MONOPSONY MARKETS IN REGIONAL CGE MODELING: THE OKLAHOMA FOREST PRODUCTS INDUSTRY CASE

By

ELIECER EDUARDO VARGAS

Bachelor of Science

University of Costa Rica

Ciudad Universitaria Rodrigo Facio

Montes de Oca, Costa Rica

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, 1999

MONOPSONY MARKETS IN REGIONAL CGE MODELING: THE OKLAHOMA FOREST PRODUCTS INDUSTRY CASE

Thesis Approved:

Dean F. Schreiner

Thesis Advisor

Arthur Stoecker

Wayne B. Powell

Dean of the Graduate College

ACKNOWLEDMENTS

My sincere gratitude to Dr. Dean F. Schreiner: advisor, mentor, and friend. His continued support and inspirational discussions on a weekly basis always gave me motivation during the Ph.D. program and formed my interest in regional science. Special thanks to members of my advisory committee, Dr. Arthur L. Stoecker, Dr. David Lewis, and Dr. Keith D. Willett for their helpful suggestions and support.

Thanks also to the U.S. Agency for International Development for their financial support for my masters and to the Department of Agricultural Economics for the research assistantship, which made my Ph.D. study possible.

Finally, I would like to dedicate this dissertation to the source of my inspiration, my wife Janice, whose invaluable support in many ways, made this day a reality. *I love you, more.*

TABLE OF CONTENTS

CHAPTER I

INTRODUCTION

1.1 General Problem

Contribution of the forest products industry (FPI) to Oklahoma's economy may be assessed through economic indicators: payroll, value added, value of the processed products, etc. According to the 1992 Census of Manufactures (USDC, 1994), there were 226 establishments classified as belonging to the forest products industry (FPI) in Oklahoma. Products of the FPI were valued in excess of $1.5 billion. Approximately seven thousand persons were paid $187.8 million in wages. In addition, the value added for the FPI was $699.1 million (Table 1.1), which represents 0.5 % of total value added for all manufacturing in Oklahoma.

TABLE 1.1

OKLAHOMA PRIMARY TIMBER PROCESSING INDUSTRIES; STATISTICS 1996

SIC CODE/INDUSTRY	Employees (thousands)	Payroll (million)	Value added (million)	Value of Shipments (million)
241 Logging	0.3	8.7	34.7	109.3
242 Sawmills and planing mills	0.5	9.9	28.2	81.6
243 Millwork, plywood, and structural members	1.2	23.3	49.8	102.2
262-3 Other paper and allied products	1.3	52.7	248.3	583.3
267 Miscellaneous converted paper	1.9	58.0	259.3	523.5
265 Paperboard Containers and boxes	0.7	20.7	38.8	74.1
Other primary timber manufacturing	1.0	15.1	40.0	76.6
Total, primary timber processing	6.9	187.8	699.1	1550.6

Source: US. Department of Commerce, 1996 Annual Survey of Manufactures.

Nevertheless, to put into clearer perspective the economic importance of the FPI, we must consider three further issues. First, for the eastern Oklahoma region[1], the FPI is a major component of the overall regional economy as described by Lewis and Goodier (1990). For example, combined wages of the forest and supporting industries account for 23 percent of all wages and salaries in 1984 and nearly 78 percent of all manufacturing employment in this region. Second, economic multipliers estimated by Schooley (1981), Aruna, et al (1997), and the USDA Forest Service (1988) reveal that the FPI sectors in Oklahoma have a substantial impact on state output, income, and employment. Third, the FPI in Oklahoma has great potential for increasing its contribution to Oklahoma's economy. Lewis and Goodier (1990) identify investment opportunities that could increase net annual timber growth on timberland, marginal crop- and pasture-land, and highly erodible cropland and thus could increase Oklahoma's timber output by 150 percent. This increased availability and reduced cost of raw material could further promote investment in wood processing. Furthermore, an attractive alternative to the multinational ownership of forest products industries in Oklahoma is the possibility of timber producers entering the value-added processing industry as a "new wave" type

---

[1] Eastern Oklahoma forest region includes the counties of Adair, Cherokkee, Delaware, McIntosh, Mayes, Muskogee, Ottawa, Sequoyah, Atoka, Bryan, Choctaw, Coal, Haskell, Latimer, LeFlore, McCurtain, Pittsburg, and Pushmataha.

cooperative[2]. This would increase capacity of wood processing and the contribution of FPI to the Oklahoma economy.

Because of these arguments, the FPI sectors provide an excellent way of stimulating economic development, especially for rural eastern Oklahoma. Changes in the economic environment for the FPI through programs and/or policies would affect the well being of Oklahoma people. Thus, building a framework where economic analysis can be carried out is of great significance. Determining the economic effects of programs and policies as well as describing how they may affect the welfare of people in the short and long run, is the challenge of this regional analysis.

Efforts to measure these effects and to build a framework for economic analysis in Oklahoma's FPI have been generally based on the Input-Output methods, i.e., Schooley (1981), Aruna, et al (1997), and the USDA Forest Service (1988). Other approaches include Marcouiller's (1992) usage of a mixed endogenous/exogenous supply-determined social accounting matrix (SAM). Descriptive work has been based on census and/or survey results, i.e., Raunikar and Booth (1960), Lewis and Goodier (1990), and Toms (1987).

The literature review in this study summarizes the approaches and methods used to study the FPI in Oklahoma. It reveals that the model specifications and assumptions imposed in those studies fall short of providing adequate and realistic modeling of the

---

[2] The term "new wave" is borrowed from the Kenkel and Lyford (1997) article "The potential for "new wave" cooperatives in Oklahoma".

economics of the FPI in Oklahoma. The following section synthesizes the specific limitations and shortcomings.

1.2 Specific Problems

In the previous section, different studies and approaches for evaluating the impact of potential changes in the wood processing industry on the Oklahoma economy were presented. Several limitations of those impact analyses are identified.

