consumption by each household group is taken from IMPLAN without modification.

Transfer payments by governments were allocated by transfer income shares by household group calculated from income data from the CES. Aggregate transfer payments for the State were determined from the BEA personal income data.

TABLE VI

COMPARISONS OF CONSUMPTION AND INCOME SHARES BY INCOME CLASSES FROM DIFFERENT SOURCES, OKLAHOMA, 1982

(unit:percent)

Source	Item	Income Class Low	Income Class Medium	Income Class High
IMPLAN	Consumption Share	19.1	52.7	28.2
CES[1]	Household Share	28.0	45.0	27.0
	Consumption Share[2]	13.4	40.5	46.1
	Consumption Share[3]	14.4	41.1	44.5
	Income Share	6.7	37.3	56.1
Money Income[4]	Household Share	23.9	46.7	29.6
	Income Share	5.4	36.5	58.1
This Study	Household Share	26.0	46.5	27.5
	Consumption Share	14.4	41.1	44.5
	Income Share	6.0	37.1	56.9

[1] Bureau of Labor Statistics, USDL, Consumer Expenditure Survey: 1982-1983 (Interview Survey), p. 15-18.

[2] Total Expenditure Share.

[3] Expenditure share excluding insurance and pensions.

[4] Bureau of Census, USDC, Aftertax Money Income Estimate of Households:1982, p.7.

Balancing the SAM Income Accounts

All column and row accounts in the SAM must balance. Column totals of the household income distribution matrix must be equal to the row totals of the institutional income accounts, and row totals of the former must be equal not only to the column totals of the household accounts (sum of consumption, savings, household tax payments, and interhousehold transfers) but also to the row totals of household income net of interhousehold income transfers and of transfers from governments. Because of these requirements, a set of parameters are involved in the process of constructing the household income distribution matrix when direct observation of the distribution is not available. In other words, related accounts are considered simultaneously for purposes of achieving balance in the SAM. The process of balancing the Oklahoma SAM is presented below.

First, the U.S. total income distribution matrix constructed by Rose, Stevens, and Davis was utilized to approximate distribution of institutional income across the rows of the Oklahoma household income distribution matrix. The matrix for the U.S. shows the amount of income going to each income class (ten classes) out of total income generated by each of 81 production sectors. Coefficients were derived from this matrix, and applied to the two Oklahoma input-output models (MSA and Non-MSA). Proportional techniques or RAS method (Miller and Blair, pp. 176-291) were used to match the results derived from the total income distribution matrix with the results from the size distribution estimates for Oklahoma.

Next, total savings of Oklahoma was approximated by referring to the U.S. average savings rate. However, it was assumed that Oklahoma's savings rate for 1982 was higher than the national average for two reasons: (1) the share of capital income is significantly higher than the U.S. average, and (2) it was the peak year of the economic boom in Oklahoma so the income growth rate was higher than the national rate. The savings rate for each income class was determined such that it was consistent with the assumption that higher income groups have higher savings rate but the rate must not vary significantly from national rates appearing in the literature. Household taxes were determined in a similar way. Results of the savings and tax rateS are presented in Tables VII and VIII with comparisons from other sources. The negative savings rate for low income households can be interpreted as consumption financed by the savings of other income classes.

With these calculated savings and tax rates it was impossible to balance the SAM accounts. To balance the SAM income accounts an inter-household income transfer matrix was introduced. Data on interhousehold income transfers are completely lacking. However, interhousehold income transfers must be considerable given the definition of household used in describing money income data.[13] The introduction of the interhousehold income transfer matrix may be an advantage for the SAM approach in that certain "guesstimations" are permitted through this approach. On the other hand, the interhousehold income transfer matrix may be, at least in part, accumulated errors made by guesstimating other parts of the SAM. Moreover, slight adjustments to the elements in the SAM are inevitable because column totals for each and every account must be exactly equal to corresponding row totals.

---

[13] A household by the U.S. Census is defined by a person or persons occupying a housing unit. A housing unit includes a house, an apartment, a single room or a group of rooms if occupied as separate living quarters. A person living alone or a group of unrelated persons sharing a housing unit as partners is also a household.

TABLE VII

HOUSEHOLD SAVINGS RATE BY SOURCE FOR 1982[1]

Source	Category	Savings Rate
BEA[3]	US Average	(6.2%)[2]
Robinson, et. al. (1990)	US Average US Labor Households US Capital Households	5.9% 6.2% 17.4%
Adelman and Robinson (1986)	US Low Income 40 % US Med Income 40 % US High Income 20 %	-4.3% 5.6% 9.1%
This Study	Oklahoma State OK Low income 26 % OK Med income 46 % OK High Income 28 %	7.8% (9.7%)[2] -4.3% 3.6% 13.0%

1 Savings Rate = Savings/Gross Income.

2 Savings Rate = Savings/Disposable Income.

3 U.S. Government Printing Office, Economic Indicators, April 1985. For other sources refer to reference list.

TABLE VIII

HOUSEHOLD TAX RATES BY SOURCE FOR 1982

Source		Average	Low	Med	High
USDC [1]	US*	17.8	4.7	12.5	22.3
	US**	12.2	3.8	11.8	17.8
USDL [2]	US*	11.0	3.6	9.3	13.0
This Study	OK**	13.7	3.7	9.3	17.6

* Tax rates based on money income.
** Tax rates based on personal income (or taxable income for this study).

Sources 1 Calculated from Bureau of Census, USDC, After Tax Money Income Estimate of Households: 1982.
2 Calculated from Bureau of Labor Statistics, USDL, Consumer Expenditure Survey (Interview Survey) 1982-83.

Social Accounting Matrix for Oklahoma

The Social Accounting Matrix (SAM) for Oklahoma was constructed following the above procedures and is presented in Table IX. The SAM summarizes the overall performance and structure of the Oklahoma economy in 1982. Each entry of the matrix is expressed in terms of millions of 1982 dollars but with normalized prices it also can be interpreted as quantities. Individual aggregate accounts are discussed below.

Sectoral output totaled 94 billion dollars in 1982. A total of 46 billion dollars of intermediate inputs were used, and the GSP (or value added including indirect taxes) was 48 billion dollars. Out of the total production, 39 billion dollars was exported. Total commodity demand in the region was 88 billion dollars, of which 36 billion dollars was met by imports. This implies that the State was a net material exporter. Out of total exports, shares of the agricultural and mining sectors were 5.7 and 26.7 percent, respectively. Had the petroleum refining industry been included in the mining sector, the share of the two natural resource based industries would have been higher.

The value added by labor was 27 billion dollars comprising 56.1 percent of total GSP. Capital (including land) and indirect tax shares were 34.2 and 9.7 percent, respectively. The factor shares represented by the U.S. SAM for the same year were 60.4 percent for labor, 31.7 percent for capital, and 7.9 percent for indirect taxes (Robinson et. al. 1990). Comparing the two sets of factor shares, labor share for Oklahoma was smaller than the national average. The considerably smaller labor share and hence larger capital share for Oklahoma compared to the nation is also observed in the GSP data series provided by the

TABLE IX

SOCIAL ACCOUNTING MATRIX FOR OKLAHOMA, 1982

(millions of 1982 dollars)

	Agri-culture	Mining	Const-ruction	ManuFac-turing-1	ManuFac-turing-2	Comm/Tran/Util	Fin/Ins/Trade	R.Estate	Services	Labor-1	Labor-2	Labor-3	Labor-4
PRODUCTION SECTORS													
Agriculture	1064.4	0.4	0.0	600.5	3.5	0.0	0.4	0.3	59.5				
Mining	3.1	2413.8	42.1	3.9	4247.7	1289.6	0.0	0.1	34.3				
Construction	44.4	25.3	8.9	19.3	177.0	297.9	56.8	246.5	261.3				
Manufacturing-1	462.2	40.3	495.9	903.0	314.2	28.6	108.5	69.2	882.4				
Manufacturing-2	437.8	2357.5	1813.9	339.7	5952.7	770.5	223.0	59.7	983.7				
Comm/Tran/P.Util	143.9	677.7	192.7	172.3	1290.4	1590.5	427.9	184.5	726.4				
Trade	208.3	380.1	646.9	193.3	731.8	98.9	106.2	25.9	401.1				
Fin/Ins/R.Estate	338.7	1505.1	77.7	47.7	284.1	157.8	413.7	980.3	685.1				
Services	243.3	988.9	564.3	211.4	1019.6	396.9	1071.6	617.8	1552.1				
FACTOR ACCOUNTS													
Labor-1	34.5	705.0	339.5	145.9	1010.7	409.4	800.7	394.1	4715.5				
Labor-2	13.8	340.9	173.9	131.7	687.7	560.3	1794.8	788.2	2243.6				
Labor-3	3.3	25.5	9.3	10.0	45.8	27.5	42.7	26.4	1859.5				
Labor-4	115.7	0.7	1.3	3.0	0.7	0.6	1.8	2.7	27.6				
Labor-5	15.9	2047.6	1608.3	398.9	2231.8	890.7	978.1	27.6	876.8				
Capital	259.8	5845.0	87.0	268.1	1030.7	2196.5	758.2	3587.5	1859.1				
Land	322.3												
INSTITUTIONS													
Urban										5284.6	4145.0	1260.1	34.6
Rural Agriculture										27.5	11.0	2.6	92.1
Rural Non-Agric.										2362.9	1886.0	576.3	11.6
HOUSEHOLDS													
Low													
Medium													
High													
Government	72.5	1500.8	70.8	26.4	424.2	350.4	1062.4	908.7	187.2	932.5	734.1	223.4	16.8
Condenced Capital													
Rest of World	676.5	1314.9	612.1	5212.7	12868.0	2445.0	1460.7	3246.9	5706.7				
Column Totals	4460.7	20169.5	6744.6	8687.7	32320.6	11511.1	9307.6	11166.4	23061.8	8607.5	6776.1	2062.4	155.1

TABLE IX (continued)

Labor-5	Capital	Land	Urban	Agric.	Non-Agric.	Low	Medium	High	Gov't	Condensed Capital	Rest-of-World	Row Totals
						37.7	94.6	91.4	250.7	28.9	2228.4	4460.7
						0.1	0.2	0.2	1.5	1652.8	10480.1	20169.5
						0.0	0.0	0.0	911.5	2999.0	1696.6	6744.6
						580.7	1610.1	1529.7	471.8	92.7	1098.5	8687.7
						475.6	1686.3	1766.5	1424.0	1794.7	12235.0	32320.6
						418.4	973.1	995.1	408.5	84.5	3225.1	11511.1
						683.6	1987.3	2163.5	99.5	311.1	1270.2	9307.6
						719.6	2156.9	2621.3	224.5	102.4	851.5	11166.4
						1112.4	2986.3	3277.3	2900.1	0.8	6119.0	23061.8
											52.2	8607.5
											41.1	6776.1
											12.5	2062.4
											0.9	155.1
											55.3	9130.8
												15891.9
												322.3
5341.3	4496.8	30.6										20592.8
12.6	94.6	240.2										609.6
2787.7	1909.4	0.0										9534.0
			388.5	-14.2	200.8		600.0	1200.0	1562.8			3937.9
			7214.6	351.2	3231.7			500.0	2501.5			13798.9
			12989.8	272.6	6101.5				1009.7			20373.6
989.2	1080.6	51.5				79.1	1207.0	3585.7				13503.3
8310.5						-169.3	497.1	2642.9	1608.2			12889.4
										5822.6		39366.3
9130.8	15891.9	322.3	20592.8	609.6	9534.0	3937.9	13798.9	20373.6	13503.3	12889.4	39366.3	304982

Bureau of Economic Analysis, U.S. Department of Commerce (Renshaw, Trott, and Freidenberg, 1988).[14]

Household income distributed to geographic institutions was 21 billion dollars for urban (67 percent) 0.6 billion dollars for rural agriculture (2 percent), and 10 billion dollars for rural non-agriculture (31 percent). The income from rural agriculture for low income households was found to be negative. This can be interpreted as a result of instability of farm proprietary income, and of the intrinsic nature of small family farms.[15]

Aggregate savings including depreciation and retained earnings was about 13 billion dollars, of which 7 billion dollars was invested and the remaining 6 billion dollars can be considered as financial outflow. Total household consumption was about 28 billion dollars, of which 4 billion dollars was spent by low income households, 11 billion dollars by medium income households, and 12 billion dollars by high income households.

Parameter Estimation

The Calibration Approach

The model parameter estimation process is closely related to the structure of the SAM construction. In most applied CGE models, parameter values for the equations are determined in a nonstochastic manner called

---

14 According to the BEA data series, Oklahoma labor and capital shares were about 53 percent and 27 percent, respectively, from 1982-86. The U.S. counterpart shares were about 60 percent and 22 percent. The share of proprietary income was about 26-27 percent for Oklahoma and 9-10 percent for the U.S. for the same period.

15 In 1982, out of 72523 farms in Oklahoma, only 7,232 farms (or 10 percent) had more than 40,000 dollars of sales per farm. The share of these farms out of total sales of agricultural output was 80.3 percent. On the other hand, estimated value of farm machinery and equipment owned by these farms was about 50 percent of the State total, indicating relatively high capital cost to small farms (UADC, 1984a. pp. 88-103). Farm income data for the U.S. shows that annual returns to farm operators for farms with less than 40,000 dollars of sales was negative from 1980-83 (USDA, 1984, pp. 81-83).

"calibration". The calibration procedure is the process of solving the model equations for parameters using benchmark or base year values of endogenous and exogenous variables. This procedure is as follows.

Suppose a n-dimensional vector function exists as the following:

$$Y = F(X\,;\alpha, \beta, \varepsilon) \qquad (5\text{-}1)$$

where Y is a vector of n endogenous variables,

X is a vector of exogenous variables,

α is a vector of known parameters selected from available knowledge,

β is a vector of unknown parameters, and

ε is a vector of stochastic disturbances.

By use of the implicit function theorem, equation (5-1) can be expressed as:

$$\beta = G(X, Y\,;\alpha, \varepsilon) \qquad (5\text{-}2)$$

As discussed before, in a SAM based CGE model the base year SAM is assumed to be a representation of general equilibrium which satisfies equation (5-1). Moreover, it is assumed that ε is a zero vector under the situation that there is only one observed general equilibrium data set. These two assumptions enable a solution to equation (5-2) as long as equation (5-1) is linear in the parameters and values for X and Y are provided by a base SAM. This procedure of calibration ensures parameter values whereby the model can reproduce the base year equilibrium.

Pros and Cons of Calibration

The calibration approach has certain intrinsic weaknesses. First, the number of parameter vectors that can be determined by this approach can not exceed one for each vector equation in the model as implied by equations (5-1) and (5-2). For example, if there are two or more unknown parameters in equation (5-1), equation (5-2) can not be solved for any of the parameters. This is the reason why the functional forms of utility (or demand) and production in most empirical CGE applications are restricted to Cobb-Douglas, Stone-Geary, or CES, etc., whether they are single staged or nested multiple stage functions.

If the number of unknown parameter vectors exceeds one, the general practice is to assume some subjective alternative values for the parameter vectors which are not determined by use of the calibration procedure, and to analyze the effects of the different values for those parameters on model performance. This sensitivity analysis is widely used for determining parameters whose values are considered to be pivotal to model results even when the unknown parameter vector in equation (5.1) is one and thus there is no problem in solving equation (5.2). An important drawback of the calibration approach, however, is that it lacks the formal statistical measures to determine the degree of reliability of calibrated parameters and thus the SAM based model itself.

Even with these weaknesses, most empirical CGE models, with some exceptions (Jorgenson; and Jorgenson and Slesnick), follow the calibration approach. The basic reason for their use is that multi-sector general equilibrium models require a large number of parameters, but available numerical information on the parameters consistent with the models is very limited, and alternatives such as econometric estimation involve other problems of data, structure, time, and budget.

The proponents of the calibration approach such as Mansur and Whalley, and Diewert emphasize the difficulties in econometric parameter estimation: (i) identification problem in relation to the number of parameters to be estimated and degrees of freedom; (ii) incompatibility of units used in the CGE model and the equations in the estimation process; and (iii) although econometric estimation allows the incorporation of flexible functional forms into the model, these functions may not be globally well behaving and may make the model more complicated.

Considering that the basic purpose of CGE analysis is counter factual simulation, the calibration approach may not cause serious problems to regional modeling. The current Oklahoma model follows the calibration procedure.

<u>Choice of Elasticity of Substitution for Trade</u>

Every equation in the current regional CGE model, except the equations for composite commodity and import demand, satisfies the condition that the number of unknown parameter vectors does not exceed one. The joint solution of the two equations in the CES functional form have three (equation 4-52) and two (equation 4-53) unknown parameter vectors. Therefore, at least one of the parameter vectors must be provided extraneously. The approach followed is to assume specific values for the elasticity of substitution parameters σ_i or $1/(1+\rho_i)$, and then calibrate the other parameters. If a value for σ_i or ρ_i is provided, the share parameter σ_i is calibrated from equation (4-53) and then the shift parameter Ψ in equation (4-52) can be calculated with values for ρ_i and δ_i.

In selecting the elasticity of substitution parameter values, it is assumed that the elasticities for tradables are greater than unity, while the elasticities for nontradables are less than unity. A graphical representation of the indifference curves for agricultural commodity demand with different elasticities of substitution for regional and import goods is presented in Figure 8 as an example. The horizontal axis measures regional goods (RQ), while the vertical axis represents imported goods (MQ). Observe that the indifference curve has less curvature as the elasticity of substitution increases implying substitution becomes easier. All curves pass through the original base year equilibrium representing 1,555 units of regional goods and 677 units of imported goods. Asymptotic minimum values of RQ and MQ are zero for all elasticity parameter values greater than one. If the 0.5 elasticity parameter is selected, then the asymptotic minimum for RQ and MQ is 205 and 1,084, respectively. For initial conditions, the values of 4.0 and 0.5 are selected as elasticities of substitution for tradables and non-tradables, respectively, in this study, even though simulations based on different elasticities will be presented.

Elasticity of Export Demand

The elasticity of export demand is an important parameter that determines the performance of an economic system and is not calculated from the SAM. Elasticity of demand for Oklahoma products for each production sector is not available. However, the elasticity of import demand for the U.S. provides important information about the Oklahoma export demand parameters. Akhtar estimated price elasticities of total import demand for the U.S. of 0.17 using 1960-76 annual data, 0.13 using 1952-76 annual data, and 0.4 using 1970-76 quarterly data.

Kreinin estimated price elasticities for U.S. imports by major commodity groups using 1964-70 data. The results show that for most of the commodity groups, the estimates are concentrated in the 0.5 to 1.0 range. Exceptions are processed fruits and vegetables (1.13), sugar and confectionery (1.14), manufactured animal feeds (3.41), cotton products (1.17), and paint and paint

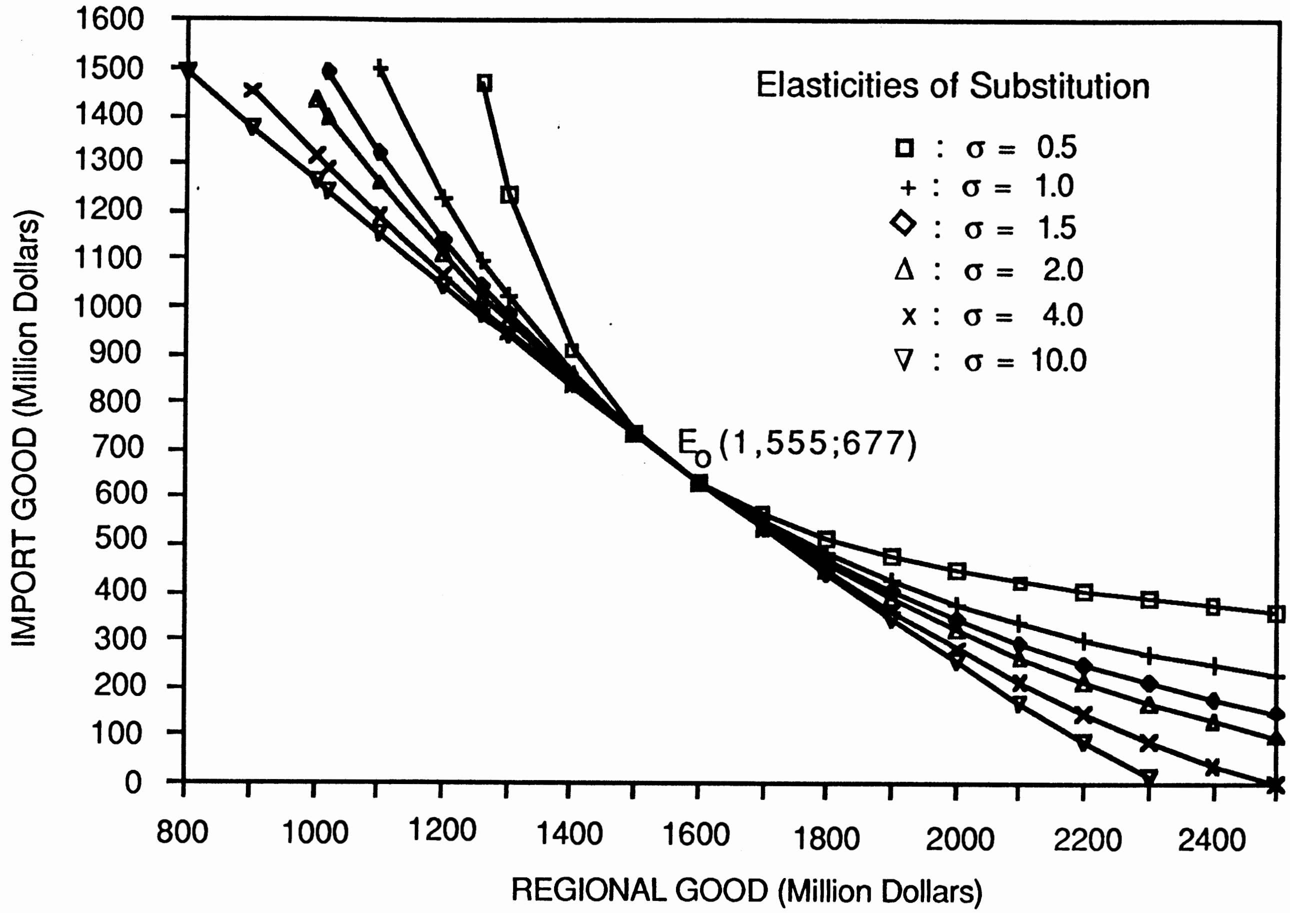

Figure 8: Form of the Indifference Curves for Agricultural Commodity Composite Demand With Different Elasticities of Substitution for Regional and Import Goods.

materials (1.56). The elasticity estimates by Deyak et. al. for five industry groups using 1958-1983 quarterly data are: 0.76 for manufactured foods, 0.84 for semi-manufactures, 1.00 for finished manufactures, 0.27 for crude foods, and 0.53 for crude materials.

Elasticities estimated from international trade data are only indicative of elasticities for regional trade. Regional trade is expected to be more price responsive. However, it is believed that responsiveness to exogenous price changes in agriculture and energy are fairly consistent for all regions. For other sectors, the existence of non-price competition including brand names, distribution channels, etc., will limit the responsiveness of demand to price changes.

Based on these considerations, the elasticity values used in model simulations are 0.7 for tradable goods, and 0.3 for non-tradable goods. Model results based on other sets of elasticity values are compared.

Solution Process

A CGE model is simply a simultaneous equation system derived from economic theory. The model equations are solved simultaneously for endogenous variables.

The first multisector general equilibrium model by Johansen was solved by log-linearization of all equations in the endogenous variables. Many activity general equilibrium (AGE) models have been solved by use of optimization techniques. However, most CGE models are solved directly for the endogenous variables using a variety of solution algorithms. Dervis, De Mello, and Robinson classified these algorithms into three categories: fixed point theorem based approach, tatonnement process based approach, and Jacobian algorithms. They also discuss the advantages and disadvantages of the algorithms (Dervis et. al. pp. 491-496).

This study uses the GAMS (General Algebraic Modeling System) algorithm to solve the regional model. The GAMS is a mathematical programming software program designed to solve both linear and non-linear problems. For non-linear problems, the GAMS/MINOS solution algorithm is used and belongs to the third category listed above. Because of the characteristic GAMS syntax of optimization, an objective function is required. All equations in the model become constraints. However, none of the equations in the model has an inequality sign. For this reason the model solution is invariant to the choice of the objective function. For example, the problem to maximize output will give the same solution as a problem to minimize output. Therefore, any equation in the model is eligible to be the objective function as long as it is a scalar equation.

Condon, Dahl and Devarajan; and Robinson, Kilkenny, and Hanson used GAMS in solving their CGE models for the Cameroon and for the U.S., respectively. Detailed programming procedures are provided in Jefferson and Boisvert and Brooke, Kendrick, and Meeraus.

One of the advantages of using GAMS is that it is designed to accept equations in almost the same format as presented in Chapter IV, allowing for the use of subset notation. Using subset notation, one can easily implement, without introducing any dummy variable, different functional forms or different closure rules for different subsets or elements in a variable vector. An example in the current model is the different treatments for skilled and unskilled labor categories in labor market equilibrium specification (equations 4-17 and 4-19).

With base year exogenous variable values, the solution values for the endogenous variables will be exactly the same as those in the base year SAM.

The program for this study which reproduces the base Oklahoma SAM is presented in Appendix 6. The objective function chosen is minimization of the sum of a set of slack variables. Two slack vectors, SLACK1 and SLACK2, were introduced in the production function equations and were also expressed in the objective function. This technique (trick) is recommended by Brooke et. al., to address the infeasibility problem that frequently occurs during the iteration process for nonlinear programing models. Both of the slacks are declared to be positive variables (see the variable declaration part of the program). If the sum of the slacks is zero (so both must be equal to zero) at the equilibrium solution, the solution will be optimal in that the objective function is minimized satisfying all of the equations in the model, and the introduction of the slacks does not affect any solution values in the model.

CHAPTER VI

ANALYSIS OF MODEL RESULTS

Comparative static analyses of the Oklahoma CGE model are reported in this chapter. Comparisons between the CGE results and fixed price SAM multiplier results are presented first. CGE results based on different assumptions about labor market behavior, variations in the elasticity of substitution between imported and regional goods, and variations in the elasticity of export demand are presented and analyzed in the next part of the chapter. Finally, an experiment on the impacts of a change in government transfer payments is presented and analyzed. Results of all simulations are compared to the base results. Hence, a value for an endogenous variable of 1.1 is interpreted as a 110 percent of the base result for the same variable whereas a value of 0.9 is interpreted as a 90 percent of the base result.

Specification of Model Experiments

Results of twelve simulations are reported in this chapter including results of two fixed price multiplier analyses. Different combinations of exogenous shocks, elasticity parameters, and labor market assumptions are incorporated into the CGE model and then the model simulates the results (Table X). The alphabetic prefix of the model number in Table X represents the type of exogenous shock simulated. The prefix A indicates a ten percent increase in agricultural exports. The prefix B indicates a 20 percent increase in exports of rural resource based manufacturing (Manufacturing-1). Models A1 and B1 give

TABLE X

SPECIFICATION OF MODEL CHARACTERISTICS FOR SIMULATION EXPERIMENTS

Model Number	Endogenous Variable in Labor Market		Elasticity of Substitution		Elasticity of Export Demand	
	Skilled Labor	Unskilled Labor	Tradable Goods	Nontradable Goods	Tradable Goods	Nontradable Goods
A1, B1	- - - - - - - - - - not relevant (fixed price multiplier model) - - - - - - - -					
A2, B2	wages	wages	2.0	0.5	-0.7	-0.3
A3, B3	wages	wages	4.0	0.5	-0.7	-0.3
C1	wages	wages	4.0	0.5	-0.7	-0.3
C2	unemp.	unempl.	4.0	0.5	-0.7	-0.3
C3	wages	unempl.	4.0	0.5	-0.7	-.03
C4	wages	unempl.	4.0	0.5	-2.0	-0.3
C5	wages	unempl.	4.0	0.5	-1.0	-0.1
C6	wages	unempl.	1.0	0.3	-0.7	-0.3

results of the fixed price multiplier approach and are utilized to compare against the CGE approach. The models A2, B2 and A3, B3 present CGE results for the same scenarios as for A1, B1 except A2, B2 assume an elasticity of substitution of 2.0 for tradable goods and A3, B3 assume an elasticity of 4.0.

For models with the prefix C, three exogenous shocks are combined: (1) a 10 percent decrease in agricultural prices, (2) a 30 percent decrease in mining prices, and (3) a 10 percent decrease in capital formation (investment demand). Shocks (1) and (2) are the approximate price changes experienced by the Oklahoma economy during the 1982-86 period, and shock (3) is added based on the assumption that shocks (1) and (2) result in a decrease in capital formation or investment demand.

For labor market specification, wage endogenized models assume full employment, and unemployment endogenized models assume wage rates fixed at base year level. For example, model C1 is wage endogenized and model C2 is the level of unemployment endogenized. Models C3, C4, C5, and C6 endogenize wage rate for skilled labor (Labor categories 1, 4, and 5) and the level of unemployment for unskilled labor (Labor categories 2 and 3).[16] For these models, it is assumed that adjustment in the wage rate will maintain full employment for skilled labor, but because of the fixed wage rate for unskilled labor unemployment is permitted.

Fixed Price Multiplier Versus CGE Results

Commodity Markets

Output response to changes in export demand is greater using the fixed price multiplier model compared to results of the CGE model (Table XI). Results of a 10 percent increase in agricultural exports are compared for the fixed price Model A1 and with the CGE Models A2 and A3. Assumed elasticity of substitution for tradable goods is 2.0 for Model A2 and 4.0 for Model A3. Similarly, results of a 20 percent increase in resource based manufacturing exports are compared for the fixed price Model B1 and the CGE Models B2 and B3 for the different elasticities of substitution for tradables.

---

16 Agricultural labor (Labor 4) can be considered as unskilled labor. However, agricultural labor has limited inter-sectoral mobility in the short run, and lower returns to agricultural labor do not necessarily produce unemployment under family farming. Hence the agricultural labor market was treated as skilled labor in this study. Labor category 5 is a mix of skilled and unskilled labor. Disaggregation of this labor market would be desirable for better results.

TABLE XI

IMPACTS OF INCREASED AGRICULTURAL AND RURAL RESOURCE BASED MANUFACTURING EXPORTS ON COMMODITY MARKETS, OKLAHOMA

		10% Increase in Agricultural Exports			20% Increase in Manufacturing-1 Exports		
Variable		MODEL A1	MODEL A2	MODEL A3	MODEL B1	MODEL B2	MODEL B3
Sectoral Output							
1.	Agricultural	1.080	1.041	1.030	1.007	1.001	1.000
3.	Mining	1.002	0.997	0.998	1.001	0.997	0.997
4.	Construction	1.004	1.000	1.000	1.002	0.999	0.999
5.	Manufacturing-1	1.020	0.986	0.984	1.076	1.058	1.050
6.	Manufacturing-2	1.006	0.998	0.999	1.002	0.997	0.998
7.	Comm/Tran/P.Util	1.005	1.000	1.000	1.002	0.999	0.999
8.	Trade	1.006	1.002	1.001	1.003	1.000	1.000
9.	Fin/Ins/R.Estate	1.009	1.001	1.001	1.003	1.000	1.000
9.	Services	1.005	1.000	1.000	1.002	0.999	0.999
Regional Prices							
1.	Agricultural	1.000	1.091	1.063	1.000	1.007	1.005
3.	Mining	1.000	1.003	1.001	1.000	1.003	1.003
4.	Construction	1.000	1.005	1.003	1.000	1.006	1.005
5.	Manufacturing-1	1.000	1.014	1.008	1.000	1.012	1.010
6.	Manufacturing-2	1.000	1.004	1.002	1.000	1.004	1.004
7.	Comm/Tran/P.Util	1.000	1.005	1.003	1.000	1.006	1.005
8.	Trade	1.000	1.008	1.005	1.000	1.008	1.006
9.	Fin/Ins/R.Estate	1.000	1.011	1.007	1.000	1.007	1.006
9.	Services	1.000	1.009	1.005	1.000	1.007	1.006
Composite Prices							
1.	Agricultural	1.000	1.062	1.042	1.000	1.005	1.003
3.	Mining	1.000	1.002	1.001	1.000	1.003	1.002
4.	Construction	1.000	1.004	1.002	1.000	1.005	1.004
5.	Manufacturing-1	1.000	1.004	1.003	1.000	1.004	1.003
6.	Manufacturing--	1.000	1.001	1.001	1.000	1.002	1.001
7.	Comm/Tran/P.Util	1.000	1.004	1.002	1.000	1.004	1.003
8.	Trade	1.000	1.006	1.004	1.000	1.006	1.005
9.	Fin/Ins/R.Estate	1.000	1.008	1.005	1.000	1.005	1.004
9.	Services	1.000	1.006	1.003	1.000	1.005	1.004
Exports							
1.	Agricultural	1.100	1.100	1.100	1.000	0.993	0.995
3.	Mining	1.000	0.997	0.999	1.000	0.997	0.997
4.	Construction	1.000	0.999	0.999	1.000	0.998	0.999
5.	Manufacturing-1	1.000	0.986	0.992	1.200	1.200	1.200
6.	Manufacturing-2	1.000	0.996	0.998	1.000	0.996	0.996
7.	Comm/Tran/P.Util	1.000	0.997	0.998	1.000	0.997	0.998
8.	Trade	1.000	0.998	0.999	1.000	0.998	0.998
9.	Fin/Ins/R.Estate	1.000	0.997	0.998	1.000	0.998	0.998
9.	Services	1.000	0.997	0.998	1.000	0.998	0.998
Imports							
1.	Agriculture	1.000	1.138	1.184	1.000	1.026	1.027
3.	Mining	1.000	1.003	1.004	1.000	1.004	1.007
4.	Construction	1.000	1.002	1.001	1.000	1.002	1.002
5.	Manufacturing-1	1.000	1.013	1.012	1.000	1.016	1.019
6.	Manufacturing-2	1.000	1.002	1.002	1.000	1.002	1.001
7.	Comm/Tran/P.Util	1.000	1.004	1.002	1.000	1.003	1.003
8.	Trade	1.000	1.007	1.004	1.000	1.005	1.004
9.	Fin/Ins/R.Estate	1.000	1.007	1.005	1.000	1.003	1.003
9.	Services	1.000	1.006	1.004	1.000	1.004	1.003

In each case, sector outputs are greater for the fixed price models as compared to the CGE models. Sector outputs are lower for the CGE results with an elasticity of substitution of 2.0 for tradable goods compared to results with an elasticity of 4.0. Prices of regional output increase for the CGE model because of fixed resources and increased exports. Prices increase more for the models with an elasticity of substitution for tradables of 2.0 compared to an elasticity of 4.0. Exports of other commodities decrease slightly for the CGE models because of competition for resources in producing more agricultural exports or more rural resource based manufacturing exports. Imports increase for the CGE models and the level of imports, in general, is greater for tradables for the models with an elasticity of substitution for tradables of 4.0 compared to an elasticity of 2.0 and is less for the nontradables with an elasticity of 4.0 for tradables compared to an elasticity of 2.0

There are several reasons for the differences in output estimates for the fixed price models compared to the CGE models. First, it is assumed that the amount of resources available are unlimited at base year price in the fixed price multiplier analysis. This contrasts to the fixed factor supply assumption in the CGE model. Some compromise between the two extreme assumptions (horizontal or vertical supply functions) can be modeled within the CGE framework by incorporating positively sloped supply functions.

Second, the fixed price multiplier model exogenizes all variables in the rest-of-the-world account (both row and column) in the SAM. However, in the CGE model, exports of other sectors and imports for all sectors are endogenized. On the other hand government demands, transfer payments by government, intrahousehold transfers, and investment demands are exogenous to the CGE models, whereas they are endogenized in the fixed price multiplier model.

Third, under the fixed price multiplier approach, neither factor substitution in production nor commodity substitution in consumption is allowed. Under the linear equation system without any price variable, it is assumed that relative prices are fixed. However, the CGE approach allows substitutions in both production and consumption.

The differences in assumptions and model structure between the fixed price approach and the CGE approach create the differences in commodity market responses including difference in sector output and regional output prices. It is possible to decompose or isolate some of the differences mentioned above by exogenizing some of the endogenous variables in the CGE model using estimates obtained from the fixed price multiplier model. Although this study does not attempt the decomposition, it is clear that the multiplier approach has a tendency to overestimate output responses, and this tendency, in part, comes from the treatment of prices as constants.

Overestimation of sector output by the fixed price model can be explained by use of Figure 9. Let E_0 be the initial equilibrium with P_0 and Q_0 as equilibrium price and quantity for a sector. Under the fixed price multiplier approach, supply is treated as infinitely elastic, while positively sloped supply curves are associated with the CGE approach. For simplicity, assume no inter-industry linkages and no income effect. If final demand changes as represented by a shift in demand from D_0 to D_1, the new equilibrium under fixed price multiplier analysis will be E_1^f. The price remains at P_0 with a new equilibrium quantity of Q_1^f. However, in the CGE framework, price increases to P_1^g, equilibrium quantity is Q_1^g, which is less than Q_1^f.