First, the input-output based models assume that sectoral production is completely demand-driven. Increased demand is always met with no price increase thanks to excess production capacity. This assumption, known as the fixed prices assumption, imposes characteristics to the FPI which are not realistic, or at least refutable. These are: a) excess capacity in all FPI sectors; b) no substitution among the different inputs in production; c) constant returns to scale (CRS); and d) price takers in the output and input markets. To correct this misspecification of the FPI in the models of impact analysis is not an easy task because of little information about elasticities of factor substitution, returns to scale, and the technology of the FPI for Oklahoma[3]. Hence, the estimation of production parameters for the forest products industry in Oklahoma is needed.

Second, with the exception of Marcouillier's work, little consideration is given to the analysis of income determination and income distribution. Fixed price multiplier methods do not accommodate distributional effects. Because the FPI in Oklahoma involves

---

[3] One may argue for the use of national estimates in regional modeling, however, there are clear differences between the regional and the national economic environments.

multinational as well as regional owners and because non-industrial private forestland owners are located mainly in the rural regions, impact policy analysis should consider possible distributional effects. Regional economic analysis based on computable general equilibrium (CGE) methods may be a more suitable approach. However, regional CGE models for Oklahoma (Schreiner, et al (1996), Budiyanti (1996), and Koh (1991)) have not modeled the FPI. The FPI was aggregated into the manufacturing sector, therefore analysis for specific industries is impossible.

Third, evidence on forest products market structure suggests that these markets are not perfectly competitive (Klemperer, 1996, Tillman, 1985, Vincent, et al., 1992). The assumption of perfect competition was imposed in all previous studies of the Oklahoma FPI. Wood processing industries often involve relatively few processors who purchase the raw product from many local producers and transform it into multiple product forms and sell to a number of consumers. For example, in Oklahoma, 70% of total employment in the Sawmills and Planning Mills industry (SIC 242) is from one multinational company. Similarly, in the Paper Mills (SIC 262) and the Paperboard mills (SIC 263) industries, which have only 7 establishments, 82.5% of the total labor force works for two multinational companies. In addition to the high concentration of the industry, Oklahoma producers have limited options on where to sell their timber because of costly transportation and long distances between processing centers. All of this propitiates some kind of imperfect structure for the timber market (raw material market) in which wood processing industries are capable of affecting the price paid for timber. Such an industry structure may result in imperfect competition not only in the buying side but also in the selling side of the market. For example, high concentration in the pulp manufacturing industry increases the likelihood of lower outputs and higher prices than under a competitive structure. As well, its actions may distort the timber market, thus affecting the welfare of both forest land owners and consumers (Tillman,1985).

Limitations of the approaches used to carry out impact analysis require better analytical models for economic analysis of the FPI in Oklahoma. Better modeling that accommodates not only the factor-product market interaction but also the imperfect market structure is required.

1.3 Objectives

The primary purpose of this research is to develop and test a model of the impact of programs and policies on the Oklahoma forest products industry which accommodates industries that do not possess constant returns to scale (CRS) in production and/or are not price-takers. Three specific objectives are defined as means to fulfill the purpose of this research:

1) To econometrically estimate the elasticity of factor substitution, returns to scale, and the technology of the FPI in Oklahoma.
2) To implement the regional CGE model of Oklahoma using the cost approach for modeling the FPI accommodating for increasing returns to scale and imperfect competition and incorporating the information derived in the first objective.
3) To assess welfare changes of forest region residents using the developed regional general equilibrium model for a suggested alternative of the market structure of the timber and wood processing sectors: "New Wave Cooperative".

The model developed here brings the CGE models closer to reality by recognizing that the FPI may face increasing returns to scale and/or face imperfect markets. Hence a contribution of this research will be the capability of modeling decreasing unit cost structure under the CGE framework. The CGE model developed here is a more integrated policy framework in which to perform economic analyses because it allows prices, quantities, and incomes to be endogenously determined in the region but considers more realistic characteristics of the market structure and production technology of the FPI.

In addition, this study improves understanding of market behavior in wood processing by developing and applying a generalized model of raw material pricing in regional general equilibrium that reflects key structural characteristics of the forest products sector. Thus, the modeling technique presented here allows the existence of a raw material (input) market and several price-behavior assumptions which bring greater flexibility to policy analysis.

CHAPTER II

LITERATURE REVIEW

In this chapter, the literature review is presented in three sections. First, the economic studies on Oklahoma's FPI are summarized emphasizing the assumptions, scope, findings and limitations of each study. Second, review of the FPI production system is presented. Here, using studies mostly developed in the field of production economics, it is intended to identify the possible magnitude and sign of production parameters such as factor elasticities, returns to scale, factor substitution, and technological bias present in the FPI. In the third and last section, the theoretical limitations of the different approaches used in regional economic analysis of the FPI are reviewed. Perfect and imperfect competition is scrutinized by reviewing the connection between returns to scale and price behavior in regional analysis.

2.1 Oklahoma's Forest Products Industry

Several studies have dealt with statistics on employment, number of establishments, value added and other variables of Oklahoma's FPI, i.e., Lewis and Goodier; May; and Hendrix, Jones and Schooley. However, I focus on those studies that explicitly have used economic analysis to study the FPI. Raunikar and Booth described and analyzed the existing structure of the processing industry for forest products in eastern Oklahoma and estimated the efficiency and capacity of local sawmills in 1958. Fifteen counties were selected and information was obtained for three major classes of firms: sawmills, piece-wood buyers, and miscellaneous outlets. The study of efficiency and capacity was restricted to sawmills where sawmill firms were grouped by type of fixed plant and examined for efficiency of operation with respect to variable inputs. In their unit cost approach, they estimated the relationship between output and unit costs by observing groups of firms with similar equipment. Consistent with theory, they found that as average output increases, average unit cost decreases. Based upon their estimates, the authors claimed the potential efficiency of firms was not being exploited, therefore they supported increasing timber supply to achieve optimum plant efficiency. They used their results in evaluating the impact of potential changes in the wood processing industry on the rural economy.