This difference in output response basically originates from a Hecksher-Ohlin type assumption on factor mobility: factors are mobile between sectors and immobile between regions. This assumption may be too strong for regional

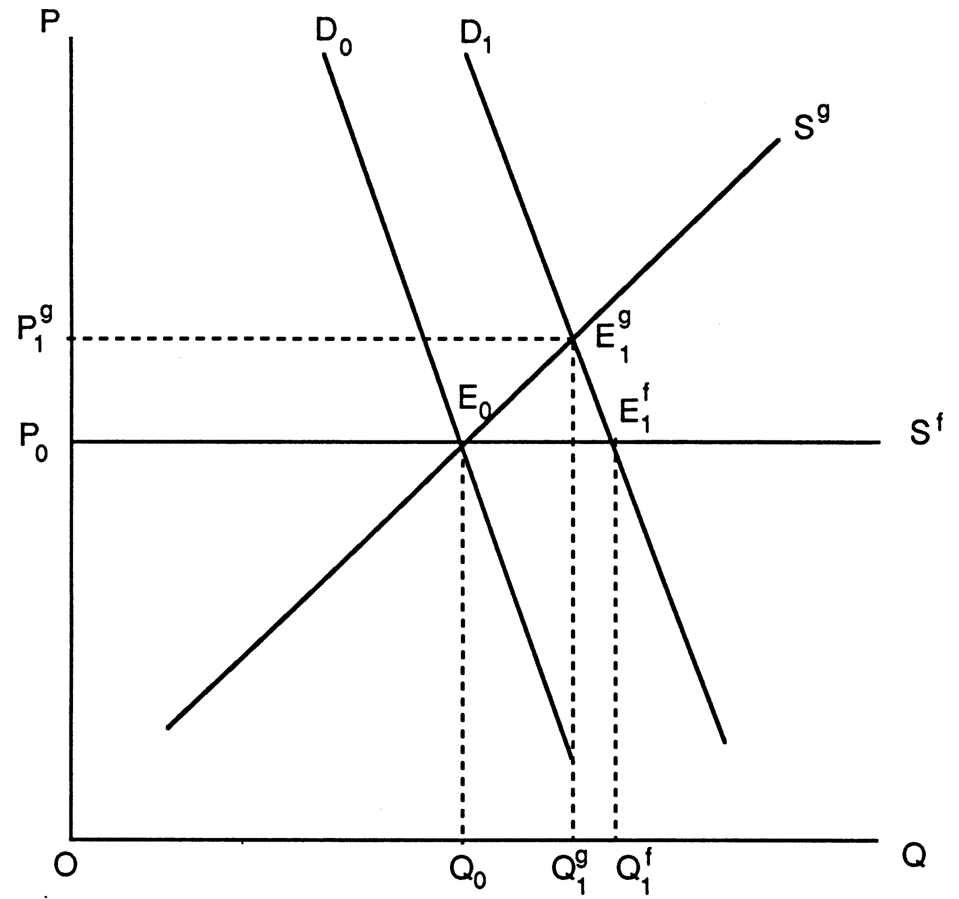

Figure 9. Commodity Market Equilibrium for Fixed Price Multiplier Model and CGE Model

versus national economic analysis. However, in the short run, especially for large regions, this assumption is useful in identifying market behavior for a regional economy under exogenous shocks. Changes in commodity market variables under the CGE framework as presented in Table XI (Models A2, A3, B2, and B3) reveal these relationships between factor and commodity markets.

Increase in output of some sectors requires decreases in output in other sectors (because of factor mobility). Output prices increase in all sectors. Exports decrease for all sectors with the exception of the sector for which export increase was exogenous. Increases in output prices result increases in regional import demand. Changes in trade volumes are based on increased intermediate demands governed by inter-industry relationships, and increased consumption originating from increased income.

Comparing model results from A1 and B1, it is observed that the impact of increased agricultural exports results in greater increases in sectoral output than the impact of increased exports from the rural resource based manufacturing sector even though the volume of exports is similar. This implies agriculture has stronger inter-industry linkages within the state economy. This result is somewhat unexpected and requires further inquiry on input and output markets for the two sectors. A possible hypothesis is that the rural resource based manufacturing sector is more dependent on imported inputs.

Factor Prices and Income Formation

As opposed to the output responses, changes in income from the exogenous changes in exports are significantly more sensitive in the CGE approach compared to the fixed price multiplier approach as shown in Table XII. Increases in overall labor income resulting from increases in exports was estimated at 0.4 percent for model A1 and 0.2 percent for model B1 using the fixed price multiplier approach compared to increases of 1.0 and 0.6 percent for models A2 and A3, respectively, and 0.9 and 0.8 percent for models B2 and B3, respectively, using the CGE

TABLE XII

IMPACTS OF INCREASED AGRICULTURAL AND RURAL RESOURCE BASED MANUFACTURING EXPORTS ON FACTOR MARKETS AND INCOME DISTRIBUTION, OKLAHOMA

Variable	10% Increase in Agric. Exports MODEL A1	MODEL A2	MODEL A3	20% Increase in Manuf.-1 Exports MODEL B1	MODEL B2	MODEL B3
Factor Income						
Labor 1	1.004	1.010	1.006	1.002	1.009	1.007
Labor 2	1.005	1.010	1.006	1.002	1.009	1.008
Labor 3	1.004	1.011	1.006	1.002	1.008	1.007
Labor 4	1.052	1.301	1.207	1.005	1.017	1.012
Labor 5	1.004	1.005	1.003	1.003	1.010	1.008
Sub Total	1.004	1.010	1.006	1.002	1.009	1.008
Capital	1.005	1.012	1.008	1.002	1.007	1.005
Land	1.068	1.400	1.276	1.006	1.018	1.012
Institutional Income						
Urban	1.004	1.010	1.006	1.002	1.009	1.007
Rural Farm	1.037	1.206	1.141	1.004	1.012	1.008
Rural Non-Ag	1.004	1.009	1.006	1.002	1.009	1.007
Household Income						
Low	1.005	1.001	1.001	1.002	1.002	1.002
Medium	1.005	1.013	1.008	1.003	1.007	1.006
High	1.005	1.012	1.008	1.002	1.008	1.007
Wage Rate						
Labor 1	1.000	1.010	1.006	1.000	1.009	1.007
Labor 2	1.000	1.010	1.006	1.000	1.009	1.008
Labor 3	1.000	1.011	1.006	1.000	1.008	1.007
Labor 4	1.000	1.302	1.208	1.000	1.017	1.012
Labor 5	1.000	1.005	1.003	1.000	1.010	1.008
Rental Price Of Capital						
1. Agricultural	1.000	1.400	1.276	1.000	1.018	1.012
3. Mining	1.000	0.999	0.999	1.000	1.000	1.000
4. Construction	1.000	1.006	1.003	1.000	1.009	1.007
5. Manufacturing-1	1.000	0.988	0.982	1.000	1.092	1.078
6. Manufacturing-2	1.000	1.005	1.003	1.000	1.006	1.005
7. Comm/Tran/P.Util	1.000	1.008	1.004	1.000	1.007	1.006
8. Trade	1.000	1.011	1.007	1.000	1.010	1.008
9. Fin/Ins/R.Estate	1.000	1.014	1.009	1.000	1.008	1.006
9. Services	1.000	1.100	1.006	1.000	1.008	1.007

approach. Larger estimates for factor income from capital and land also result for the CGE model compared to the fixed price model.

The fixed price multiplier framework captures changes in factor income by changes in quantities of factors used in production. The CGE framework captures changes in factor income caused by sectoral changes in factor use and changes in factor prices associated with given aggregate factor availability . This can be explained by Figure 10.

Assume an economy with one input (X) and two goods (A and B). Initial equilibrium is depicted by point E_0 in Figure 10. The distance from O_a to X_0 and from O_b to X_0 on the horizontal axis measure equilibrium quantities of X

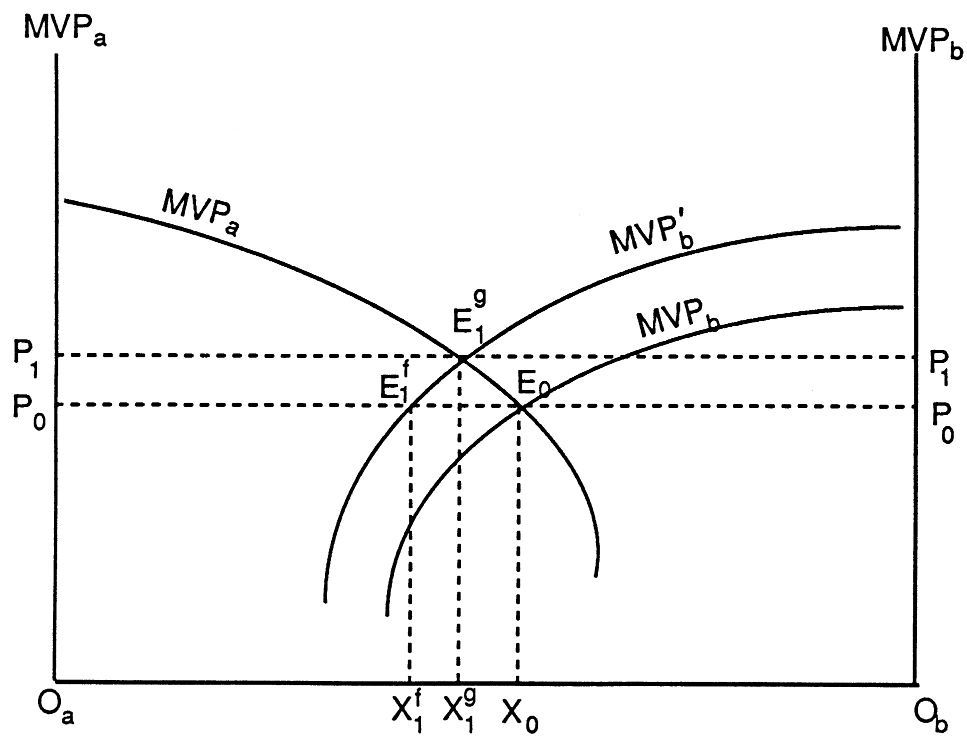

Figure 10. Factor Market Equilibrium for Fixed Price Multiplier Model and CGE Model.

allocated to production of goods A and B, respectively. Equilibrium price of X is represented by Po on the vertical axis. Factor income is measured by the rectangular area $O_aP_oP_oO_b$. If price of B increases for some reason, value of the marginal product of X will increase for the production of B (MVP_b to MVP'_b). For simplicity, assume that this will not affect the price of A. Under fixed price multiplier analysis new equilibrium quantities of X used in production of A and B will be O_aX_o and $O_bX_1^f$, respectively. Initial equilibrium price, P_o, is still valid for the new equilibrium. This implies that the availability of factor X increases by the distance from X_o to X_1^f at the equilibrium price. Consequently, the change in factor income under this approach is only a quantity effect and equal to the area $X_oX_1^fE_1^fE_o$.

On the other hand, in the CGE model the assumption remains that the total amount of X available is fixed to O_aO_b. The change in price of B will bring about a new equilibrium price for X of P_1, and new equilibrium quantities of X allocated to A and B of $O_aX_1^g$ and $O_bX_1^g$, respectively. The rectangular area $P_1P_oP_0P_1$ is the change in factor income for X.

According to the CGE results (models A2, A3 and B2, B3), wage rate increased for all labor categories. However, wage rate for agricultural labor (Labor 4) increased most significantly. This is because of limited possibility for the reallocation of agricultural labor between sectors. Notice that most of agricultural labor was allocated to agricultural production at the initial equilibrium in the base SAM.

The same reasoning applies to the estimates for changes in land and capital in response to the exogenous shock. Because of the assumption that land is used only in the agricultural sector and that capital is immobile between sectors, there is no interaction between sectors for these factors. Prices for the immobile factors are more sensitive to shocks from the output market than are prices for the mobile factors.

As for institutional income, the income increases for rural farm are higher than for the other institutions. This result is common to both exogenous shocks. For household income (excluding all transfer income), medium income households experienced higher changes in income than did low and high income households.

Impacts of Oklahoma's Economic Bust on Commodity Markets

Output Prices

The combined exogenous shocks of the "Oklahoma Economic Bust" (30 percent decrease in mining prices, 10 percent decrease in agricultural prices, and a 10 percent decrease in investment demand) reduced regional output prices for all sectors irrespective of other model formulations (Table XIII). The magnitude of price decreases was largest when full employment was imposed on the labor market following the neoclassical paradigm (model C1). It was found that output prices were sensitive to the elasticity of export demand and elasticity of substitution between imported goods and regional goods. The larger elasticities generated more stable output prices as expected (models C4 vs. C5, and C3 vs. C6).

Sectoral Output

The three shocks combined gave significant impacts on sectoral output (Table XIV). Price decreases in agriculture and mining caused decreased output in those sectors and related sectors. However, manufacturing output

TABLE XIII

IMPACTS ON OUTPUT PRICES FROM OKLAHOMA'S ECONOMIC BUST UNDER ALTERNATIVE MODEL FORMULATIONS

	Model	C1	C2	C3	C4	C5	C6
	Labor Market						
	Skilled	full employ	fixed wages	full employ	full employ	full employ	full employ
	Unskilled	full employ	fixed wages	fixed wages	fixed wages	fixed wages	fixed wages
	Elasticity of Sub.						
	Tradable goods	4.0	4.0	4.0	4.0	4.0	1.0
	Nontradable goods	0.5	0.5	0.5	0.5	0.5	0.3
	Elasticity of Export Demand						
	Tradable goods	-0.7	-0.7	-0.7	-2.0	-1.0	-0.7
	Nontradable goods	-0.3	-0.3	-0.3	-0.3	-0.1	-0.3
	Sector						
1	Agriculture	0.900	0.900	0.900	0.900	0.900	0.900
2	Mining	0.700	0.700	0.700	0.700	0.700	0.700
3	Construction	0.891	0.982	0.912	0.935	0.905	0.881
4	Manufacturing-1	0.919	0.973	0.935	0.951	0.930	0.904
5	Manufacturing-2	0.865	0.924	0.882	0.902	0.879	0.856
6	Comm/Tran/P.Util	0.864	0.934	0.889	0.912	0.877	0.853
7	Trade	0.869	0.980	0.927	0.947	0.919	0.895
8	Fin/Ins/R.Estate	0.841	0.887	0.879	0.899	0.868	0.838
9	Services	0.875	0.985	0.929	0.949	0.920	0.898

showed positive changes in response to the combined shock of decreased prices in agriculture and mining. With full employment of labor enforced (model C1), output effects are less significant except for manufacturing-2 and services. Fixed wage rates imposed on all labor categories (model C2) reduced output most significantly. With labor market specification mixed (models C3 through C6), i.e., fixed wage for unskilled labor and flexible wage for skilled labor, results were in between the two labor market extremes.

TABLE XIV

IMPACTS ON SECTORAL OUTPUT FROM OKLAHOMA'S ECONOMIC BUST UNDER ALTERNATIVE MODEL FORMULATIONS

Model	C1	C2	C3	C4	C5	C6
Labor Market						
Skilled	full employ	fixed wages	full employ	full employ	full employ	full employ
Unskilled	full employ	fixed wages	fixed wages	fixed wages	fixed wages	fixed wages
Elasticity of Sub.						
Tradable goods	4.0	4.0	4.0	4.0	4.0	1.0
Nontradable goods	0.5	0.5	0.5	0.5	0.5	0.3
Elasticity of Export Demand						
Tradable goods	-0.7	-0.7	-0.7	-2.0	-1.0	-0.7
Nontradable goods	-0.3	-0.3	-0.3	-0.3	-0.1	-0.3
Sector						
1 Agriculture	0.997	0.906	0.980	0.970	0.985	0.996
2 Mining	0.806	0.710	0.781	0.755	0.790	0.820
3 Construction	0.978	0.955	0.971	0.970	0.966	0.970
4 Manufacturing-1	1.157	1.010	1.112	1.109	1.116	1.016
5 Manufacturing-2	1.221	1.095	1.184	1.258	1.174	1.097
6 Comm/Tran/P.Util	1.037	0.985	1.020	1.025	1.011	1.008
7 Trade	1.000	0.935	0.969	0.978	0.964	0.951
8 Fin/Ins/R.Estate	0.983	0.948	0.962	0.966	0.959	0.951
9 Services	1.101	0.957	0.986	0.988	0.969	0.976

The elasticity of export demand was found to be important in the sectoral allocation of resources. Comparing the results of models C3, C4, and C5, the effects of different elasticity values on sectoral outputs are mixed. Higher elasticities for tradables (model C4 vs. model C3) reduced outputs of sectors 1 through 4 more than did the lower elasticity values. Outputs for the other sectors (sectors 5 through 9) reduced less with the higher export demand elasticities for tradables than with lower elasticities. This tendency was generally consistent in the comparisons between results of models C3 vs. C4, and C4 vs. C5.

The same was true for trade elasticities of substitution. The higher the elasticities the greater the decreases in sectoral outputs for the sectors with the direct exogenous shock, and the less the reduction in output for the other sectors (model C3 compared to model C6).

This implies that in the short run where capital is immobile between sectors, efficiency in labor allocation between sectors has positive relationships with both types of elasticities. This point is made more clearly when considering changes in labor income.

Regional Trade

The decrease in exogenous output prices for the agricultural and mining sectors reallocated labor across sectors as indicated by the changes in sectoral output. These changes in output together with changes in intermediate and consumption demand necessarily requires adjustments in regional trade. This study divided the world into two; Oklahoma and the rest-of-the-world, assuming all exports and imports limited to interregional trade. More meaningful results could be derived by disaggregating the rest-of-the-world account in the SAM into the rest-of-the-nation and "foreign countries" for example. This approach would capture the effect of international trade on the regional economy or vice versa.

The model results presented in Table XV reveal that exports of the price depressed sectors declined significantly, and that exports of other sectors increased. Imports generally moved in the opposite direction. Export

TABLE XV

IMPACTS ON REGIONAL TRADE FROM OKLAHOMA'S BUST UNDER ALTERNATIVE MODEL FORMULATIONS

Model	C1	C2	C3	C4	C5	C6
Labor Market						
Skilled	full employ	fixed wages	full employ	full employ	full employ	full employ
Unskilled	full employ	fixed wages	fixed wages	fixed wages	fixed wages	fixed wages
Elasticity of Sub.						
Tradable goods	4.0	4.0	4.0	4.0	4.0	1.0
Nontradable goods	0.5	0.5	0.5	0.5	0.5	0.3
Elasticity of Export Demand						
Tradable goods	-0.7	-0.7	-0.7	-2.0	-1.0	-0.7
Nontradable goods	-0.3	-0.3	-0.3	-0.3	-0.1	-0.3
Export						
1. Agriculture	0.971	0.872	0.955	0.940	0.962	0.999
2 Mining	0.622	0.518	0.596	0.529	0.616	0.691
3. Construction	1.035	1.005	1.028	1.020	1.010	1.039
4. Manufacturing-1	1.061	1.019	1.048	1.106	1.037	1.073
5. Manufacturing-2	1.107	1.057	1.092	1.229	1.069	1.115
6. Comm/Tran/P.Util	1.045	1.021	1.036	1.028	1.013	1.049
7. Trade	1.043	1.006	1.023	1.016	1.009	1.034
8. Fin/Ins/R.Estate	1.053	1.036	1.039	1.033	1.014	1.054
9. Services	1.041	1.005	1.022	1.016	1.008	1.033
Imports						
1 Agriculture	1.035	0.954	1.016	1.013	1.017	0.992
2 Mining	1.037	0.950	1.011	1.038	1.008	0.981
3 Construction	0.903	0.928	0.907	0.920	0.902	0.909
4 Manufacturing-1	0.855	0.901	0.873	0.907	0.860	0.894
5 Manufacturing-2	0.792	0.844	0.810	0.864	0.795	0.912
6 Comm/Tran/P.Util	0.960	0.933	0.954	0.977	0.945	0.940
7 Trade	0.924	0.911	0.923	0.945	0.915	0.905
8 Fin/Ins/R.Estate	0.894	0.883	0.893	0.908	0.887	0.890
9 Services	0.929.	0.924	0.931	0.948	0.924	0.915

decreasing sectors imported more, and export increasing sectors imported less. These responses are sensitive to the elasticity of export demand. The more elastic the export demand for tradables, the lower the exports in the price depressed sectors and the higher the exports in other tradable sectors (model C4 vs. models C3 and C5). The direction of change in both exports and imports was consistent among the elasticity values evaluated.

The trade elasticity of substitution parameter also has significant influence on the magnitude of the changes. The direction of change was not affected by the alternative elasticity parameter values for exports, however the direction of change in imports for the price depressed sectors was found to be reversed by the elasticity of substitution parameters (model C6 vs. model C3). Alternative labor market closures also produced opposite signs for the imports of the price depressed sectors (model C2 vs. models C1 and C3).

Household Demand

Combined effects of price changes and income changes on household demand are revealed in Table XVI. Results of all model formulations are consistent in terms of sign and magnitude of change. Increased demand for mining implies that the price effect dominates the income effect although the absolute level of consumption is minimal as presented in the base SAM. For all other sectors, decreases in consumption demand were significant. Taking into account the decline in all commodity prices (Table XIII), the consistent decrease in consumption demand indicates that the income effect dominates the price effects. This implies that income growth by the lower income classes generates higher levels of economic activity than the same amount of income growth by the higher income groups. This is because of the higher marginal propensities to consume for the former. Moreover, it is generally believed that demand for luxury goods is more income elastic than for necessities, and intuitively, more luxuries are consumed by the rich. In an economy-wide study with highly aggregated industry sectors it is difficult to analyze this income-elasticity effect, however, the effect of differences in marginal propensities to consume is self-evident. This point will be discussed later.

TABLE XVI

IMPACTS ON HOUSEHOLD DEMAND FROM OKLAHOMA'S ECONOMIC BUST UNDER ALTERNATIVE MODEL FORMULATIONS

Model	C1	C2	C3	C4	C5	C6
Labor Market						
Skilled	full employ	fixed wages	full employ	full employ	full employ	full employ
Unskilled	full employ	fixed wages	fixed wages	fixed wages	fixed wages	fixed wages
Elasticity of Sub.						
Tradable goods	4.0	4.0	4.0	4.0	4.0	1.0
Nontradable goods	0.5	0.5	0.5	0.5	0.5	0.3
Elasticity of Export Demand						
Tradable goods	-0.7	-0.7	-0.7	-2.0	-1.0	-0.7
Nontradable goods	-0.3	-0.3	-0.3	-0.3	-0.1	-0.3
Sector						
1 Agriculture	0.946	0.983	0.964	0.995	0.952	0.916
2 Mining	1.223	1.269	1.245	1.284	1.230	1.185
3 Construction	0.000	0.000	0.000	0.000	0.000	0.000
4 Manufacturing-1	0.875	0.891	0.886	0.910	0.877	0.849
5 Manufactúring-2	0.896	0.906	0.906	0.927	0.897	0.962
6 Comm/Tran/P.Util	0.944	0.929	0.943	0.956	0.940	0.921
7 Trade	0.949	0.896	0.919	0.932	0.913	0.891
8 Fin/Ins/R.Estate	0.948	0.943	0.940	0.957	0.935	0.918
9 Services	0.925	0.891	0.907	0.924	0.901	0.880

Impacts of Oklahoma's Economic Bust on Factor Markets and Income Formation

Factor Demand

Changes in factor demand have a direct relationship to changes in sectoral output because production technology is assumed to be constant. Because capital and land are not allowed to move between sectors, and because full employment is enforced for these factors, the source of sectoral output change is labor reallocation. Change in industry mix or in sectoral output leads to a substitution in labor use among sectors. Changes in labor demand because of Oklahoma's economic bust (model C1) are presented in Table XVII. These changes reveal that labor demand decreased more than the decrease in sector output for agriculture, mining, and construction (Table XIV, Model C1), the sectors effected most by the Oklahoma's Economic bust. Labor in the mining sector is reduced by 44 to 48 percent versus a 20 percent reduction in sector output (Table XIV). Increased or less reduction in employment of Labor-4 and Labor-5 by the agricultural or mining sector implies that these labor categories are the most adversely affected by the commodity market shocks.

The tradable sectors without the direct output price shock (manufacturing sectors) absorbed most of the labor force displaced by the other sectors indicating that the availability of export markets for these sectors is an important determinant of maintaining wage rates under model formulation C1, or of limiting amount of unemployment under model C2.

TABLE XVII

IMPACTS ON LABOR DEMAND FROM OKLAHOMA'S ECONOMIC BUST UNDER FULL EMPLOYMENT ASSUMPTION (MODEL C1)

Sector	Labor-1	Labor-2	Labor-3	Labor-4	Labor-5
Agriculture	0.978	0.972	0.966	0.990	1.014
Mining	0.562	0.523	0.520	0.533	0.545
Construction	0.952	0.946	0.940	0.964	0.986
Manufacturing-1	1.201	1.194	1.187	1.216	1.245
Manufacturing-2	1.262	1.254	1.247	1.278	1.308
Comm/Tran/P.Util	1.067	1.060	1.054	1.080	1.106
Trade	0.993	0.987	0.981	1.006	1.029
Fin/Ins/R.Estate	0.939	0.933	0.928	0.951	0.974
Services	1.013	1.006	1.001	1.025	1.050

Factor Prices

Changes in factor prices have significant implications on the interregional flow of factors in the long run. Although the present study assumed region specific factors, declining factor prices indicate a possible outflow of factors. The changes in factor prices estimated by the different model formulations are reported in Table XVIII. When full employment of all labor is imposed (Model C1), wage rates decrease by 14 to 18 percent. The most significant wage decline was found for Labor-5, which is highly associated with the mining and construction sectors. Imposing fixed wage rate for all labor categories

TABLE XVIII

IMPACTS ON FACTOR PRICES FROM OKLAHOMA'S ECONOMIC BUST UNDER ALTERNATIVE MODEL FORMULATIONS

Model	C1	C2	C3	C4	C5	C6
Labor Market						
Skilled	full employ	fixed wages	full employ	full employ	full employ	full employ
Unskilled	full employ	fixed wages	fixed wages	fixed wages	fixed wages	fixed wages
Elasticity of Sub.						
Tradable goods	4.0	4.0	4.0	4.0	4.0	1.0
Nontradable goods	0.5	0.5	0.5	0.5	0.5	0.3
Elasticity of Export Demand						
Tradable goods	-0.7	-0.7	-0.7	-2.0	-1.0	-0.7
Nontradable goods	-0.3	-0.3	-0.3	-0.3	-0.1	-0.3
Wage Rate						
Labor-1	0.851	1.000	0.883	0.920	0.867	0.825
Labor-2	0.856	1.000	1.000	1.000	1.000	1.000
Labor-3	0.861	1.000	1.000	1.000	1.000	1.000
Labor-4	0.840	1.000	0.803	0.783	0.811	0.828
Labor-5	0.821	1.000	0.831	0.879	0.817	0.762
Unemployment						
Labor-1	0.000	0.086	0.000	0.000	0.000	0.000
Labor-2	0.000	0.084	0.112	0.058	0.128	0.173
Labor-3	0.000	0.057	0.094	0.066	0.011	0.143
Labor-4	0.000	0.270	0.000	0.000	0.000	0.000
Labor-5	0.000	0.137	0.000	0.000	0.000	0.000
Rental Price of Capital						
1. Agriculture	0.832	0.661	0.770	0.734	0.785	0.823
2. Mining	0.448	0.374	0.422	0.402	0.431	0.453
3. Construction	0.810	0.954	0.827	0.867	0.809	0.766
4. Manufacturing-1	1.022	1.104	1.013	1.052	1.003	0.838
5. Manufacturing-2	1.074	1.120	1.080	1.215	1.053	0.919
6. Comm/Tran/P.Util	0.908	0.968	0.932	0.794	0.902	0.859
7. Trade	0.845	0.921	0.891	0.923	0.877	0.838
8. Fin/Ins/R.Estate	0.799	0.813	0.823	0.848	0.808	0.768
9. Services	0.862	0.949	0.909	0.935	0.893	0.863
Land Rent	0.832	0.661	0.770	0.734	0.785	0.823

(Model C2), the highest unemployment rate is 27 percent for Labor-4. Unemployment rates for Labor-1, Labor-2, and Labor-3 are found to be less than 10 percent.

Fixed wage rates on Labor-2 and Labor-3 make Labor-1 and Labor-5 better off, but make Labor-4 worse off (Model C3 vs. C1). This implies that labor categories 1 and 5 are more substitutable for labor categories 2 and 3 than for Labor-4 (agricultural labor).

The price of capital decreased for all sectors except for the two tradable goods producing sectors (manufacturing) which had a price increase. These results on the sectoral rental price of capital indicate that the positive impacts of the exogenous commodity market disturbances dominated the negative impacts for the two remaining tradable sectors while the opposite was true for the non-tradable sectors. The positive impacts come from the decrease in factor (labor) prices and the decrease in intermediate input prices. The negative impacts originate from decreases in regional demand because of the decrease in incomes. For the two manufacturing tradable sectors, the degree of dominance by the positive effects over the negative effects are found to be positively related to the elasticity of export demand (C4 vs. C3 and C5) and negatively related to the trade elasticity of substitution (C3 vs. C6).

The change in land price exactly follows the price of capital in agriculture because of the constant returns to scale production function and the immobilities associated with both factors.

Factor Income Formation

Impact of the commodity market disturbances on factor income formation is presented in Table XIX. In general, decreases in capital and land income are more significant than decreases in labor income for all models. This result is not surprising because capital and land are treated as sector specific, hence they are not allowed to move from sectors with low returns to those with high returns.

The different assumptions about labor market behavior generate different results with respect to factor income formation. If wage rates are endogenized for all labor categories (Model C1), total labor income decreases by about 15.6 percent, and capital and land incomes decrease by 28.3 and 16.8 percent, respectively.

If wage rates are fixed for all labor categories (Model C2), aggregate labor income is significantly larger than for the full employment case (Model C1). A significant decrease in land income is observed under this labor market assumption (Model C2). Moreover, agricultural labor (Labor-4) is worse off under fixed wage rates while all other labor categories are better off in terms of aggregate income formation.

If fixed wage rate is imposed only on unskilled labor (Labor-2 and Labor-3), labor owners, except agricultural labor, are better off than without the wage constraints (Model C3 vs. C1) but labor in the aggregate is worse off (Model C3 vs. Model C1). However, capital is slightly better off and land is worse off. The more wage rates are constrained, the worse off is land income and agricultural labor income.

Comparing factor income effects with sectoral output responses, it is observed that increases in output are not necessarily associated with increases in factor incomes. For the first three models (C1, C2, and C3), C1 generates more output for all sectors compared to C2 and C3, and output for C3 is greater than for C2 for all sectors. Consequently, output ranking is C1 > C3 > C2. However, ranking by aggregate labor income is C2 > C3> C1, which is the

TABLE XIX

IMPACTS ON FACTOR INCOME FORMATION FROM OKLAHOMA'S ECONOMIC BUST UNDER ALTERNATIVE MODEL FORMULATIONS

Model	C1	C2	C3	C4	C5	C6
Labor Market						
Skilled	full employ	fixed wages	full employ	full employ	full employ	full employ
Unskilled	full employ	fixed wages	fixed wages	fixed wages	fixed wages	fixed wages
Elasticity of Sub.						
Tradable goods	4.0	4.0	4.0	4.0	4.0	1.0
Nontradable goods	0.5	0.5	0.5	0.5	0.5	0.3
Elasticity of Export Demand						
Tradable goods	-0.7	-0.7	-0.7	-2.0	-1.0	-0.7
Nontradable goods	-0.3	-0.3	-0.3	-0.3	-0.1	-0.3
Factor Income						
Labor-1	0.852	0.914	0.883	0.920	0.868	0.826
Labor-2	0.857	0.917	0.889	0.927	0.873	0.828
Labor-3	0.862	0.944	0.906	0.934	0.890	0.858
Labor-4	0.841	0.731	0.804	0.785	0.812	0.829
Labor-5	0.822	0.864	0.832	0.879	0.818	0.764
SubTotal	0.844	0.899	0.869	0.908	0.853	0.808
Capital	0.717	0.715	0.723	0.741	0.714	0.691
Land	0.832	0.661	0.770	0.734	0.785	0.823

opposite to output ranking. Agricultural labor income and land income follow output ranking, and ranking for capital income is C3>C1>C2. Moreover, considering that models C2 and C3 produce unemployment while model C1 does not, policy decisions that affect labor market behavior inevitably require value judgements.

These types of mixed rankings also exist with respect to the elasticities of export demand and the trade elasticities of substitution. Comparing results of models C4 and C5, higher elasticities of export demand are preferred in terms of aggregate labor and capital incomes. But in terms of returns to agricultural land and agricultural labor, lower elasticities are preferred. Similar relationships are found with respect to trade elasticities of substitution.

Incomes for Regional Institutions and Households

The distributional impacts of the combined shocks of Oklahoma's bust are given in Table XX. Implications of the results on factor prices and factor incomes are revealed by the results on distributions of income. There is approximately a 13 to 22 percent decline in the incomes for all geographic institutions. Under the full employment option for all labor skills (Model C1), the decrease in income for rural agriculture is the lowest. When fixed wage rates are imposed for all labor categories (Model C2), rural agricultural income is the lowest as implied by the factor price for land and the rate of unemployment for agricultural labor. The elasticity values affect the magnitudes of the changes, but the signs of the changes are not influenced.

Size distribution of household income is presented as changes in income net of government and interhousehold income transfers because transfers are assumed to be fixed at the base year level. The lowest decrease in income was observed for medium income households. This implies that this income class is less dependent upon income from capital, land, and labor categories 4 and 5. The larger income decreases for high and low income households can be interpreted as more dependence on property income by the former and on labor income from categories 4 and 5 for the latter.

Constraints imposed on wage rates (Models C2 and C3 vs. C1) reduce incomes less for all household groups compared to full employment of labor. Under the general equilibrium framework, various factors are related to this result. However, the most important implication can be derived from the relationship between output price change and marginal value product as illustrated by Figure 11.

Let the distance O_aO_b on the horizontal axis measure the availability of aggregate labor, and the two vertical axes measure marginal value products (MVP) of labor used in the production of commodities A and B. Assume that A represents a composite of mining and agricultural outputs, and B is a composite of all other outputs. Through the general equilibrium process, MVP of labor in B decreases as well as the MVP of labor in A. Initial equilibrium was E_o with wage rate w_o and employment O_aX_o and O_bX_o for sectors A and B, respectively. With the commodity market disturbances, the MVP curves shift downward. The new equilibrium wage rate is w_1 for full employment of labor. Decrease in aggregate labor income is represented by the area $w_ow_ow_1w_1$. On the other other hand, aggregate labor income decrease under a fixed wage rate is the unemployment (distance from X_1^a to X_1^b) multiplied by the initial wage rate, which is represented by the area $abX_1^bX_1^a$. If the unemployment effect is smaller than the wage rate effect, the fixed wage rate version of the model (C2 and C3) will generate more labor income than the full employment version (C1).

TABLE XX

INCOMES FOR GEOGRAPHIC INSTITUTIONS AND HOUSEHOLDS FROM OKLAHOMA ECONOMIC BUST UNDER ALTERNATIVE MODEL FORMULATIONS

Model	C1	C2	C3	C4	C5	C6
Labor Market						
Skilled	full employ	fixed wages	full employ	full employ	full employ	full employ
Unskilled	full employ	fixed wages	fixed wages	fixed wages	fixed wages	fixed wages
Elasticity of Sub.						
Tradable goods	4.0	4.0	4.0	4.0	4.0	1.0
Nontradable goods	0.5	0.5	0.5	0.5	0.5	0.3
Elasticity of Export Demand						
Tradable goods	-0.7	-0.7	-0.7	-2.0	-1.0	-0.7
Nontradable goods	-0.3	-0.3	-0.3	-0.3	-0.1	-0.3
Institutional Income						
Urban	0.816	0.859	0.837	0.872	0.823	0.783
Rural Agric.	0.852	0.773	0.825	0.815	0.830	0.840
Rural Non-Agric.	0.818	0.862	0.839	0.874	0.825	0.783
Household Income (Net of Transfer)						
Low	0.817	0.864	0.839	0.876	0.825	0.783
Med	0.885	0.926	0.905	0.940	0.892	0.851
High	0.817	0.850	0.838	0.872	0.824	0.784

The magnitude of the shifts in the MVP curves and their slopes determine the degree of change in labor income. The responsiveness and slopes of the MVP curves are inversely related to the elasticities of output demand.[17] Moreover, labor income is almost totally distributed to households whereas the

[17] Let production function of output y be y(x), downward sloped output demand function be P(y(x)), then $MVP = d[P\{y(x)\}y(x)]/dx = P\frac{dy}{dx} + y\frac{dP}{dy}\frac{dy}{dx} = \frac{dy}{dx}(P + y\frac{dP}{dy}) = P\frac{dy}{dx}[1+1/(\frac{dy}{dp}\frac{P}{y})]$

capital income is distributed after deductions for retained earnings and depreciation. Seemingly contradictory model results for C1 and C2, i.e., income for each household group is greater with less labor employed, can be explained by the above argument. The relationship between elasticity of output demand and household income can be observed by comparing results of model C3 with models C4 and C5.

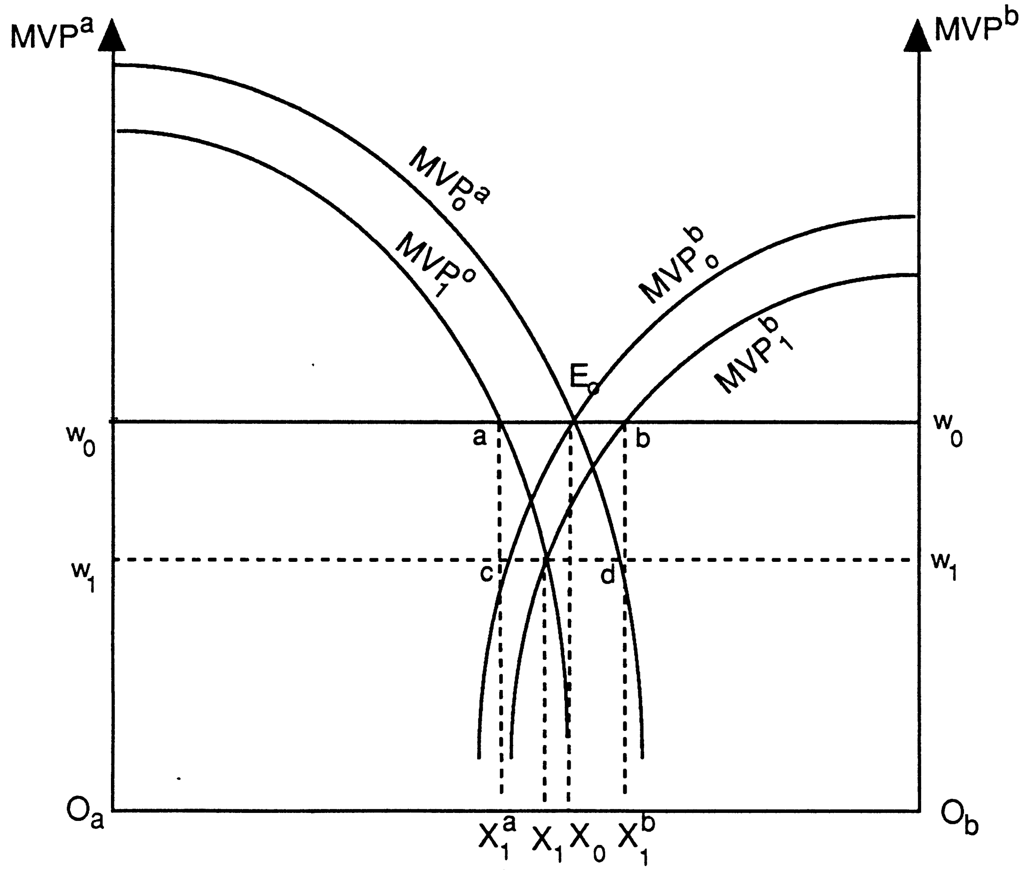

Figure 11. Labor Income Under Alternative Labor Market Assumptions

General Equilibrium Impact of Income Redistribution

Earlier it was shown that as a result of an exogenous commodity price shock, the income effect was greater than the price effect on household demand for commodities, and hence it was implied that income growth by lower income households would increase the demand more than a comparable income growth by high income households. This point can be tested through a simulation of the CGE model.