The potential regional economic impact and the welfare effects of changes in Oklahoma's FPI have been studied mainly using the Input-Output (I-O) approach. Schooley and Jones's I-O model of the Oklahoma economy was developed to describe the role of the FPI in the state's 1978 economy. It consisted of 31 endogenous sectors, four exogenous sectors, and six FPI sub-sectors. Data for the FPI sectors were collected by personal interviews, telephone interviews, and/or on-site plant inspections. The remaining sectors of the economy were estimated from regionally adjusted 1972 national I-O coefficients. This data was further adjusted to represent 1978 prices and production levels. The model is presented in terms of a transaction matrix, a technical coefficients matrix, and two interdependence coefficients matrices. Type I and Type II output, income, and employment multipliers were estimated. Among their findings is that 84% of the inputs necessary to produce FPI output in 1978 were locally produced. This implies strong linkages between the FPI sectors and the rest of the economy. Also, FPI sectors have substantial impacts in the state's economy based on output, employment and income multipliers. As an aggregate, the FPI sectors have the fourth highest Type I output multiplier (1.98), and the seventh largest Type II multiplier (3.40). Particularly, the paper and allied products sector reported the second largest Type I and Type II income multipliers of 3.25 and 4.87, respectively. As an aggregate, the FPI sectors were found to have the fifth largest Type I and Type II income multipliers and the second highest Type I and Type II employment multipliers. Paper and allied products and logging sectors had the second and third largest Type II employment multipliers for the state (see Table 2.1).

More recently, Aruna et al. used the I-O approach to study the forest-based industries in the southern region of the United States. Using the 1992 IMPLAN (IMpact analysis for PLANning) database, and U.S. Department of Commerce, Census of Manufactures, regional economic multipliers were estimated for Oklahoma. Adjustments for differences between the IMPLAN national level and the regional level aggregation were carried out by using the concept of regional purchase coefficients (RPC)[4]. To estimate the regional economic impacts of the forest-based industries, Type I and Type III multipliers were generated for output, employment, total income, personal income, and value added. Table 2.1 presents those multipliers together with those obtained by Schooley and Jones.

---

[4]RPC are estimated using regional production coefficients. Aruna defines it as "the proportion of the total supply of a good or service used to fulfill the demands (intermediate and final) of a region that is supplied to itself. The remainder represents imports" (page 36).

Several authors have used these multipliers to assess the impact of potential changes in policy and alternatives of development for the Oklahoma region (see Lewis and Goodier; USDA, Forest Service). On the other hand, Marcouiller developed and used a supply-determined social accounting matrix (SDSAM) to evaluate economic impacts of industrial, nonindustrial, and public timber production in McCurtain County during 1985. He used a mixed endogenous/exogenous supply-determined social accounting matrix with specific results focusing attention on issues of income distribution. This approach constitutes a departure from standard demand side input-output models.

TABLE 2.1

MULTIPLIERS FOR OKLAHOMA FPI, BY TYPE AND INDUSTRY.

	Paper and allied products			Wood furniture			Lumber and wood products		
	Type			Type			Type		
	I	II	III	I	II	III	I	II	III
Output multipliers	2.07-1.26	3.38	1.50	1.67-1.31	3.21	2.07	2.03-1.50	3.58	2.22
Income Multipliers	3.25-1.31	4.88	1.67	1.56-1.31	2.34	2.15	2.07-1.63	3.19	2.74
Employment Multipliers	6.29-1.83	10.14	3.04	1.42-1.30	2.05	2.21	2.45-154	3.94	2.62
Value Added multipliers	1.34		1.73	1.33		2.28	1.67		2.90
Personal Income multipliers	1.50		2.04	1.24		1.87	1.62		2.61

Source: Aruna et al.; and Schooley and Jones.

Marcouiller justifies the use of a mixed endogenous/exogenous SDSAM approach upon two observations. First, he argues that limited productive potentials of forest lands and exorbitant hauling costs causes the inputs of raw materials to wood processors to be fixed with what is currently available for harvest. Secondly, he claims that since the demand for processed wood products such as plywood, dimensional timber, and paper are determined in the national marketplace (demand is relatively elastic) giving fixed prices for output, processors are forced to allocate (or ration) raw materials supplies to meet this exogenously determined demand.

An important observation with direct implications for the present study is made by Marcouiller when he adjusted timber production sector value added. According to him, "it appears that values for timber production output (particularly industrial timber production) are often included with non-timber production sectors in which industrial firms are vertically integrated"(page 87). He adjusted the account for timber production sector output by assuming that annual stumpage value of removals is the most appropriate measure of total industry output[5]. After the adjustment, Marcouiller's SDSAM included six aggregated sectors: agricultural production, timber production and services, manufacturing, food/fiber processing, timber and wood processing and services and government. The aggregation of the wood processing sectors is based on the active sectors for McCurtain County, Oklahoma during 1985, and might differ from the aggregation of the industry at the state level.

Finally, there have been several CGE studies modeling the Oklahoma economy. The FPI is generally aggregated into the manufacturing sector (Koh; Lee; and Amera and Schreiner). Budiyanti, however, included paper and allied products as a sector and

---

[5] Removals were obtained using the reported softwood and hardwood volumes derived through the interactive SOFIA (Southern Forest Inventory and Analysis) database.

aggregated the other industries of the FPI into other manufactures for her regional CGE framework. Even though Budiyani did not intend to analyze the FPI, it may well be considered as a base for implementing a regional CGE with emphasis in this industry. As Amera & Schreiner have revealed, regional equilibrium models may produce very different policy results compared to fixed-price multiplier models (i.e., I-O models). Further elaboration of the CGE framework and its assumptions of analysis are presented in section 2.3.

2.2 Production Technology and Market Structure of the FPI

The previous section reveals a lack of information on technological parameters (i.e., elasticity of factor substitution, returns to scale) and market structure of Oklahoma's FPI. In this section, a review of literature is presented concerning these two areas: production technology and market structure. This review brings insights as to the technological and market characteristics of Oklahoma's Forest Products Industry.

2.2.1 Production Technology

Production technology of the Forest Products Industry is generally estimated using econometric methods although nonparametric methods have recently been explored (see i.e., Hseu and Buongiorno 1995 and 1997). Stier and Bengston have classified econometric studies in first, second, and third generation. First generation studies based on value-added measures of output employs simple functional forms and incorporate only capital and labor inputs. Second generation studies estimate more complex, flexible dual cost or profit functions and typically include other inputs (logs, energy, and so on). Third generation studies use the dual formulation, include multiple factors, and specify the dynamics of adjustment of quasi-fixed factors over time (i.e., quasi-fixed capital, and/or non-production workers). Second- and third-generation studies allow richer theoretical specifications of the model, therefore they are the focus of the present review. Three properties of the production function are emphasized: the elasticity of factor substitution, returns to scale, and technological change bias. These three properties describe the essential structure of the FPI's production technology (Stier).