The simulation is a change in government transfer payments by household income class size. Government transfer payments for base year SAM were 1563 million dollars, 2502 million dollars, and 1010 million dollars for the low, medium, and high income households, respectively. The alternative simulation is that all government transfers to the high income class and 50 percent of the transfers to the medium income class are shifted to the low income class. Thus, aggregate transfers by government do not change but distribution of transfers does change. This alternative was simulated along with model C3 assumptions. The results for the new scenario (C3-T) are compared with the results of model C3 (Table XXI).

The new transfer scheme generates positive effects on the overall economy with a few exceptions. The exceptions are mainly associated with agriculture. Outputs increased for all sectors except agriculture, mining, and manufacturing-2. Factor incomes are higher for model C3-T except for Labor-4 and land. Wage rates increased for all labor skills except Labor-4. Household incomes (net of transfers) are higher for all income classes.

Institutional incomes are higher except for rural agriculture. The differences between the two models are the results of the general equilibrium process in determining consumption demand, which is determined by the model parameters of savings rate and expenditure shares. In this regard, impacts of the new transfer scheme must be interpreted in relation to those parameters. The marginal propensity to save is constant and larger for the higher income classes. Because investment is a function of saving and investment is assumed exogenous in the CGE model, the lower savings under the new transfer scheme (model C3-T) does not translate into lower investments and hence results of model C3-T are biased upward. The higher household consumption demand is the result of higher marginal propensities to consume for the lower income class and the higher level of income for this income class. The unexpected results are the lower factor incomes for land and agricultural labor and the lower rural agriculture income.

TABLE XXI

GENERAL EQUILIBRIUM IMPACT OF CHANGE IN GOVERNMENT TRANSFER PAYMENTS ON OKLAHOMA'S ECONOMY

Variable	Before Transfer Model C3 (a)	After Transfer Model C3-T (b)	Percent Change (b-a)/(a)
Sectoral Output			
1 Agriculture	0.980	0.977	-0.31
2 Mining	0.781	0.775	-0.77
3 Construction	0.971	0.971	0.00
4 Manufacturing-1	1.112	1.117	0.45
5 Manufacturing-2	1.184	1.179	-0.42
6 Comm/Tran/P.Util	1.020	1.027	0.69
7 Trade	0.969	0.979	1.03
8 Fin/Ins/R.Estate	0.962	0.966	0.42
9 Services	0.986	0.992	0.61
Factor Income			
Labor-1	0.883	0.894	1.25
Labor-2	0.889	0.901	1.35
Labor-3	0.906	0.919	1.43
Labor-4	0.804	0.799	-0.62
Labor-5	0.832	0.838	0.72
Total	0.869	0.878	1.04
Capital	0.723	0.730	0.97
Land	0.770	0.759	-1.43
Institutional Income			
Urban	0.837	0.846	1.08
Rural Agriculture	0.825	0.822	-0.36
Rural Non-agriculture	0.839	0.848	1.07
Household Income (Net of Transfer)			
Low Income	0.839	0.849	1.11
Medium Income	0.863	0.871	1.03
High Income	0.838	0.846	1.05

TABLE XXI (continued)

Variable	Before Transfer Model C3 (a)	After Transfer Model C3-T (b)	Percent Change (b-a)/(a)
Wage Rate			
Labor-1	0.883	0.893	1.13
Labor-2	1.000	1.000	0.00
Labor-3	1.000	1.000	0.00
Labor-4	0.803	0.798	-0.62
Labor-5	0.831	0.837	0.72
Unemployment Rate			
Labor-1	0.000	0.000	0.00
Labor-2	0.112	0.099	-10.91
Labor-3	0.094	0.081	-13.86
Labor-4	0.000	0.000	0.00
Labor-5	0.000	0.000	0.00
Household Consumption Demand			
1 Agriculture	0.964	1.008	4.56
2 Mining	1.245	1.330	6.83
3 Construction	0.000	0.000	0.00
4 Manufacturing-1	0.886	0.917	3.50
5 Manufacturing-2	0.906	0.915	0.99
6 Comm/Tran/P.Util	0.943	0.984	4.35
7 Trade	0.919	0.938	2.07
8 Fin/Ins/R.Estate	0.940	0.951	1.17
9 Services	0.907	0.934	2.98

CHAPTER VII

SUMMARY AND CONCLUSIONS

Summary

Decreased agricultural and energy prices during the 1982-86 period brought about considerable economic hardship to Oklahoma. The impacts of the commodity market shocks were not confined to the two production sectors but were channeled to all other commodity and factor markets in the regional economic system through the general equilibrium process: horizontal market interactions (between commodity markets and between factor markets) and vertical interactions (between commodity and factor markets).

The main objective of this study was to construct a computable general equilibrium (CGE) model for the state of Oklahoma that facilitates investigation of basic adjustment mechanisms in a regional economy. To capture the general equilibrium processes, interindustry linkages, factor substitution relationships, structure of consumption and trade, and structure of income formation and distribution are incorporated into the CGE model.

A Social Accounting Matrix (SAM) was constructed for the state of Oklahoma based on the IMPLAN and other published data. The SAM is useful not only for fixed price multiplier analysis but also for structuring a CGE model which explicitly endogenizes both price and quantity variables in the model. Moreover, the SAM for Oklahoma contributed to a better overall understanding of the structure and performance of the state's economy. It provided information on sector outputs, factor uses, trade, and income formation and distribution.

Comparisons between the fixed price SAM multiplier approach and the CGE approach were made. It revealed that output responses estimated by the former method appear to be upper limits of impacts for given exogenous shocks to the state economy. On the other hand, changes in income estimated by the CGE approach are significantly greater than those predicted by the fixed price multiplier approach. Because there are no resource constraints and no fixed period of adjustment embodied in the fixed price multiplier approach, this method may be useful in estimating long term impacts for small regions where full mobility of factors appear to be appropriate. However, in evaluating relatively short term impacts (2 to 5 years) for large regions, the CGE approach appears to be more appropriate because it captures both price effects and quantity effects compared with the fixed price multiplier approach which captures only quantity effects.

A set of commodity market shocks (i.e., a 10 percent decrease in agricultural prices, a 30 percent decrease in mining sector output prices, and a 10 percent decrease in investment demand) was simulated using the Oklahoma CGE model. Results of additional simulations were compared for alternative assumptions about labor market behavior, alternative parameter values for elasticity of substitution between imported and regional goods, and different price elasticities of export demand. Output prices decreased for all sectors for all alternative model formulations. Production in the tradable good producing sectors with endogenous output prices increased for all model configurations. Exports of the price endogenous sectors increased and imports decreased. The opposite changes in trade occurred for the price exogenous sectors of agriculture and mining. For household consumption demand, the effect of decreased income dominated the effect of decreased commodity prices, except for the mining sector.

Changes in labor demand and factor prices were consistent with changes in output in that labor use increased in sectors with increased output. However, because of factor substitution, rate of change in demand by labor category was not identical. For example, decrease in labor demand by the mining sector was 40-50 percent compared with about a 20 percent decrease in output when full employment of labor was enforced by the model. Output price endogenous tradable sectors absorbed the labor force displaced by the other sectors. With full employment imposed on all labor markets, the estimated wage rate decreases were 14-18 percent. When fixed wage rates were imposed, estimated unemployment rates were 5-9 percent for Labor-1 (managerial and professional occupations), Labor-2 (technical, sales, and administrative support occupations), and Labor -3 (service occupations); 14 percent for Labor-5 (precision production, crafts, repair occupations, operators, fabricators, and laborers); and 27 percent for Labor-4 (farming, forestry, and fishing occupations). Under both labor market behavior assumptions, the adverse effects of the given set of commodity market shocks were relatively severe to labor categories 4 and 5.

In general, decreases in capital and land income were more significant than decreases in labor income because of the assumption of labor mobility between sectors. With wage rates endogenized for all labor categories, the decrease in aggregate labor income was about 15.5 percent compared with the 28.3 percent and 16.8 percent decreases in capital and land income, respectively. Aggregate labor income was larger when fixed wage rates were assumed compared to the assumption of full employment which gave higher sector outputs. However, income for agricultural related resources (Labor-4, (Labor-4, and Land) was lower for the fixed wage rate specification as compared to the full employment alternative. Decreases in incomes for geographical institutions was also significant with about 13 to 23 percent across all model configurations. However, the rates of change were significantly different for the institutions under different model assumptions. For example, with the full employment assumption income decreases were 15 percent for rural agriculture, and 18 percent for rural non-agricultural and urban institutions. When fixed wage rates were imposed for all labor categories, the unemployment rates were 23 percent for rural agriculture, and about 14 percent for rural non-agriculture and urban. Similar trade offs exist between different trade related elasticity parameters. Household incomes for the medium income class size were relatively stable under the given set of commodity market shocks. Incomes for this income class size decreased by 6 to 15 percent versus decreases of 12 to 22 percent for low income households and 13 to 22 percent for high income households.

Interestingly, household incomes were higher for the fixed wage rate model than for the full employment model. The reason for this is explained, in part, by the slope of the marginal value product (MVP) curve for labor. If the slope of the MVP for labor is steep, decreases in labor income through reduced wage rates under full employment can be greater than decreases in labor income through unemployment with fixed wage rates. This result is made possible because of fixed sector specific capital.

The magnitudes of change in factor market variables were found to be sensitive to trade related parameter values. The general tendency is that the higher the elasticity of demand for tradable goods the lower the output for the price exogenous sectors and the higher the output for the price endogenous sectors. Higher output for the price endogenous sectors gives higher returns (incomes) for capital and aggregate labor, but lower returns (incomes) for agricultural labor (Labor-4) and land. The same tendency exists with respect to the trade elasticity of substitution.

A hypothetical redistribution of government transfer payments from high income households to low income households generated higher non-transfer incomes for all income classes. Even with possibilities for over estimation of the aggregate incomes, this implies that differences in consumption and savings behavior by income class may have significant impacts on income growth of regional economies.

Conclusions and Policy Implications

The economic hardships experienced by Oklahoma during the 1982-86 period were explained by use of a CGE model. The price declines in agriculture and mining reduced intermediate costs for other sectors and reduced prices to final consumers inside and outside the state. The magnitudes of these positive impacts, however, were limited because of three reasons: (1) capital stocks in specific sectors have limited mobility in the short run, (2) export demand for Oklahoma output is not perfectly price elastic and input demand involving the output price shocked sectors has limited elasticities of substitution and (3) consumer demand is limited by decreased household incomes.

Decreased household incomes resulting from the general equilibrium processes are summarized by the following effects: (1) decreased labor demand in the agricultural and mining sectors decreased wage rates but increased labor demand in other sectors from decreased wage rates is limited for the reasons stated in the above paragraph. Labor income decreased because of lower wage rates and/or unemployed labor. (2) Capital and land incomes decreased because of reduced output prices and sector specific fixed resources. Although capital income from the non-price shocked tradable sectors increased, this increase did not compensate for decreased capital income from the other sectors. (3) Decreased labor income (either by wage rate decreases or unemployment) works as an incentive for outmigration, and outmigration causes further decreases in commodity demands. (4) Decreased investment demand also worked as an additional decrease in commodity demand.

Alternative assumptions on labor market behavior and trade related elasticities have significant effects on the overall economy. Trade offs were found between output and aggregate factor income, and between incomes for different factors and institutions. Trade offs between different household groups by income size were relatively small. Existence of the trade offs implies a need for a political exchange system in addition to the market exchange system.

A set of policy implications are suggested from results of the analysis.

(1.) Industry diversification designed to decrease dependence of the State's economy on the agricultural and mining sectors will reduce income instability caused by exogenous shocks in commodity markets. Industry diversification is a way of distributing risks of commodity market shocks across more labor and other factor markets.

(2) Policy instruments that increase factor mobility between sectors will reduce the impact of adverse shocks and increase the impact of favorable shocks on the overall economy. Possible policy instruments include fostering of public and private information services (including employment agencies), government training and retraining programs, accelerated depreciation and investment credit

tax write-offs, and joint public and private financing programs for rapid start-up.

(3) Policies designed to increase elasticities of export demand for Oklahoma products will reduce the impact of adverse commodity market shocks. This is important not only for output markets but also for factor markets in that the slopes of marginal value product curves become less steep if output demands are more elastic. Moreover, policies promoting industry diversification should target industries with elastic output demands. Recent trends show that traditionally non-tradable commodities and sectors such as recreation, education, information, communication, health services, banking, insurance, etc., are becoming more tradable. Price elasticities for these commodities may be affected by promotional activities initiated through public programs.

(4) Marginal increases in income of low income households generate high levels of short run aggregate demand because of high marginal propensities to consume and low savings rates. Therefore, policies which increase earning capacities of low income households should have immediate effects on aggregate demand and aggregate income.

Limitations

Limitations associated with this study can be classified into three categories: (1) theoretical limitations generally associated with CGE models, (2) limitations originating from the model structure employed in this study, and (3) inaccurate data. In general, the classifications are not mutually exclusive.

Theoretical limitations of CGE models include discrepancies in model results depending on selection of macro economic closure rules. For example, in this study the closure rule on labor markets, i.e., full employment or fixed wage rates gives very different results on labor income and subsequent aggregate household income. Another critical limitation of SAM based CGE models is the inability to associate model results with probability distributions. Another limitation is the difficulty in interpretation of model results because of the complex interdependencies among variables. Long term contracts in commodity and factor markets and government regulation must specifically be incorporated in model structure.

Every model has its own strengths and weaknesses including CGE models. The major strengths of CGE models include accounting consistencies, recognition and treatment of interindustry relationships, theoretical consistencies, wider perspectives of economic systems, and usefulness in welfare analysis (Hertel, 1990). A distinctive characteristic of CGE models is that they reflect the view of emphasizing complexity of economic structure rather than the view of emphasizing the complexity of statistical error structure. The apparent weakness of parameter calibration associated with CGE models is actually a challenge that should be overcome (Whalley, 1985).

Limitations originating from the current model structure and assumptions include (1) exogenous treatment of investment demand, (2) fixed resource availability, and (3) full employment for sector specific capital and land. Moreover, the current model can be characterized as a general purpose model compared to a problem specific model designed to analyze specific policy alternatives. For an evaluation of specific policy, the model structure would need to be modified accordingly. This would include appropriate sector aggregation, design of factor accounts, and accounts for institutions and households. However, a certain degree of compromise may be necessary, especially at the regional level, between desirable SAM accounts classification and data availability. With development and refinement of the IMPLAN data base, data related difficulties in applying the CGE approach at the regional level is expected to be reduced.

REFERENCES

Adelman, I. and C. T. Morris. 1973. Economic Growth and Social Equity in Developing Countries. Stanford University Press. Stanford, California.

Adelman, I. and S. Robinson. 1978. Income Distribution Policy in Developing Countries: A Case Study of Korea. Stanford University Press, Stanford, California.

Adelman, I., and S. Robinson. 1986. "U.S. Agriculture in a General Equilibrium Framework: Analysis with a Social Accounting Matrix." American Journal of Agricultural Economics. Vol. 68. pp. 1196-1207.

Adelman, I., J. E. Tayler and S. Vogel. 1988. "Life in a Mexican Village: A SAM Perspective." Journal of Development Studies. Vol. 25. pp. 5-24.

Ahluwalia, M. S. 1975. "Income Inequality: Some Dimensions of Problem." In Redistribution With Growth. Oxford University Press. pp. 3-37.

Akerlof, G. A. and J. L. Yellen. 1982. "Labor Contracts as Partial Gift Exchange." Quarterly Journal of Economics, Vol. 97. pp. 543-69.

Akhtar, M. A. 1980. "Income and Price Elasticities of Imports in Industrial Countires". Business Economics, Sep. 1980, pp. 69-75.

Alward, Greg, et. al. 1989. Micro Implan, Software Manual. Colorado State University, Fort Collins, Colorado.

Aradhyula, V. S., K. Eswaramoorthy, K. Frohberg. 1988. "An Application of Computable General Equilibrium Model to Analyze U. S. Agriculture." Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa.

Armington, P. 1969. "A Theory of Demand for Products Distinguished by Place of Production." International Monetary Fund Staff Papers Vol. 16, March, pp. 159-76.

Arrow, K. J. 1951. "An Extension of Basic Theorems of Classical Welfare Economics." In P. Newman ed. Readings in Mathematical Economics I. Johns Hopkins University Press 1968, pp. 365-390.

Arrow, K. J. and G. Debreu. 1954. "Existence of an Equilibrium for a Competitive Economy." Econometrica Vol. 22, pp. 256-291.

Atkinson, A. B. 1970. "On the Measurement of Inequality." Journal of Economic Theory. Vol. 2. pp. 244-263.

Atkinson, A. B. 1975. The Economics of Inequality. Oxford University Press, London.

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

Bartels, C. P. A. 1977. Economic Aspects of Regional Welfare, Income Distribution and Unemployment. Martinus Nijhoff Social Science Division, the Netherlands.

Bell, C. and T. N. Srinivasan. 1984. "On the Uses and Abuses of Economywide Models in Development Policy Analysis." In Economic Structure and Performances, edited by Syrquin, M., L. Taylor and E. L. Westphal, Academic Press, Inc. New York, 1984.

Beauchamp, T. L. 1980. "Distributive Justice and the Difference Principle." In John Rawls' Theory of Social Justice. (ed.) H. G. Blocker and E. H. Smith. Ohio University Press. pp. 133-161.

Binswanger, H. and J. Quizon. 1984. Distributional Consequences of Alternative Food Policies in India. Washington, D.C.: World Bank, Pap. No. ARU 20.

Braun, D. 1988. "Multiple Measures of U.S. Income Inequality." Review of Economics and Statistics. Vol. 70. pp. 398-405.

Bronfenbrenner, M. 1972. Income Distribution Theory. Aldine, Chicago.

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

Buchanan, J. M. 1987. Economics Between Predictive Science and Moral Philosophy. Texas A & M University Press. College Station, Texas.

Campano, F. and D. Salvarote. 1988. "Economic Development, Income Inequality and Kuznets U-Shaped Hypothesis." Journal of Policy Modeling. Vol. 10(2). pp. 265-279.

Chiswick, B. R. 1974. Income Inequality: Regional Analyses within a Human Capital Approach. National Bureau of Economic Research, New York.

Cline, W. R. 1972. Potential Effects of Income Redistribution on Economic Growth: Latin American Cases. Praeger Publishers. New York.

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.

Cowel, F. A. 1980. "On the Structure of Additive Inequality Measures." Review of Economic Studies. Vol. 47. PP. 521-532.

Decaluw'e, B. and A. Martens. 1989. "CGE Modeling and Developing Economies: A Concise Empirical Survey of 73 Applications to 26 Countries." Journal of Policy Modeling, Vol. 10(4), pp. 529-568.

de Melo, J. 1979. "Agricultural Policies and Development: A Socioeconomic Investigation Applied to Sri Lanka." Journal of Policy Modeling, Vol. 1, pp. 217-34.

de Melo, J. 1988. "Computable General Equilibrium Models for Trade Policy Analysis in Developing Countries: A Survey." Journal of Policy Modeling. Vol. 10(4), pp. 469-503.

Dervis, K., J. de Melo, and S. Robinson. 1982. General Equilibrium Model's For Development Policy, Cambridge University Press, Cambridge.

Devarajan, S., J. D. Lewis, and S. Robinson. 1986. A Bibliography of Computable General Equilibrium (CGE) Models Applied to Developing Countries (mimeo.).

Dewatripont, M., and G. Michel. 1987. "On the Closure Rules, Homogeneity and Dynamics in Applied General Equilibrium Models." Journal of Development Economics,a Vol. 26, pp. 65-76.

Deyak, T. A., W. C. Sawyer, and R. L. Sprinkle. 1989. "An Empirical Examination of the Structural Stability of Disaggregated U. S. Import Demand." Review of Economics and Statistics, Vol. 71, pp. 337-341.

Diewert, W. E. 1985. "The Measurement of Waste and Welfare in General Equilibrium Models." in Piggott, J. and J. Whalley (eds.). New Developments in Applied General Equilibrium. Cambridge: Cambridge University Press, pp. 43-103.

Dixon, P., B. Parmenter, J. Sutton, and D. Vincent. 1982. ORANI: A Multi Sector Model of the Australian Economy. North-Holland Press, Amsterdam.

Feldstein, M. 1974. "Induced Retirement and Aggregate Capital Accumulation." Journal of Political Economy. Vol. 82(5). pp. 905-26.

Fisher, A. C. and K. A. Despotakis. 1989. "Energy Taxes and Economic Performance." Energy Economics, April, 1989

Flood, D. and D. F. Schreiner. 1972. "Availability of Retail and Business Services to Rural Populations; Application to South Central Oklahoma." In Research Application in Rural Economic Development and Planning. pp. 164-177. Oklahoma State University Agricultural Experiment Station Research Report, P-665, July 1972.

Formby, J. P , and T. G. Seaks. 1980. "Paglin's Gini Measure of Inequality: A Modification." American Economic Review. Vol. 70(3). pp. 479-482.

Friedman, M. 1953., "Choice, Chance, and The Personal Distribution of Income." Journal of Political Economy. Vol. 61(4). pp. 2977-90.

Galbraith, J. K. 1958. "Consumer Behavior and Dependence Effect." In Mansfield, E. (ed) Micro Economics: Selected Readings. Third Edition, W. W. Norton and Company, New York 1979. pp. 3-6.

Gardener, B. 1983. "Efficient Redistribution through Commodity Markets." American Journal Agricultural Economics, Vol. 65, pp. 225-234.

Ginsburgh, V. and S. Robinson. 1984. "Equilibrium and Prices in Multisector Models." In Syrquin, M., L. Taylor and E. L. Westphal, (eds.) Economic Structure and Performance. Academic Press, Inc. Orlando, Florida.

Gottschalk, P. T. 1978. "A Comparison of Marginal Productivity and Earnings by Occupation." Industrial Labor Relation Reviews. Vol. 31. pp. 368-78.

Goulder, L. and L. Summers. 1987. Tax Policy, Asset Policy, and Growth; A General Equilibrium Analysis, NBER Working Paper, No. 2128. National Bureau of Economic Research, Cambridge.

Hahnel, R. and M. Albert. 1990. Quiet Revolution in Welfare Economics Princeton University Press. Princeton, New Jersey.

Hanson, K. A. and S. Robinson. 1990. "Data, Linkages, and Models: U.S. National Income and Product Accounts in the Framework of a Social Accounting Matrix." Paper Presented at a conference on "A SAM for Europe." Valencia, Spain, September 3-4, 1990.

Hanson, K., S. Robinson, S. Tokaric. 1990. "U. S. Adjustment in the 1990's: A CGE Analysis of Alternative Trade Strategies." USDA. Economic Research SErvice, Staff Report No. AGES 9031.

Harberger, A. C. 1962. "The Incidence of Corporate Income Tax." Journal of Political Economy, Vol. 70(3), pp. 215-240.

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

Hazell, B. P. and D. R. Norton. 1986. Mathematical Programming for Economic Analysis in Agriculture. Macmillan Publishing Company, New York.

Henderson, J. M. and R. E. Quandt. 1980. Micro-economic Theory. (3rd ed.), McGraw-Hill Book Company, New York.

Hertel, T. W., and M. E. Tsigas. 1988. "Tax Policy and U. S. Agriculture: A General Equilibrium Analysis." American Journal of Agricultural Economics. Vol. 70, pp. 289-302.

Hertel, T. W. 1990. "General Equilibrium Analysis of U. S. Agriculture: What Does It Contribute?" Journal of Agricultural Economics Research. Vol. 42(3), pp. 3-9

Hirschman, A. O. 1973. "The Changing Tolerance for Income Inequality in the Course of Economic Development." Quarterly Journal of Economics, Vol. 8(1973). PP. 544-566.

Hildreth, R. J., K. R. Krause, and P. E. Nelson, Jr. 1973. "Organization and Control of the U.S. Food and Fiber Sector." American Journal of Agricultural Economics. Vol. 55(8). pp. 851-859.

Hochman, H. M. 1972. "Individual Preferences and Distributional Adjustments." American Economic Review. Vol. 62. pp. 353-360.

Jefferson, R. W. and R. N. Boisvert. 1989. A guide to Using the General Algebraic Modeling System (GAMS) for Applications in Agricultural Economics. Department of Agricultural Economics, Cornell University, Ithaca, New York.

Jeffrey, L. and S. Urata. 1984. "Anatomy of Balance of Payment Crisis: Application of a Computable General Equilibrium Model to Turkey,, 1978-80." Economic Modeling, Vol. 1(3), pp. 281-303.

Jencks, C. et. al. 1972. Inequality: A Reassessment of the Effect of Family and Schooling in America. Basic Books. New York.

Johansen, L. 1960. A Multi-Sectoral Study of Economic Growth. North-Holland Press, Amsterdam.

Jones, J. and C. H. Barnard. 1985. Farm Real Estate: Historical Series Data, 1950-85. ERS, USDA Statistical Bulletin No. 738.

Jones, R. and J. Whalley. 1986. A Canadian Applied General Equilibrium Regional Model and Some Applications. University of Western Ontario, Ontario.

Jorgenson, D. W. 1984. "Econometric Methods for Applied General Equilibrium Analysis." In Scarf, H. E. and J. B. Shoven (eds.). Applied General Equilibrium Analysis. Cambridge University Press, Cambridge, pp. 139-203.

Jorgenson, D. and D. Slesnick. 1985. "General Equilibrium Analysis of Economic Policy." in Piggott, J. and J. Whalley (eds.). New Developments in Applied General Equilibrium. Cambridge University Press, Cambridge, pp. 293-370.

Kaldor, N. 1955. "Alternative Theories of Distribution." Review of Economic Studies. Vol. 23(3). pp. 83-100.

Krauss, M. B. and H. G. Johnson. 1974. General Equilibrium Analysis: A Micro Economic Text. Aldine Publishing Company, Chicago.

Kreinin, M. E. 1973. "Disaggregated Import Demand Functions - Further Results." Southern Economic Journal. Vol. 39, pp. 19-25.

Kuznets, S. 1963. "Quantitative Aspects of Economic Growth of Nations." Economic Development and Cultural Change. Vol. 11(2). pp. 1-80.

Ladd, G. W. 1983. "Value Judgements and Efficiency in Publicly Supported Research." Southern Journal of Agricultural Economics, Vol. 15(9), pp. 1-7.

Leibenstein, H. 1966. "Allocative Efficiency and X-Efficiency". American Economic Review Vol. 56. pp. 393-415.

Lerner, A. P. 1956. Economics of Control, MacMillan, New York.

Levy, S. and L. Gutman. 1976. "On the Multivariate Structure of Well-being." Social Indicators Research. Vol. 2, pp. 361-88.

Mandelbrot, B. 1960. "The Pareto-Levy Law, and Distribution of Income." International Economic Review. Vol. 1. pp. 99-106.

Manne, A. S. and P. Preckel. 1983. "A Three Region Intertemporal Model of Energy, International Trade and Capital Flows." Operations Research, March 1983, Stanford University.

Marshall, J. U. 1969. The Location of Service Towns: An Approach to the Analysis of Central Place System. Toronto, University of Toronto Press.

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 (eds.). Applied General Equilibrium Analysis. Cambridge University Press, Cambridge, pp. 69-127.

McKenzie, W. L. 1989. "General Equilibrium." in General Equilibrium, American Edition, Macmillan Press Limited.

Melichar, E. 1979. "Capital Gains Versus Current Income in Farming Sector." American Journal of Agricultural Economics, Vol. 61(5), pp. 1085-1092.

Miller, R. E., and P. D. Blair, Input-Output Analysis: Foundations and Extensions, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Mincer, J. 1958. "Investment in Human Capital and Personal Income Distribution." Journal of Political Economy. Vol. 66. pp. 281-302.

Morgan, J. 1962. "The Anatomy of Income Distribution." Review of Economics and Statistics. Vol. 54. pp. 270-281.

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. 81, pp. 626-635.

Nelson, J. I. 1984. "Income Inequality: The American States." Social Science Quarterly. Vol. 65(3). pp. 854-860.

O'Connell, F. J. 1982. Welfare Economic Theory. Auburn House Publishing Company. Boston, Massachusetts. pp. 119.

Okun, A. M. 1975. Equality and Efficiency: The Big Tradeoff. The Brookings Institution. Washington, D.C.

Paglin, M. 1975. "The Measurement and Trend of Inequality: A Basic Revision." American Economic Review. Vol. 65(4). pp. 598-609.

Penn, D. 1990. "Measures of Diversification." In State Policy and Economic Development in Oklahoma: 1990. Oklahoma 2000, Inc. Oklahoma City, Oklahoma.

Pereira, A. M. 1988. "Survey of Dynamic Computational General Equilibrium Models for Tax Policy Evaluation." Journal of Policy Modeling, Vol. 10(3), pp. 401-436.

Philips, L. 1983. Applied Consumption Analysis. North-Holland Publishing Company, New York.

Pyatt, G. 1988. "A SAM Approach to Modeling." Journal of Policy Modeling, Vol. 10(3), pp. 327-351.

Pyles, D. 1989. "Demand Theory and Elasticity Matrix Construction." In Tweeten, Luther (ed.) Agricultural Policy Analysis Tools For Economic Development. Boulder, Colorado: Westview Press: 56-72.

Rausser, G. C., J. M. Perloff and P. Zusman. 1987. "The Food Marketing System: The Relevance of Economic Efficiency Measures." In Economic Efficiency in Agricultural and Food Marketing. (ed.) R. L. Kilmer and W. J. Armbruster. Iowa State University Press. Ames, Iowa. pp. 3-31.

Rawls, J. 1971. A Theory of Justice. Harvard University Press, Cambridge, Massachusetts.

Renshaw, V., E. A. Trott, Jr., and H. L. Friedenberg. 1988. "Gross State Product by Industry, 1963-86." Survey of Current Business, May 1988, pp. 30-46.

Robinson, D. E. 1961. "Economics of Fashion Demand." Quarterly Journal of Economics. Vol 75. pp. 377-399.

Robinson, S. and D. W. Roland-Holst. 1986. "Modeling Structural Adjustment in the U.S. Economy: Macro Economics in a Social Accounting Framework." Paper presented at annual meetings of American Economic Association, New Orleans. Dec. 1986.

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

Rogers, J. 1985. "General Equilibrium Effects of An Agricultural Land Retirement Scheme in A Large, Open Economy." Staff Paper Series P85-16, University of Minnesota, St. Paul, Minnesota.

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

Rubenstein, W. D. 1974. "Men of Property: Some Aspects of Occupation, Inheritance and Power Among Top British Wealth Holders." In Stanworth, P. and A. Giddens (ed.) Elites and Power in British Society, Cambridge University Press, London.

Ruttan, V. W. and T. T. Stout. 1960. "Regional Differences in Factor Shares in American Agriculture:1925-57." Journal of Economics, Vol. 42(1), pp. 52-68.

Sahota, G. S. 1978. "Theories of Personal Income Distribution: A Survey." Journal of Economic Literature. Vol. 16. pp. 1-55.

Saith, A. 1983. "Development and Distribution: A Critique of the Cross-Country U-Hypothesis." Journal of Development Economics, Vol. 13(3), pp. 367-382.

Sale, T. S. 1974. "Inter State Analysis of Size Distribution of Family Income 1950-1970." Southern Economic Journal. Vol. 40(1). pp. 434-441.

Scherer, F. M. 1973. Industrial Structure and Economic Performance. Rand McNally and Company, Chicago.

Schultz, T. W. 1960. "Capital Formulation of Education." Journal of Political Economy. Vol. 68. pp. 571-83.

Shapiro, C. and J. E. Stiglitz. 1984. "Equilibrium Unemployment as a Worker Descipline Device." American Economic Review, Vol. 74, pp. 433-44.

Shoven, J. B. and J. Whalley. 1972. "A General Equilibrium Calculation of the Effects of Differential Taxation of Income from Capital in U. S." Journal of Public Economics, Vol. 1, pp. 281-321.

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. XXII. pp. 1007-1051.

Smith, A. 1983. "Development and Distribution: A Critique of the Cross-Country U-Hypothesis." Journal of Economic Development. Vol. 13(3). PP. 437-440.

Staehle, H. 1943. "Ability, Wages, and Income." The Review of Economics and Statistics. Vol. 25. pp. 77-88.

Thorbecke, E. 1985. "The Social Accounting Matrix and Consistency-type Planning Models." In Pyatt G. and J. I. Round (eds.). Social Accounting Matrices. A Basis for Planning. The World Bank

Thurow, L. 1968. "Disequilibrium and the Marginal Productivity of Capital and Labor." Review of Economics and Statistics. Vol. 50, pp. 23-31.

Tinbergen, J. 1985. Production, Income and Welfare: The Search for an Optimal Social Order. University of Nebraska Press. Lincoln, Nebraska.

Tool, M. R. 1983. "Equational Justice and Social Value." Journal of Economic Issues. Vol. 17(2). pp. 335-343.

Tullock, G. 1967. "Welfare Costs of Tariff, Monopolies, and Theft." Western Economic Journal. Vol. 5. pp. 224-32.

Tullock, G. 1984. Economics of Income Redistribution. (2nd ed.) Kluwer Nijhoff Publishing. Boston, Massachusetts.

Tweeten, L. 1985. "Introduction to Agricultural Policy Analysis: The Distribution of Economic Cost and Benefits from Market Intervention." Agricultural Policy Analysis Background Paper B-5. Stillwater: Department of Agricultural Economics, Oklahoma State University.

U. S. Department of Commerce, Bureau of Census. 1983. Aftertax Money Income Estimate of Households: 1982.

U. S. Government Printing Office. Economic Indicators. April 1985.

U. S. Department of Human Services. 1983. The Multi-regional Input-Output Accounts, 1977. Vol. I-VI, Jack Faucett Associates, Report Submitted to the U. S. Department of Human Services, Contract No. HHS-100-81-0057, July 1983.

U. S. Department of Commerce, Bureau of Economic Analysis 1983. Gross State Product by Industry 1963-86, Regional Economic Information System (Computer Printout).

U. S. Department of Commerce, Bureau of Economic Analysis. 1989. Personal Income by Major Sources and Earnings by Major Industry, Regional Economic Information System (Computer Print Out).

U. S. Department of Commerce. Bureau of Census. 1983. Money Income of Households, Families, and Persons in the United States: 1982. Current Population Reports, Series P-60, No. 142.

U. S. Department of Labor, Bureau of Labor Statistics. 1983. Consumer Expenditure Survey: Interview Survey. 1982-83. Bulletin 2246.

Varian, H. R. 1984. Microeconomic Analysis, second ed., New York, W. W. Norton and Company.

Wallace, T. D. 1962. "Measure of Social Costs of Agricultural Programs." Journal of Farm Economics. Vol. 44, pp. 580-94.

Whalley, J. 1982. "An Evaluation of the Tokyo Round Trade Agreement Using General Equilibrium Computations Method." Journal of Policy Modeling. Vol. 4(3), pp. 341-361.

Whalley, J. 1985. "Hidden Challenges in Recent Applied GE Exercises" in Piggott, J., and J. Whalley, (eds.) New Development in Applied General Equilibrium Analysis. Cambridge University Press, Cambridge.

Williamson, J. G. and P. H. Lindert. 1980. American Inequality: A Macro Economic History. Academic Press. New York.