Two important reviews of the FPI literature include Vincent et al. who summarize the econometric research that pertains to labor demand and Stier and Bengston who review econometric analyses of the rate and bias of technical change. In the review by Vincent et al, more than 40 articles are classified according to product and regional coverage, and empirical approach. Vincent et al. draw the following observations:

a) Labor demand is inelastic with respect to wage rate (range: -0.35 to –0.66),
b) Capital, materials (including wood), and energy are all substitutes for labor, and labor demand is inelastic with respect to prices of these inputs,
c) The solid-wood products sector shows constant returns to scale (1.08), whereas the pulp and paper sector shows increasing returns to scale (1.13), and
d) Technical change is biased against use of labor, in the range of -0.014 to –0.011.

Stier and Bengston review 24 studies and conclude that technical change has largely been labor-saving and energy-using. They do not argue for a wood-saving technical change, however.

The observations of Vincent et al. and Stier and Bengston, should be reviewed with caution. They represent a general and/or broad view of very different studies. For example, a study of the pulp industry in Canada and a study of the lumber industry of Pacific Northwest of the Unites States should not be pooled together. To reduce shortcomings of aggregation, these studies are reviewed here by industry and region.

General description and findings of the studies are presented in Table 2.2. For the Lumber and Wood Products (SIC 24) group of industries, studies fail to provide conclusive answers about substitutability, returns to scale or technical change bias. When specific industries are considered, however, we may find some common ground. First, for the Sawmills and Planing Mills industry (SIC 242), evidence supports a degree of complementarity between capital and stumpage, and substitutability between labor and capital and labor and stumpage. With respect to returns to scale, only two studies did not impose the CRS assumption a priori. One study found increasing returns to scale (IRS) while the other failed to reject CRS. Labor-saving and capital and energy-neutral technical change appeared to be the norm for this industry.

On the other hand, evidence is mixed about technical change for stumpage (raw material) input. For the Softwood Veneer and Plywood industry (SIC 243), a degree of substitution exists between labor and capital, and between labor and raw material (stumpage). The substitutability between capital and stumpage (raw material) appears difficult to ensure because some studies find a degree of complementarity. Of those studies that did not impose CRS, Merrifield and Singleton found evidence of IRS. Based on these studies, conclusions about technical bias in this industry are inconclusive.

Table 2.2
Description and findings of reviewed studies by industry and region.

SIC Code	Forestry Industry	Study	Region	Time period	Elasticity of Substitution	Returns to Scale	Technical Change Bias	Model Specification
24	Lumber and Wood products	Merrifield and Haynes (1983)	U.S. PNW	1950-76	LS=-0.91; KL=1.35; KS=2.26	CRS		Translog Prod. Fns.
		Wear	U.S. Montana	1955-78			L,W-	Quadratic normalized total cost function
		Rockel and Buongiorno	U.S.	1968-77	Unitary elast. Substitution	Imposed	Neutral	Derived Demand
242	Sawmills and Planing Mills	Sullivan and Gilless	U.S. California	1978-85				Cost function
			U.S. Northern California	1974-85				Cost function
		Stevens	U.S. Western Washington	1980-88	L(uns), E, S Compl. in med. & LR;		Neutral	Normalized quadratic profit function
2421	Sawmills and Planing Mills, General	Merrifield and Singleton	U.S.-PNW	1954-80	k&S compl.; k&l subst.; L&s subs.;	IRS (cost reduction 0.70-0.74)	S-;K+; L+S&MR; L-LR	Dynamic quadratic variable cost: capital as the Quasi-Fixed Factor
		Merrifield and Haynes(1985)	U.S.-PNW Eastside	1950-79			L,K,W-	Translog total cost: K for equipment and structures.
		Merrifield and Haynes(1985)	U.S.-PNW Westside	1950-79			Lo,Ko,Wo	Translog total cost: K for equipment and structures.
		Abt	U.S.-PNW	1963-78		CRS	L-,W+	Translog variable cost
		Abt	U.S. Southeast	1963-78		CRS	L-,W-	Translog variable cost

TABLE 2.2 (CONTINUED)

SIC Code	Forestry Industry	Study	Region	Time period	Elasticity of Substitution	Returns to Scale	Technical Change Bias	Model Specification
		Abt	U.S.-Appalachian	1963-78		IRS (Cost reduction 0.96)	L-,W+	Translog variable cost
		Stier(1980)	U.S.	1950-74	k&l=0.194; KW=0.176; l&W=0.36;	CRS imposed	L-,Wo	Translog Cost Function
2436	Softwood Veneer and Plywood	Merrifield and Singleton	U.S.-PNW	1954-80	k&S ?; k&l subs; L&S subst.;	IRS (Cost reduction 0.66)	L-;K+:S+	Dynamic quadratic variable cost: capital as the Quasi-Fixed Factor
		Merrifield and Haynes(1985)	U.S.-PNW Eastside	1950-79			K(e)-;K(s); L;W	Translog total cost: K for equipment and structures.
		Merrifield and Haynes(1985)	U.S.-PNW Westside	1950-79			K(s)+ K(e)-; L;W	Translog total cost: K for equipment and structures.
26	Paper and Allied Products	Hseu and Buongiorno(1995)	U.S.	1959-87			biased tech.ch.	Nonparametric analysis
		Stier(1985)	U.S.	1948-76	subst. Is difficult	IRS(Cost reduction 0.74)	L-, W+,	Translog Cost function
262	Paper Mills	De Borger and Buongiorno	US	1958-81	LE=0.05, LM=0.42*, EM=0.67*	SR no sig. LR DRS (0.65)	L-,E+,M	a simplified translog variable cost: homotheticity and homogeneity imposed
263	Paperboard Mills	De Borger and Buongiorno	US	1958-81	LE=-0.19, LM=0.39*, EM=1.07*	SR IRS (Cost red. 0.66); LR DRS (0.79)	L,E,M	a simplified translog variable cost: homotheticity and homogeneity imposed

Elasticity of substitution: LS= Labor and Stumpage, KL= capital and labor, KS= capital and stumpage; also W is used for several studies a raw material (Wood)
Returns to scale: cost reduction means the cost reduction obtained by the measurement of the cost elasticity with respect to output produce, this is the dual formulation to returns to scale
Technical Change Bias: a + implies using-bias for the input, a – implies saving-bias for the input, the letter along means neutral-biasness; SR stands for short run, MR for median run and LR for long run.

The Paper and Allied Products (SIC 26) group in the U.S. has not been studied as much as its Canadian counterpart. However, studies on Paper and Paperboard Mills (SIC 262-263) are consistent and offer similar conclusions. More precisely, the presence of low substitutability was found between labor and materials, energy and labor, and capital and materials. Also, increasing returns to scale (with values of 0.65 to 0.79) seem to characterize this industry. With respect to technological bias, labor-using and neutral technical change for materials, energy and capital were supported by the studies findings. In conclusion, the studies cited in Table 2.2 show consistent information on basic production technology for the sub-sectors of Paper and Allied Products. However, consistent information is not shown for the other sub-sectors of the FPI; specifically, those industries belonging to the Lumber and Wood Products sector.

2.2.2 Market Structure

The United States FPI has been long recognized by many authors as not having the pure competition market structure. In 1966, Mead concluded that the U.S. lumber industry faces a perfectly elastic demand curve for lumber and an inelastic factor supply. Thus, the timber market is oligopsonistic rather than competitive. For the Douglas Fir region he found a significant degree of market power among the few large firms in the national forest timber markets. He found lower average cost for national forest timber purchased by large firms relative to small firms.

What favors market power is market structure, and what promotes the presence of only a few large firms is the technological trends of the FPI. Tillman's publication "Forest Production: Advanced Technologies and Economic Analysis" introduces the achievements of the industry integration not only at the corporate level but also at the mill site level. Vertically and horizontally (product) integrated mills have allowed efficiency gains in plant operating and maintenance expenses; economies of scale in capital investments such as log handling systems, debarking systems, etc.; energy conservation; use of residues; and flexibility in use of timber (Tillman, page 25).

While the trends described above are responsible for highly efficient mills, it may also be responsible for an industry characterized by high capital intensity, difficulty of market entry, and moderate economic concentration. The latter characteristic has been extensively studied using concentration ratios.

The concentration ratio gives the percentage of one industry's output value produced by the largest firms, usually the top four or eight (i.e., "four-firm concentration ratio"). Moderate concentration (25 to 49 percent ratios) is common in the softwood veneer and plywood, pulp mills, and paper mills industries. Low concentration in sawmills seems to be the norm (Klemperer).

Buongiorno and Lu used a mark-up model of price formation to investigate the reasons for changes in the prices of seven forest products industries. The model explained 83% to 98% of the variation in annual price changes depending on the industry. In the case of the Pulp Mills (SIC 261) industry, a downward price inflexibility was detected consistent with oligopolistic competition. The authors, in their "decomposition analysis", concluded that changes in unit cost were the major source of price changes as opposed to negligible effects of changes in demand.

2.3 Regional Analysis and The Forest Products Industry

Several approaches have been used for regional analysis of the FPI. Among them, input-output (I-O) models (i.e., McWillians and George; Schalla), econometric sectoral analysis (Kant, et al.), and SAM (i.e., Marcouiller). Surprisingly, regional CGE for analysis of the FPI is limited. Rather than review each approach and/or intent to explain how the FPI is evaluated under the different alternative approaches, the limitations of each approach is reviewed and the compatibility of each approach with the current research is pursued.

The input-output based models assume that sectoral production is completely demand-driven. Increased demand is always met with no price increase because of excess production capacity. This assumption, known as the fixed prices assumption, imposes characteristics to the FPI which are not realistic, or at least refutable. These are: a) excess capacity in all FPI sectors; b) no substitution among the different inputs in production because resources are unlimited; c) constant returns to scale (CRS); and d) price takers in the output and input markets. Thus, economic impacts due to changes in supply of a commodity/service cannot be modeled (Aruna, et al. and Sadoulet and de Janvry).

Another issue with respect to analysis with I-O models is the limited ability to model income determination and income distribution. Fixed price multiplier methods do not easily accommodate distributional effects. SAM models are an extension of the input-output framework and allow better analysis of income distribution, taxation and consumption (Marcouiller; Berck, et al.). However, SAM models retain the key assumption that production activities are endogenous and demand-driven and thus existence of excess capacity.

On the other hand, sectoral econometric analysis has strength in partial economic considerations. When lagged variables and a variety of other exogenous variables are incorporated into the analysis, sectoral econometric models offer unique flexibilities. The extensive data needed in econometric analysis, however, restricts their empirical use. An important limitation in their use is the inability to consider all intersectoral and/or macroeconomic specifications of factor markets and institutions.

Finally, the CGE framework offers an alternative for regional analysis. It encompasses both the I-O and SAM frameworks by making demand and supply of goods and factors dependent on prices. Partridge and Rickman surveyed the literature related to regional CGE modeling. They outline the basic approach of regional CGE modeling and provide an appraisal of the current state of the art. At the Oklahoma level, several studies have used this framework for policy analysis (Koh; Lee; Budiyanti; and Amera and Schreiner,)

For the present study, it is vital that the approach chosen reflects the current economic environment of Oklahoma's FPI, specifically, production technology, inter-industry linkages and, most important, market structure. Several research studies have used the regional CGE framework for policy analysis. However, few studies have considered market structure other than perfect competition. Also, few have incorporated increasing returns in their analysis.