APPENDIXES

APPENDIX A

LIST OF EQUATIONS, VARIABLES, AND PARAMETERS IN THE CGE MODEL FOR OKLAHOMA

TABLE XXII

LIST OF EQUATIONS IN CGE MODEL FOR OKLAHOMA

Description	Equation Number	Number. of Equations
Production Function		
$X_i = \theta_i(\prod_s LAB_{is}^{\alpha_{is}}) CAP_i^{\alpha_{ik}} LND_i^{\alpha_{il}}$	(4-6)	n
Value Added Price of Sector Output		
$NPX_i = RP_i - \sum_j a_{ij} P_j - idtx_i RP_i$	(4-11)	n
Demand for Intermediate Use		
$INTD_i = \sum_j a_{ij} X_i$	(4-12)	n
Labor Demand		
$LAB_{is} = \alpha_{is} NPX_i X_i / WAGE_s$	(4-15)	nxs
$LAB_{is} = \sum_i \alpha_{is} NPX_i X_i / \overline{WAGE_s}$	(4-18)	
Labor Market Equilibrium		
$\sum_i LAB_{is} - \overline{LAB_s} = 0$	(4-17)	s
$UNEMP_s = \overline{LAB_s} - \sum_i LAB_{is}$	(4-19)	
Demand for Land		
$LND_i = \alpha_{il} NPX_i X_i / LNDRNT$	(4-20)	n
Land Market Equilibrium		
$\sum_i LND_i - \overline{LND} = 0$	(4-21)	1

TABLE XXII (continued)

Description	Equation Number	Number. of Equations
<u>Demand for Capital Stock</u>		
$CAP_i - \alpha_{ik} NPX_i X_i / CAPRNT_i = 0$	(4-22)	n
<u>Capital Stock Market Equilibrium</u>		
$CAP_i - \overline{CAP}_i = 0$	(4-24)	n
<u>Labor Income</u>		
$YLAB_s = WAGE_s LAB_s + TRLABY_s$	(4-29)	s
$TOTYLAB = \sum_s YLAB_s$	(4-30)	1
<u>Land Income</u>		
$YLND = \sum_i LND_i LNDRNT$	(4-31)	1
<u>Capital Income</u>		
$YCAP = \sum_i NPX_i X_i - \sum_i (YLAB_s - TRLABY_s) - YLND$	(4-32)	1
<u>Institutional Income</u>		
$YINST_t = \sum_s b_{ts} YLAB_s (1-sstx_s) + w_t YCAP (1 - ktx - dprt)$		
$+ z_t YLND (1-ltx) + TRINST_t$	(4-34)	t
<u>Household Income</u>		
$TXHHY_h = \sum_t d_{ht} YINST_t + TRGHH_h$	(4-35)	h
$HHY_h = TXHHY_h (1 - hhtx_h) + TRHHR_h$	(4-36)	h

TABLE XXII (continued)

Description	Equation Number	Number. of Equations
<u>Government Revenue</u>		
$YGVT = \sum_i idtxRP_iX_i + \sum_s sstx_s YLAB_s + ktxYCAP + ltx\,YLND$		
$+\sum_h hhtx_h\,TXHHY_h$	(4-37)	1
<u>Household Saving</u>		
$HHSAV_h = mps_h\,(TXHHY_h + TRHHR_h)$	(4-38)	h
<u>Household Consumption</u>		
$D_i = \sum_h \beta_{ih}\,(HHY_h - HHSAV_h - TRHHC_h)/P_i$	(4-51)	n
<u>Import Transformation</u>		
$Q_i = \psi_i\,[\,\delta_i\,MQ_i^{-\rho i} + (1-\delta_i)\,RQ_i^{-\rho i}]^{-\frac{1}{\rho i}}$	(4-52)	n
<u>Import Demand</u>		
$MQ_i = RQ_i\left(\frac{RP_i}{PM_i}\right)^{\frac{1}{1+\rho i}}\left(\frac{\delta_i}{1-\delta_i}\right)^{\frac{1}{1+\rho i}}$	(4-53)	n
<u>Composite Commodity Price</u>		
$P_i = [RP_i\,RQ_i + PM_i\,MQ_i]\,/\,Q_i$	(4-54)	n
<u>Export Demand</u>		
$RP_i = PM_i$	(4-55)	
		n
$EXQ_i = EXQB_i\,RP_i^{e_i}$	(4-56)	
<u>Balance for Regional Output</u>		
$X_i = RQ_i + EXQ_i$	(4-57)	n

TABLE XXII (continued)

Description	Equation Number	Number. of Equations
<u>Commodity Market Equilibrium</u>		
$X_i + MQ_i = D_i + GVTD_i + INVD_i + INTD_i + EXQ_i$	(4-58)	n
<u>Gross State Product</u>		
$GSP = \sum_s(YLAB_s - TRLABY_s) + YCAP + YLND + \sum_i idtx_i X_i$	(4-59)	1
<u>Financial Flow</u>		
$FINCL = \sum_i P_i GVTD_i + \sum_t TRINST + \sum_h TRGHH - YGVT$ $+ \sum_i RP_i EXQ_i - \sum_i PM_i MQ_i$ $+ \sum_i P_i INVD_i - dprt\ YCAP - \sum_h HHSAV_h$	(4-60)	1
Total number of equations	13n + (n+2) s + t + 3h + 7	

TABLE XXIII

LIST OF ENDOGENOUS VARIABLES

Symbol	Description	Number
X_i	Output by sector i	n
LAB_{is}	Demand for labor skill s by sector i	n x s
CAP_i	Demand for capital stock by sector i	n
LND_i	Demand for land by sector i	n
RP_i	Price of commodity i produced in the region	n
NPX_i	Value added price of industry output by sector i	n
P_i	Price of composite commodity i	n
$INTPD_i$	Demand for composite commodity i for intermediate use	n
$WAGE_s$	Wage rate for labor category s	s
$UNEMP_s$	Unemployment of labor categorys	s
LNDRNT	Rental price of land	1
$CAPRNT_i$	Rental price of capital stock in sector i	n
$YLAB_s$	Income for labor category s	s
TOTYLAB	Total labor income	1
YCAP	Capital income	1
YLND	Rental income from land	1
$YINST_t$	Institutional income for t	t
$TXYHH_h$	Taxable household income for income group h	h
HHY_h	Disposable household income for income group h	h
YGVT	Government revenue	1
$HHSAV_h$	Household saving for income group h	h

TABLE XXIII (continued)

Symbol	Description	Number
D_i	Household consumption demand for commodity i	n
Q_i	Supply of composite commodity i	n
MQ_i	Import of commodity i	n
RQ_i	Regionally produced commodityi sold in the region	n
EXQ_i	Export of regionally produced commodity i	n
GSP	Gross state product	1
FINFL	Net financial inflow	1
Total number of endogenous variables		13n + (n+2) s + t + 3h + 7

TABLE XXIV

LIST OF EXOGENOUS VARIABLES IN CGE MODEL FOR OKLAHOMA

Symbol	Description	Number
$\overline{LAB}_s$	Labor supply of skill category s	s
$\overline{WAGE}_s$	Exogenous wages for labor skills	s
$\overline{LAD}$	Land supply	1
$\overline{CAP}_i$	Capital stock in sector i	n
$\overline{TRNS}_t$	Government transfer to institution t	t
$\overline{PM}_i$	National price of commodity i	n
$TRLABY_s$	Labor income from rest of world for labor skills	s
$TRINST_t$	Transfer income for institutions t	t
$TRGHH_h$	Transfer payments from government to household income group h	h
$TRHHR_h$	Interhousehold transfer income to group h	h
$TRHHC_h$	Interhousehold transfer payment from group h	h
$GVTD_i$	Government Demand for commodity i	h
$INVD_i$	Investment Demand for commodity i	n

TABLE XXV

LIST OF PARAMETERS IN CGE MODEL FOR OKLAHOMA

Symbol	Description	Number
θ_i	shift parameter of value added function for i	n
α_{is}	partial production elasticity of labor category s in sector i	n x s
α_{ik}	partial production elasticity of capital in sector i	n
α_{ik}	partial production elasticity of capital in sector i	n
a_{ij}	direct requirement coefficient (Use Matrix)	n x n
$idtx_i$	indirect tax rate for sector i	n
b_{ts}	institutional labor income distribution coefficient	t x s
$sstx_s$	social security tax rate for labor category s	s
w_t	institutional capital income distribution coefficient	t
ktx	capital income tax rate	1
dprt	rate of depreciation and retained earnings	1
z_t	institutional land income distribution coefficient	t
ltx	land tax rate	1
idtx	land income tax rate	1
d_{ht}	household income distribution coefficient	h x t
$hhtx_h$	household income tax rate	h
mps_h	household savings rate	h
β_{ih}	marginal expenditure share of commodity i by household group h	n x h
ψ_i	shift parameter of trade transformation function	n

TABLE XXV

LIST OF PARAMETERS IN CGE MODEL OF OKLAHOMA

Symbol	Description	Number
δ_i	share parameter of trade transformation function	n
ρ_i	exponent parameter of trade transformation function	n
e_i	elasticity of export demand	n

APPENDIX B

INDUSTRY CLASSIFICATION

USED IN THIS STUDY

TABLE XXVI

INDUSTRY CLASSIFICATION USED IN THIS STUDY

Sector	IMPLAN sector number 1/
Agriculture	1-25
Mining	41-43,71,75,28-40,44-65
Construction	66-70, 66-70, 72-74
Manufacturing-1	82-234
Manufacturing-2	76-81, 215-445
Comm/Tran/P.Util	446-459
Trade	468-463
Fin/Ins./R.Estate	464-470
Services	26-27, 471-528

1/ Alward Greg, et. al. 1989. "Micro IMPLAN: Software Manual." Fort Collins, Colorado State Unviersity.

APPENDIX C

GAMS PROGRAM TO SOLVE THE BASE CGE MODEL FOR OKLAHOMA

APPENDIX C

GAMS PROGRAM TO SOLVE CGE MODEL FOR OKLAHOMA

```
************************************************************************
*    COMPUTABLE GENERAL EQUILIBRIUM MODEL FOR OKLAHOMA STATE           *
* This model is based on 1982 social accounting matrix for Oklahoma *
************************************************************************
$OFFUPPER
$OFFSYMXREF
$OFFSYMLIST
************************************************************
*          DECLARATION OF SETS AND SUBSETS                  *
************************************************************
SETS
I SECTORS
   / AGRI, MNNG, CNST, MFCG1, MFCG2, UTIL, TRDE, BNKG, SERV/

TRI(I) TRADABLES
   / AGRI, MNNG, MFCG1, MFCG2/

NTI(i) NON-TRADABLES
   / CNST, UTIL, TRDE, BNKG, SERV/

F FACTORS
   / LABA, LABB, LABC, LABD, LABE, CAPTL, LAND /

S(F) LABOR SKILLS
   / LABA, LABB, LABC, LABD,LABE /

SKL(s) SKILLED LABOR
   / LABA, LABD,LABE /

UNS(s)  UNSKILLED LABOR
   / LABB, LABC /

T INSTITUTIONS
   / URBAN, RFARM, RNFARM /

HI HOUSEHOLDS
   / LOW, MED, HIGH /;

Alias(i,j);
Alias(Hi,Hj);

************************************************************
*                PRARAMETER DECLARATION                     *
************************************************************
PARAMETERS

************PARAMETERS FOR BASE YEAR VALUES****************

INTDO(i)           Intermediate Demand
LABO(i,s)          Labor Demand
CAPO(i)            Capital Demand
LNDO(i)            Land Demand
XO(i)              Sector Output
RQO(i)             Regional Goods Demanded In the Region
MQO(i)             Imports
EXQO(i)            Exports
QO(i)              Composite Goods
WAGEO(s)           Wage Rate
CAPRNTO(i)         Rental Price OF Capital
```

```
LNDRNTO(i)          Retal Price Of Land
FCTRYO(f)           Factor Income
YLABO(s)            Labor Income
YCAPO               Capital Income
YLNDO               Land Income
TOTYLABO            Total Labor Income
YINSTO(t)           Institutional Income
TXHHYO(hi)          Taxable Income for Households
HHYO(hi)            Disposable Income for Households
HHDO(i)             Household Consumption Demand
HHSAVO(hi)          Household Savings
RPO(i)              Price of Regional Goods
PO(i)               Price of Composite Goods
TRFCTRYO(f)         Transfer income for Factors
YGVTO               Government Revenue
FINCLO              Net Financial Flow
GSPO                Gross State Products
VADDSEC(i)          Value Added by Sector
HHTXO(hi)           Household Taxes Paid
HHCONO(hi)          Household Consumption
INSTHHO(t)          Institutional Income Distributed to Households
IDTXO(i)            Indirect Taxes Paid
FCTRTXO(f)          Factor Tax Paid
TRGHHO(hi)          Government Transfer To Households
INVDO(i)            Investment Demand
GVTDO(i)            Government Demand
LabBar(s)           Available Labor
CapBar(i)           Available Capital
LndBar(i)           Available Land
ExogP(i)            Exogenous Price  PMi
sigma(i)            Extraneous Elasticity of Substitution
gamma(i)            Extraneous Elasticity of Export Demand
FCTRYINSTO(f)       Factor Income Dustributed to Institutions
UNEMPLO(s)          Unemployment

************MODEL PARAMETERS TO BE CALCULATED**************

alpha(i,f)          Production Function Exponents
theta(i)            Production Function Shift Parameters
idtx(i)             Indirect Tax Rates
ftx(f)              Factor Tax Rates
mps(hi)             Savings Rates
hhtx(hi)            Household Tax Rates
beta(i,hi)          Expenditure Shares For Household Consumption
rho(i)              Exponents for Trade Transformation Function
delta(i)            Share Parameter for Trade Transformation Function
eta(i)              Shift Parameter for Trade Transformation Function
A(i,j)              Input Output Coefficients
B(t,f)              Institutional Income Distibution Coefficients
D(hi,t)             Household Income Distribution Coefficients
dprt                Rate of Repreciation and Retained Earnings
;

************************************************************
* DATA ASSIGNMENT   Submatrices of base year SAM and       *
*                   other exgogenous values are assigned   *
************************************************************
```

Table USE(i,j) Use Matrix

	AGRI	MNNG	CNST	MFCG1	MFCG2
AGRI	1064.4	0.4	0.0	600.5	3.5
MNNG	3.1	2413.8	42.1	3.9	4247.7
CNST	44.4	25.3	8.9	19.3	177.0
MFCG1	462.2	40.3	495.9	903.0	314.2
MFCG2	437.8	2357.5	1813.9	339.7	5952.7
UTIL	143.9	677.7	192.7	172.3	1290.4
TRDE	208.3	380.1	646.9	193.3	731.8
BNKG	338.7	1505.1	77.7	47.7	284.1
SERV	243.3	988.9	564.3	211.4	1019.6