Solutions and modeling techniques dealing with imperfect competition and increasing returns to scale have been suggested at the national level (i.e., international trade). However, little is known about implementing such techniques at the regional level. Partridge and Rickman have identified six studies at the regional level that deal with imperfect market structure (Brocker; Hertel; Hertel and Mount; Kilkenny, 1993; Kilkenny, 1996; Treyz and Bungardner; and Whalley and Trela). What is brought out, according to Partridge and Rickman's review, is the sensitivity of the results produced by alternative market and strategic behavior assumptions made about firms and/or an industry. In general, there is opportunity for improvement in modeling imperfect competition and IRS using the regional CGE framework. This is both, an opportunity and a risk for the present research of Oklahoma's FPI.

CHAPTER III

PRODUCTION TECHNOLOGY AND MARKET EXERTION IN THE OKLAHOMA FOREST PRODUCTS INDUSTRY

This chapter presents theoretical considerations on technology and market exertion. The empirical model, description and requirements for data are presented. Econometric estimates are presented in section 3.4.

3.1 Technology Estimation

The Oklahoma Forest Product Industry production technology may be described by information on elasticity of factor substitution, returns to scale, and technological change bias. The dual relationship between technology and its associated cost function provide the necessary tools for estimating technological properties of the FPI in Oklahoma. *The cost function of a firm summarizes all of the economically relevant aspects of its technology* (Varian, 1992). Define the cost function to show the minimum cost of producing y units of output produced under a given technology of the firm using the vector $\mathbf{x}$ of factors and inputs. The assumption of cost minimization implies the following optimization problem to the firm:

(3.1) $\min\limits_{x} \mathbf{wx}$

Subject to

(3.2) $f(\mathbf{x}) = y$

where $\mathbf{w}$ is a vector of factor prices and $f(\mathbf{x})$ is a well-behaved technology. Solving this optimization problem for the first order condition, the conditional factor demands of the firm $\mathbf{x}(\mathbf{w},y)$ can be derived. The cost function is expressed as the value of the conditional factor demands:

(3.3) $$c(\mathbf{w}, y) \equiv \mathbf{w}\mathbf{x}(\mathbf{w}, y)$$

In the short run, the firm doesn't have the flexibility to optimize over all factors/inputs. Some factors such as "non-production workers" may be attached to contracts or/and structure capital may be realized only in the medium or long run. Let $\mathbf{x}_f$ be the vector of fixed factors, $\mathbf{v}_v$ the vector of variable factors, and thus decompose $\mathbf{w}$ into $\mathbf{w} = (\mathbf{w}_f, \mathbf{w}_v)$. Theory suggests that in the short-run the conditional factor demands will depend on the level of the fixed factors: $\mathbf{x}_v(\mathbf{w}, y, \mathbf{x}_f)$. Thus, the short-run total cost function is

(3.4) $$c(\mathbf{w}, \mathbf{x}_f, y) = \mathbf{w}_v \mathbf{x}_v(\mathbf{w}, \mathbf{x}_f, y) + \mathbf{w}_f \mathbf{x}_f = \text{SVC} + \text{FC}$$

where SVC and FC are the short-run average cost and fixed cost components, respectively.

For a function to qualify as a cost function, it must be non-decreasing, homogeneous, concave, and continuous in prices. These conditions are derived directly from the firm's price behavior and the properties of the underlying technology. If the cost function (3.3) or (3.4) is estimated, duality theory can be used to indirectly estimate the parameters of the production function. The elasticity of scale $e(\mathbf{x})$ is defined as:

(3.5) $$e(\mathbf{x}) = \frac{c(\mathbf{w}, y)/y}{\partial c(\mathbf{w}, y)/\partial y} = \frac{AC(y)}{MC(y)}$$

where AC is average cost and MC is marginal cost. Partial elasticities of substitution σ_{ij} can also be derived as:

$$(3.6) \quad \sigma_{ij} = \frac{(\partial^2 c(\mathbf{w}, y) / \partial p_i \partial p_j)}{(\partial c(\mathbf{w}, y) / \partial p_i) / (\partial c(\mathbf{w}, y) / \partial p_j)}$$

where p_i is price of the i input.

3.1.1 Empirical Model: Technology Estimation

The empirical specification assumes the industry only adjusts variable factors of production to cost minimization levels. This specification is a restrictive short-run cost function approach consistent with the first term of equation (3.4) where capital is treated as a quasi-fixed input. The restricted translog variable cost function is selected. Caves et al.; Borger and Buongiorno; Abt; Neil and Nautiyal; and Neil et al. used this functional form in their studies of the FPI. The translog form allows elasticities of substitution to be unrestricted (i.e., not constant). Also, it allows for testing of other important characteristics of the underlying technology, i.e., homogeneity and homotheticity. One may wish to test the validity of these restrictions in a cost minimization hypothesis; or estimate the variable cost function with these restrictions imposed a priori.

The empirical variable cost function is expressed in the translog functional form as:

$$(3.7) \quad \begin{aligned} \ln(VC) = {} & \alpha_o + \alpha_Q \ln Q + \tfrac{1}{2}\alpha_{QQ}(\ln Q)^2 + \alpha_t t + \tfrac{1}{2}\alpha_{tt} t^2 + \\ & \sum_i \beta_i \ln P_i + \alpha_K \ln K + \tfrac{1}{2}\sum_i \gamma_{ii}(\ln P_i)^2 + \gamma_{RML} \ln P_L \ln P_{RM} + \tfrac{1}{2}\gamma_{kk}(\ln K)^2 + \\ & \sum_i \delta_{iQ} \ln P_i \ln Q + \delta_{tQ} t \ln Q + \delta_{KQ} \ln K \ln Q + \sum_i \delta_{ti} t \ln P_i + \\ & \delta_{tK} t \ln K + \sum_i \delta_{iK} \ln P_i \ln K \qquad \forall i = RM, L \end{aligned}$$

where VC is total variable cost, Q is an index of output, t is a time trend proxy for technological advancement, P's are prices of the inputs: labor (L) and materials (RM), and K is capital stock.