+	UTIL	TRDE	BNKG	SERV
AGRI	0.0	0.4	0.3	59.5

```
MNNG         1289.6       0.0       0.1      34.3
CNST          297.9      56.8     246.5     261.3
MFCG1          28.6     108.5      69.2     882.4
MFCG2         770.5     223.0      59.7     983.7
UTIL         1590.5     427.9     184.5     726.4
TRDE           98.9     106.2      25.9     401.1
BNKG          157.8     413.7     980.3     685.1
SERV          396.9    1071.6     617.8    1552.1
;

TABLE VADD(i,f) Value Added Matrix
               LABA      LABB      LABC      LABD      LABE     CAPTL      LAND
AGRI         34.478    13.814     3.337   115.747    15.863   259.800     322.3
MNNG        704.961   340.944    25.532     0.673  2047.584  5845.027
CNST        339.506   173.931     9.274     1.323  1608.268    87.009
MFCG1       145.926   131.683     9.975     3.000   398.882   268.070
MFCG2      1010.749   687.718    45.821     0.711  2231.761  1030.748
UTIL        409.397   560.254    27.465     0.596   890.651  2196.517
TRDE        800.650  1794.808    42.664     1.795   978.115   758.180
BNKG        394.134   788.214    26.354     2.722    27.559  3587.461
SERV       4715.513  2243.624  1859.474    27.570   876.769  1859.080
;

Table INSTYDIST(t,f) Institutional Income distrbution
               LABA      LABB      LABC      LABD      LABE     CAPTL      LAND
URBAN      5284.632  4144.963  1260.062    34.572  5341.255  4496.766    30.600
RFARM        27.487    10.975     2.618    92.126    12.586    94.607   240.200
RNFARM     2362.859  1886.018   576.317    11.579  2787.747  1909.440     0.000
;

Table HHYDIST(hi,t)  Houshold Income Distribution
              URBAN     RFARM    RNFARM
LOW         388.467   -14.167   200.765
MED        7214.631   351.161  3231.664
HIGH      12989.751   272.603  6101.531
;

Table HHCON(i,hj)  Household Commodity Demand
                LOW       MED      HIGH
AGRI           37.7      94.6      91.4
MNNG            0.1       0.2       0.2
CNST            0.0       0.0       0.0
MFCG1         580.7    1610.1    1529.7
MFCG2         475.6    1686.3    1766.5
UTIL          418.4     973.1     995.1
TRDE          683.6    1987.3    2163.5
BNKG          719.6    2156.9    2621.3
SERV         1112.4    2986.3    3277.3
;

Parameter TRINST Transfer To Institutions
/
URBAN         0.000
RFARM       129.000
RNFARM        0.000
/;

Table TRHH(hi,hj) Inter Household Income Distribution
                LOW       MED      HIGH
LOW                   600.000  1200.000
MED                             500.000
HIGH
;

TABLE PRMA(*,i)  Base Year Values for Goods Market
               AGRI      MNNG      CNST     MFCG1     MFCG2
XO         3784.158 18854.594  6132.422  3475.013 19452.631
EXQO       2228.373 10480.103  1696.620  1098.484 12234.992
RQO        1555.786  8374.490  4435.802  2376.530  7217.639
MQO         676.540  1314.911   612.130  5212.718 12867.971
QO         2232.326  9689.401  5047.932  7589.248 20085.610
IDTXO        72.530  1500.824    70.782    26.434   424.150
```

```
INVDO       28.870  1652.775  2998.982    92.688  1794.674
GVTDO      250.700     1.500   911.500   471.800  1424.000
RPO          1.00      1.00      1.00      1.00      1.00
PO           1.00      1.00      1.00      1.00      1.00
CAPRNTO      1.00      1.00      1.00      1.00      1.00
LNDRNTO      1.00      1.00      1.00      1.00      1.00
ExogP        1.00      1.00      1.00      1.00      1.00
sigma        4.00      4.00      0.50      4.00      0.50
gamma        0.00      0.00      0.00      0.00      0.00

+            UTIL      TRDE      BNKG      SERV
XO       9066.086  7846.859  7919.454 17355.105
EXQO     3225.117  1270.156   851.491  6118.976
RQO      5840.969  6576.703  7067.963 11236.129
MQO      2444.999  1460.743  3246.938  5706.724
QO       8285.967  8037.446 10314.901 16942.853
IDTXO     350.360  1062.367   908.725   187.196
INVDO      84.482   311.086   102.357     0.800
GVTDO     408.500    99.500   224.500  2900.100
RPO          1.00      1.00      1.00      1.00
PO           1.00      1.00      1.00      1.00
CAPRNTO      1.00      1.00      1.00      1.00
LNDRNTO      1.00      1.00      1.00      1.00
ExogP        1.00      1.00      1.00      1.00
sigma        0.50      0.50      0.50      0.50
gamma        0.00      0.00      0.00      0.00
;

TABLE PRMB(f,*) Base Year Vlues for Factor Market
          TRFCTRYO   FCTRTXO     WAGEO
LABA        52.163   932.500       1.0
LABB        41.064   734.100       1.0
LABC        12.499   223.400       1.0
LABD         0.940    16.800       1.0
LABE        55.334   989.200       1.0
CAPTL               1080.629
LAND                  51.500
;

TABLE PRMC(hi,*) Base Year Values For Households
             HHTXO    HHSAVO    TRGHHO
LOW         79.101  -169.313  1562.792
MED       1207.000   497.095  2501.482
HIGH      3585.684  2642.937  1009.726
;
Scalar YGVTO Government revenue      / 13503.281 /;
Scalar DPRTO  Depreciation and retained Earnings
       /  8310.451 /;

***************************************************************
*     ASSIGN BASE YEAR VALUES FROM SAM DATA TABLES            *
*        OR CALCULATE PARAMETERS FROM BASE YEAR VALUES        *
***************************************************************

ExogP(i)=PRMA("ExogP",i);
GVTDO(i)=PRMA("GVTDO",i);
INVDO(i)=PRMA("INVDO",i);
INTDO(i)=sum(j,USE(i,j));
LABO(i,uns)=VADD(i,uns);
LABO(i,skl)=VADD(i,skl);
CAPO(i)=VADD(i,"CAPTL");
LNDO(i)=VADD(i,"LAND");
XO(i)=PRMA("XO",i);
RQO(i)=PRMA("RQO",i);
MQO(i)=PRMA("MQO",i);
EXQO(i)=PRMA("EXQO",i);
QO(i)=PRMA("QO",i);
IDTXO(i)=PRMA("IDTXO",i);
WAGEO(s)=PRMB(s,"WAGEO");
CAPRNTO(i)=PRMA("CAPRNTO",i);
LNDRNTO(i)=PRMA("LNDRNTO",i);
TRGHHO(hi)=PRMC(hi,"TRGHHO");
```

```
YINSTO(t)=sum(f,INSTYDIST(t,f))+TRINST(T);
TXHHYO(hi)=sum(t,HHYDIST(hi,t))+TRGHHO(hi);
HHTXO(hi)=PRMC(hi,"HHTXO");
HHSAVO(hi)=PRMC(hi,"HHSAVO");
FCTRTXO(f)=PRMB(f,"FCTRTXO");
HHDO(i)=sum(hi,HHCON(i,hi));
HHCONO(hi)=sum(i,HHCON(i,hi));
TRFCTRYO(f)=PRMB(f,"TRFCTRYO");
FCTRYO(f)=sum(i,VADD(i,f))+TRFCTRYO(f);
RPO(i)=PRMA("RPO",i);
PO(i)=PRMA("PO",i);
FCTRYINSTO(f)=sum(t,INSTYDIST(t,f));
GSPO=Sum(f,sum(i,VADD(i,f)))+sum(i,IDTXO(i));
YLABO(s)=sum(i,VADD(i,s))+TRFCTRYO(s);
YCAPO=sum(i,VADD(i,"CAPTL"));
YLNDO=sum(i,VADD(i,"LAND"));
TOTYLABO=sum(s,YLABO(s));
VADDSEC(i)=sum(f,vadd(i,f));
INSTHHO(t)=sum(hi,HHYDIST(hi,t));
A(i,j)=USE(i,j)/XO(j);
B(t,f)=INSTYDIST(t,f)/FCTRYINSTO(f);
D(hi,t)=HHYDIST(hi,t)/INSTHHO(t);
alpha(i,f)=VADD(i,f)/VADDSEC(i);
theta(i)=XO(i)/PROD(f,(vadd(i,f)**(alpha(i,f))));
idtx(i)=IDTXO(i)/XO(i);
ftx(f)=FCTRTXO(f)/FCTRYO(f);
hhtx(hi)=HHTXO(hi)/TXHHYO(hi);
LabBar(s)=sum(i, VADD(i,s));
CapBar(i)=VADD(i,"CAPTL");
LndBar(i)=VADD(i,"LAND");
HHYO(hi)=TXHHYO(hi)*(1-hhtx(hi))+sum(hj,TRHH(hi,hj));
dprt=DPRTO/(sum(i,VADD(i,"CAPTL")));
sigma(i)=PRMA("sigma",i);
gamma(i)=PRMA("gamma",i);
rho(i)=1/sigma(i)-1;
delta(i)=((MQO(i)/RQO(i))**(1+rho(i)))/
            (1+(MQO(i)/RQO(i))**(1+rho(i)));
eta(i)=QO(i)/(delta(i)*MQO(i)**(-rho(i))
          +(1-delta(i))*RQO(i)**(-rho(i)))**(-1/rho(i));
beta(i,hi)=HHCON(i,hi)/HHCONO(hi);
mps(hi)=HHSAVO(hi)/(TXHHYO(hi)+sum(hj,TRHH(hi,hj)));

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

****************ENDOGENOUS VARIABLS***********************
VARIABLES

Z                  Objective Function Value
X(i)               Sector Output
LAB(i,s)           Labor Demand
CAP(i)             Capital Demand
LND(i)             Land Demand
RP(i)              Price of Regional Output
NPX(i)             Net Price
P(i)               Composite Price
INTD(i)            Intermendiate Demand
YLAB(s)            Labor Income
YCAP               Capital Income
YLND               Land Income
TOTYLAB            Total Labor Income
YINST(t)           Institutional Income
WAGE(s)            Wage Rate
UNEMPL(s)          Unemployment
LNDRNT             Rental Price of Land
CAPRNT(i)          Rental Price of Capital
TXHHY(hi)          Taxable Income for Households
HHY(Hi)            Disposible Income for Households
YGVT               Government Revenue
HHSAV(hi)          Household Savings
HHD(i)             Household Demand
```

```
Q(i)              Composit Goods Demand
MQ(i)             Imports
RQ(i)             Regional Goods Demanded In the Region
EXQ(i)            Exports
FINCL             Net Financial Flow
GSP               Gross State Products
SLACK1(i)         Slack Variable
SLACK2(i)         Slack Variable

***********Variables As Index With 1982=1.000**************

CYLAB(s)
CTOTYLAB
CYCAP
CYLND
CTXHHY(hi)
CYINST(t)
CRP(i)
CP(i)
CWAGE(s)
CLRNT(i)
CCAPRNT(i)
CLAB(i,s)
CCAP(i)
CLND(i)
CX(i)
CRQ(i)
CMQ(i)
CQ(i)
CEXQ(i)
CINTD(i)
CHHD(i)
CGSP
CYGVT
CUNEMPL(uns)
;
Positive Variable  SLACK1, SLACK2;

*************************************************************
*                  EQUATION DECLARATION                     *
*************************************************************
EQUATIONS

EqZ               Objective Function
OutPut(i)         Production Function
NetPrice(i)       Value Added Price
IntmdDmnd(i)      Capital Demand
ExogWage(uns)     Land Demand
LaborDmnd(i,s)    Price of Regional Output
LabrMktEq1(uns)   Labor Market Equilibrium for Unskilled Labor
LabrMktEq2(skl)   Labor Market Equilibrium for Skilled Labor
LandDmnd(i)       Land Demand
LndMktEq(i)       Land Market Equlibrium Condition
CapDmnd(i)        Capital Demand
CapMktEq(i)       Cpaital Market Equilibrium Condition
LaborY(s)         Labor Income by Category
TotalYLAB         Total Labor Income
LandY             Land Income
CapitalY          Capital Income
InstuteY(t)       Institutional Income
TxbleHHY(hi)      Taxable Income for Households
DispHHY(hi)       Disposable Income for Households
HHsavng(hi)       Household Saving
HHDmnd(i)         Household Consumption Demand
GvnmntRev         Government Revenue
TrdeTfrm(i)       Trade Transformation Function
ImprtDmnd(i)      Import Demand Function
CompPrice(i)      Price of Composite Goods
XBalnce(i)        Material Balance for Regional Output
ExprtAG           Export Demand for Agricutural Output
ExprtMN           Export Demand for Mining Output
ExQMFCG1          Export Demand for Manufacturing-1
```

```
ExQMFCG2            Export Demand for Manufacturing-2
ExPrtD2(nti)        Export Demand for Non-Tradable Goods
ComMktEq(i)         Commodity Market Equilibrium Condition
EqGSP               Gross State Product
EqCapFlow           Net Financial Flow

****Equations for Calculation of Index with 1982=1.000*****

RtYLAB(s)
RtTOTYLAB
RtYCAP
RtYLND
RtTXHHY(hi)
RtYINST(t)
RtRP(i)
RtP(i)
RtWAGE(s)
RtLRNT(i)
RtCAPRNT(i)
RtLAB(i,s)
RtCAP(i)
RtLND(i)
RtX(i)
RtRQ(i)
RtMQ(i)
RtQ(i)
RtEXQ(i)
RtINTD(i)
RtHHD(i)
RtGSP
RtYGVT
RtUNEMPL(uns)
;
*************************************************************
*                   EQUATION ASSIGNMENT                     *
*************************************************************

*********************MODEL EQUATIONS**********************

EqZ..               Z=E=sum(i,SLACK1(i)+SLACK2(i));
OutPut(i)..         X(i)+SLACK1(i)-SLACK2(i)=E=
                         Theta(i)*Prod(s,LAB(i,s)**alpha(i,s))
                    *(CAP(i)**alpha(i,"CAPTL"))
                    *(LND(i)**alpha(i,"LAND"));
NetPrice(i)..       NPX(i)=E=RP(i)-sum(j,A(j,i)*P(j))-idtx(i)*RP(i);
IntmdDmnd(i)..      INTD(i)=E=sum(j,A(i,j)*X(j));
LaborDmnd(i,s)..    LAB(i,s)*WAGE(s)=E=alpha(i,s)*NPX(i)*X(i);
ExogWage(uns)..     WAGE(uns)=E=WAGE0(uns);
LabrMktEq1(uns)..   LabBar(uns)-Sum(i,LAB(i,uns))-UNEMPL(uns)=E=0;
LabrMktEq2(skl)..   LabBar(skl)-Sum(i,LAB(i,skl))=E=0;
LandDmnd(i)..       LND(i)*LNDRNT(i)=E= alpha(i,"LAND")*NPX(i)*X(i);
LndMktEq(i)..       LND(i)-LndBar(i)=E=0;
CapDmnd(i)..        CAP(i)*CAPRNT(i)=E= alpha(i,"CAPTL")*NPX(i)*X(i);
CapMktEq(i)..       CAP(i)-CapBar(i)=E=0;
LaborY(s)..         YLAB(s)=E=sum(i,LAB(i,s)*WAGE(s))+TRFCTRY0(s);
TotalYLAB..         TOTYLAB=E=sum(s,YLAB(s));
LandY..             YLND=E=Sum(i,LND(i)*LNDRNT(i));
CapitalY..          YCAP=E=sum(i, NPX(i)*X(i))
                           -sum(s,(YLAB(s)-TRFCTRY0(s)))-YLND;
InstuteY(t)..       YINST(t)=E=Sum(s,B(t,s)*YLAB(s)*(1-ftx(s)))
                            +B(t,"CAPTL")*YCAP*(1-ftx("CAPTL")-dprt)
                            +B(t,"LAND")*YLND*(1-ftx("LAND"))+TRINST(t);
TxbleHHY(hi)..      TXHHY(hi)=E=(sum(t,D(hi,t)*YINST(t))+TRGHH0(hi));
DispHHY(hi)..       HHY(hi)=E=TXHHY(hi)*(1-hhtx(hi))+sum(hj,TRHH(hi,hj));
HHsavng(hi)..       HHSAV(hi)=E=mps(hi)*(TXHHY(hi)+sum(hj,TRHH(hi,hj)));
HHDmnd(i)..         HHD(i)*P(i)=E=Sum(hi,beta(i,Hi)
                            *(HHY(hi)-HHSAV(hi)-sum(hj,TRHH(hj,hi))));
GvnmntRev..         YGVT=E=Sum(i,idtx(i)*RP(i)*X(i))
                             +Sum(s,ftx(s)*YLAB(s))
                             +ftx("CAPTL")*YCAP+ftx("LAND")*YLND
                             +Sum(hi,hhtx(hi)*TXHHY(hi));
TrdeTfrm(i)..         Q(i)=E= Eta(i)*(delta(i)*MQ(i)**(-rho(i))
```

```
                          +(1-delta(i))*RQ(i)**(-rho(i)))**(-1/rho(i));
ImprtDmnd(i)..       MQ(i)=E= RQ(i)*((RP(i)/ExogP(i))**(1/(1+rho(i))))
                           *((delta(i)/(1-delta(i)))**(1/(1+rho(i))));
CompPrice(i)..       P(i)*Q(i)=E=RP(i)*RQ(i)+ExogP(i)*MQ(i);
XBalnce(i)..         X(i)=E=RQ(i)+EXQ(i);
ExprtAG..            RP("AGRI")=E=ExogP("AGRI");
ExprtMN..            RP("MNNG")=E=ExogP("MNNG");
ExQMFCG1..           EXQ("MFCG1")=E=EXQ0("MFCG1")*RP("MFCG1")**(gamma("MFCG1"));
ExQMFCG2..           EXQ("MFCG2")=E=EXQ0("MFCG2")*RP("MFCG2")**(gamma("MFCG2"));
ExPrtD2(nti)..       EXQ(nti)=E=EXQ0(nti)*RP(nti)**(gamma(nti));
ComMktEq(i)..        X(i)+MQ(i)=E=HHD(i)+GvtD0(i)+InvD0(i)+INTD(i)+EXQ(i);
EqGSP..              GSP=E=Sum(s,(YLAB(s)-TRFCTRY0(s)))
                           +YCAP+YLND+sum(i,idtx(i)*X(i));
EqCapFlow..          FINCL=E=sum(i,P(i)*GvtD0(i))+sum(t,TRINST(t))
                         +sum(hi,TRGHH0(hi))-YGVT
                         +sum(i,RP(i)*EXQ(i))-sum(i,MQ(i)*ExogP(i))
                         +sum(i,RP(i)*InvD0(i))
                         -YCAP*dprt-sum(hi,HHSAV(hi));

*******EQUATIONS TO CALCULATE INDEX WITH 1982=1.000*********

RtYLAB(s)..          CYLAB(s)=E=YLAB(s)/YLAB0(s);
RtTOTYLAB..          CTOTYLAB=E=TOTYLAB/TOTYLAB0;
RtYCAP..             CYCAP=E=YCAP/YCAP0;
RtYLND..             CYLND=E=YLND/YLND0;
RtTXHHY(hi)..        CTXHHY(hi)=E=TXHHY(hi)/TXHHY0(hi);
RtYINST(t)..         CYINST(t)=E=YINST(t)/YINST0(t);
RtRP(i)..            CRP(i)=E=RP(i)/RP0(i);
RtP(i)..             CP(i)=E=P(i)/P0(i);
RtWAGE(s)..          CWAGE(s)=E=WAGE(s)/WAGE0(s);
RtLRNT(i)..          CLRNT(i)=E=LNDRNT(i)/LNDRNT0(i);
RtCAPRNT(i)..        CCAPRNT(i)=E=CAPRNT(i)/CAPRNT0(i);
RtLAB(i,s)..         CLAB(i,s)=E=LAB(i,s)/LAB0(i,s);
RtCAP(i)..           CCAP(i)=E=CAP(i)/CAP0(i);
RtLND(i)..           CLND(i)=E=(LND(i)/LND0(i))$(LND0(i) NE 0);
RtX(i)..             CX(i)=E=X(i)/X0(i);
RtRQ(i)..            CRQ(i)=E=RQ(i)/RQ0(i);
RtMQ(i)..            CMQ(i)=E=MQ(i)/MQ0(i);
RtQ(i)..             CQ(i)=E=Q(i)/Q0(i);
RtEXQ(i)..           CEXQ(i)=E=EXQ(i)/EXQ0(i);
RtINTD(i)..          CINTD(i)=E=INTD(i)/INTD0(i);
RtHHD(i)..           CHHD(i)=E=(HHD(i)/HHD0(i))$(HHD0(i) NE 0);
RtGSP..              CGSP=E=GSP/GSP0;
RtYGVT..             CYGVT=E=YGVT/YGVT0;
RtUNEMPL(uns)..      CUNEMPL(uns)=E=UNEMPL(uns)/sum(i,LAB0(i,uns));

*************************************************************
*                INITIAL VALUE ASSIGNMENT                   *
*************************************************************

X.L(i)=X0(i);                 YLAB.L(s)=YLAB0(s);
Q.L(i)=Q0(i);                 TOTYLAB.L=0.95*TOTYLAB0;
MQ.L(i)=MQ0(i);               YCAP.L=YCAP0;
RQ.L(i)=RQ0(i);               YLND.L=YLND0;
EXQ.L(i)=EXQ0(i);             YINST.L(t)=YINST0(t);
RP.L(i)=RP0(i);               YGVT.L=YGVT0;
P.L(i)=P0(i);                 TXHHY.L(hi)=TXHHY0(hi);
LAB.L(i,s)=LAB0(i,s);         HHY.L(hi)=HHY0(hi);
CAP.L(i)=CAP0(i);             HHSAV.L(hi)=HHSAV0(hi);
LND.L(i)=LND0(i);             HHD.L(i)=HHD0(i);
WAGE.L(s)=WAGE0(s);           GSP.L=GSP0;
CAPRNT.L(i)=CAPRNT0(i);       INTD.L(i)=INTD0(i);
LNDRNT.L(i)=LNDRNT0(i);
UNEMPL0(uns)=0.0000001*sum(i,LAB0(i,uns));

OPTION LIMROW=0;
OPTION LIMCOL=0;

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

MODEL OKGE /ALL/;
Solve OKGE Using NLP Minimizing Z;
```

```
*****************SOLUTION DISPLAY STATEMENT*****************
*--------------SOLUTION VALUES AS INDICE--------------------
*   The values must be 1.000 if exogenous variables are    *
*           equal to base year values                      *
*-----------------------------------------------------------
DISPLAY sigma, gamma, ExogP;
DISPLAY Z.L, CGSP.L, CYGVT.L, CYCAP.L, CYLND.L, CTOTYLAB.L
   CYLAB.L, CLAB.L, CUNEMPL.L, CTXHHY.L, CYINST.L,
   CRP.L, CP.L, CWAGE.L, CLRNT.L, CCAPRNT.L, CCAP.L, CLND.L,
   CX.L, CRQ.L, CMQ.L, CQ.L, CEXQ.L, CINTD.L, CHHD.L;

*------------------SOLUTION VALUES--------------------------
*    The values must be identical to base year values      *
*         with base year exogenous variable values         *
*-----------------------------------------------------------

DISPLAY Z.L, GSP.L, FINCL.L, YGVT.L, YCAP.L, YLND.L,TOTYLAB.L,
   YLAB.L, LAB.L, TXHHY.L, HHY.L, HHSAV.L, YINST.L,
   NPX.L, CAP.L, LND.L,
   X.L, RQ.L, MQ.L, Q.L, EXQ.L, INTD.L, HHD.L,UNEMPL.L;

*-----------------The End Of Program-----------------------*
```

VITA

Young-Kon Koh

Candidate for the Degree of

Doctor of Philosophy

Thesis: ANALYSIS OF OKLAHOMA'S BOOM AND BUST ECONOMY BY MEANS OF A CGE MODEL

Major Field: Agricultural Economics

Biographical:

Born in Chonpook, Korea, September 29, 1948, the son of Koh Dong-Suk and Lee Jeong-Hyoun.

Education: Graduated from Chonjoo High School in 1966; received Bachelor of Science degree in Agriculture from Seoul National University in 1970; received Master of Science degree in Agricultural Economics from Oklahoma State University in 1989; completed requirements for the Doctor of Philosophy degree at Oklahoma State University in July 1991.

Professional Experience: Researcher, Agricultural Economics Research Section, Department of Research, National Agricultural Cooperative Federation (DOR/NACF), 1973-1975; Assistant Manager, Kochang County Office of the NACF, 1975-1976; Assistant Chief, Marketing Research Section of the DOR/NACF, 1976-1983; Deputy Manager, Mooan County Office of the NACF, 1983-1984; Section Chief, Marketing Research Section of the DOR/NACF, 1984-1987; Graduate Research Assistant, Department of Agricultural Economics, Oklahoma State University, 1988-1991.

Honor: The Honor Society of Agriculture "Gamma Sigma Delta"