For the cost function to represent a well-behaved technology, it should be linearly homogeneous in factor prices. Letting *i* and *j* be indices of input prices (i, j = L, RM), the following constraints must be imposed on the parameters of model (3.7) to satisfy price homogeneity, and other requirements of the cost function;

$$\sum_i \beta_i = 1$$

$$\sum_i \delta_{iQ} = 0$$

$$\gamma_{ii} + \gamma_{ij} = 0 \quad \forall i = j = L, M$$

$$\sum_i \delta_{ti} = 0$$

$$\sum_i \delta_{iK} = 0$$

Shephard's lemma implies that $\partial VC / \partial P_i = X_i$. This is the conditional factor demand. This result allows us to obtain the factor share equations as:

(3.8) $$S_i = \beta_i + \delta_{iQ} \ln Q + \gamma_{ij} \ln p_j + \gamma_{ii} \ln p_i + \delta_{ti} t + \delta_{iK} \ln K$$

where S_i is the share of factor *i* in variable costs. The factor share equations (3.8) may be used to estimate the substitution and price elasticities of factor demand. Allen elasticities of substitution, own price and cross-price elasticities of factor demand are, respectively, calculated as:

$$\sigma_{ij} = (\gamma_{ij} + S_i S_j) / S_i S_j$$

(3.9) $$\varepsilon_{jj} = s_j - 1 + \frac{\gamma_{jj}}{s_j}$$

$$\varepsilon_{ij} = s_j + \frac{\gamma_{Iij}}{s_i} \quad i \neq j$$

The flexibility of the translog form allows the researcher to incorporate previous information available to him in the empirical model. Thus, for example, knowing that technological change in the paper and allied product industry is of the Hicks-neutral type, one may want to impose Hicks-neutral technology by equating, $\alpha_{tt} = 0$, and $\delta_{ti} = 0 \; \forall I$. This could be very significant for the present research because there is, apparently, limited data and thus few degrees of freedom[6].

3.2 Market Exertion Estimation

A measure of mark-up of product price (*P*) over marginal cost (*MC*) should be estimated as an indicator of the degree of competition in Oklahoma's FPI. We turn now to the theoretical background for measuring market power exertion. In the industrial organization literature there exist several approaches for measuring market power exertion including concentration ratios, profit ratios and mark up ratios. Mark up ratio estimation can be understood using the theoretical framework for profit maximization. Richards, et al., and Wann and Sexton develop the mark up framework that allows market power exertion in product and factor markets.

Assuming a hypothetical processor which utilizes a homogenous raw material (input) in fixed proportion, $q=\gamma RM$, where γ is the coefficient converting *RM* amount of material input into *q* amount of output. The profit optimization problem for the i^{th} industry is represented as:

---

[6] It is possible to impose homotheticity and homogeneity by equating $\alpha_{QQ} = 0$ and $\delta_i = 0$. Similarly, unit elasticity of substitution (Cobb-Douglas) is imposed by equating $\gamma_{ij} = 0$.

(3.10) $\max_{RM^i} \pi_i = p(Q)\gamma RM^i - C^i(q^i, \mathbf{w}_v, \mathbf{f}) - p_{RM}(RM)RM^i$

where C^i is processing costs and $\mathbf{w}_v$ is a vector of variable input prices and **f** is a vector of fixed input quantities. It is assumed that these two vectors are separable from raw material costs, implying non-substitutability between the processing inputs and the raw material. Q is the total supply of processed output, *RM* is total input demanded for the industry, and p and p_{RM} are the prices received by the processor and the provider of raw materials, respectively. The first-order condition is:

(3.11) $$\partial\pi^i / \partial RM^i = [\partial p/\partial Q][\partial Q/\partial q^i][\partial q^i/\partial RM^i]\gamma RM^i + p\gamma - [\partial C^i/\partial q^i][\partial q^i/\partial RM^i] - p_{RM} - [\partial p_{RM}/\partial RM][\partial RM/\partial RM^i]RM^i = 0$$

Notice that $\partial q^i / \partial RM^i$ equals γ. Rearranging the first-order condition (3.11) we obtain the following relative price-spread formulation:

(3.12)

$$M = \frac{\gamma(p - C) - p_{RM}}{p_{RM}} = \frac{[\partial p_{RM}/\partial RM][\partial RM/\partial RM^i]RM^i}{p_{RM}} - \frac{[\partial p/\partial Q][\partial Q/\partial q^i]\lambda q^i}{p_{RM}}$$

where M is a relative markup which has been adjusted for marginal processing costs, C. It is possible to express (3.12) in elasticity form by multiplying the first term of the right hand side by (*RM/RM*), and the second term by (*Q/Q*) and (*p/p*). This yields:

(3.13) $$M = \frac{\gamma(p - C) - p_{RM}}{p_{RM}} = \frac{\theta^i_{RM^i}}{\varepsilon_{p_{RM},RM}} - \frac{\theta_{q^i}}{\varepsilon_{p,Q}} \frac{\gamma \cdot p}{p_{RM}}$$

where $\theta^i_{q^i} = [\partial RM/\partial RM^i][RM^i/RM]$ and $\theta^i_{q^i} = [\partial Q/\partial q^i][q^i/Q]$ are the firm's quantity conjectural elasticities in the raw material and the product market, respectively. And,

$\varepsilon_{p_{RM},RM} = [\partial RM / \partial p_{RM}][p_{RM} / RM]$ and $\varepsilon_{p,Q} = [\partial Q / \partial p][p / Q]$ are the own-price elasticity of demand for output and the elasticity of supply of raw material, respectively.

Thus, equation (3.13) states that the relative markup, adjusted for processing costs, depends on the perceived degree of market power of the firm in the output and raw material markets. Furthermore, for each of the conjectural elasticities, a value of zero indicates perfect competition in that market, while a value of one indicates that the firm acts like a monopoly or monopsony. Values between zero and one, then, represent degrees of oligopoly and oligopsony market structure.

Equation (3.13) and its various alternative specifications provide the base for testing the presence of competitive behavior/market power of processing firms in both input and output markets.

3.2.1 Empirical Model: Market Exertion Estimation

The markup price model selected for empirical analysis in the market power exertion in Oklahoma's FPI, is a simple version of that presented in equation (3.13). Specifically, it is a model which only allows market power exertion on the product side. Buongiorno and Lu proposed a markup price model which, for its simplicity, allows it to cover several industries within the FPI using the same theory and the same data sources. If we allow only some degree of oligopoly, equation (3.13) can be shown to become:

(3.14) $P / \varepsilon_{pQ} + P = MC$

were ε_{pQ} is the price elasticity of demand for the output, MC is marginal cost and P is the output price.

If average variable cost (AVC) is constant over the range of output so that AVC=MC, the price model can be written as:

(3.15) $P = [\varepsilon_{PQ} /(1+\varepsilon_{PQ})]AVC = m \cdot AVC$

where $m = \varepsilon_{PQ} /(1+\varepsilon_{PQ})$. Differentiating equation (3.15) and multiplying by *P* leads to the following equation in terms of discrete price changes:

$$(3.16) \quad \frac{\Delta P}{P} = \frac{\Delta m \cdot AVC}{P} + \frac{m \cdot \Delta AVC}{P} = \frac{\Delta m}{m} + \frac{\Delta AVC}{AVC}$$

where Δ is the difference operator computed between successive periods. Equation (3.16) shows that the periodic relative change in price is equal to the relative change in the mark-up factor plus the relative change in unit cost.

Buongiorno and Lu following other authors used the inventory-output ratio (*IQ*) as the demand proxy for the $\Delta m / m$ component of equation (3.16). Specifically, they specified a linear relationship between rate of price change, rate of change in inventory-output ratio, and rate of change in unit cost. Therefore, the model to be estimated is as follows:

$$(3.17) \quad \frac{\Delta P}{P} = a_o + a_1 (\frac{\Delta IQ}{IQ}) + a_2 \frac{\Delta AVC}{AVC} + u$$

where *u* is a residual with the usual properties.

3.3 Data Requirements and Description

The FPI includes SIC-coded industries under groups 24, 25, and 26. The industries selected are shown in Table 3.2. These have been selected to ensure an adequate coverage but also it is dictated by data availability. Table 3.3 presents the description of variables to be used in this study and their sources. Most data are from the

U.S. Department of Commerce, Bureau of the Census, Annual Surveys of Manufactures (1939-96).

TABLE 3.2

SIC INDUSTRY CODES AND NAMES, OKLAHOMA'S FPI STUDY

SIC code	Industry	Years of Data	Commodity
24	Lumber and wood products	39	
242	Sawmills and planing mills	14	Lumber
243	Millwork, plywood, and Structural members	12	Millwork and Plywood
25	Furniture and fixtures	30	
254	Partitions and fixtures	15	Partitions
26	Paper and allied product	37	
261-3	Pulp, paper and paperboard mills	11	Paper and paperboard

TABLE 3.3

DATA SERIES

Series Name	Description
PPI	Producer price index (1982=100)[1]
L	Cost of labor – Payroll for all employees (in million dollars)[2]
M	Cost of materials (in million dollars):direct charges actually paid or payable for items consumed or put into production during the year[2]
K	Capital stock derived using the perpetual inventory method and data obtained in census.
S	Value of shipments (in million dollars)[2]
INV	Value of end-of-year inventories (in million dollars)[2]
Q	Index of real output (S/PPI)
IQ	Inventory-output ratio (INV/PPI)
VC	Variable cost: L+M
AVC	Average variable cost VC/S
P_q	Price index of output for industry q [3].

[1] U.S. Department of Labor, Bureau of Labor Statistics.
[2] U.S. Department of Commerce. Bureau of the Census
[3] Producer Prices and Price Index, US Dept. of Labor, Bureau of Labor Statistics (BLS).

Deflating value of shipments and adjusting for inventory change derived an output series. This series was derived from the Annual Survey of Manufactures and Census of Manufactures and was therefore consistent with the input data.

Capital stock estimates were derived from Annual Survey capital expenditure data. A perpetual inventory model consistent with Bureau of Labor Statistics procedures was employed. Benchmarks were established using gross book-value data for Oklahoma at the 24 SIC code group, 1978. In the perpetual inventory method, the sequence of relative efficiencies -or varying productive capacity- of capital goods of different ages enables us to represent capital stock at the end of each period as a weighted sum of all past investments (Ahearn, et al.). Estimation of replacement requirements is based on the following relationship, which relates the productive capacity to the age of the asset:

$$d_\tau = (L-\tau)/(L-\beta\tau),\ 0 \le \tau \le L$$

where L is the service life of the asset, τ is year-age, and β is a curvature or decay parameter. The upper limit of β is one, and as its value approaches zero, decay increases at an increasing rate over time. In this study, the β values chosen were 0.50 for durable equipment and machinery and 0.75 for buildings and structures. Service life was estimated using actual state and national rate of depreciation for the 24 SIC code level. Thus, we estimated 10 and 25 years of service life for machinery and equipment, and buildings and structures, respectively.

The cost of labor was taken to be the wages paid to production and related workers as reported by ASM and CM. The price of labor is also an implicit price and was obtained by dividing the total production-related wages by the number of hours paid.

The total cost of materials was derived from the cost of materials data in the ASM. At the national level, CM data indicate non-wood material has remained a fixed proportion of material cost for the Lumber and Wood Products group. This was assumed to hold at the state level.

A series of average stumpage price of pine sawtimber for Oklahoma (dollars per MBF, Scribner Scale) was assembled. To complete the series, it was necessary to use the Producer Price Index for Southern Pine Sawtimber. This index is published in Internet by Bureau of Labor Statistics. The price index was used to represent the material input cost and is justified because roundwood is the single most important material used in lumber manufacturing, comprising almost 90 percent of all material used.

Total variable cost for the 24 SIC code industry group was calculated by adding total expenditures on labor and materials in each year (Data series are given in appendix C).

3.4. Econometric Results in Technology

The generalized form of the translog variable cost function (equation 3.7) that allows for nonhomotheticty and biased technical change was estimated for the lumber and wood products industry of Oklahoma (SIC 24). Data limitation on the other components of the FPI (SIC 25 and 26) limited our econometrics analysis exclusively to this industry.

Estimation of the cost function and the labor-share equation was carried out using SYSLIN SUR SAS™: procedure for handling seemingly unrelated equations. The cost and labor-share equations were estimated jointly to impose cross-equation parameter constraints, gain efficiency, and increase degrees of freedom, a common practice among researchers.

TABLE 3.4

COEFFICIENT ESTIMATES OF TRANSLOG MODELS: OKLAHOMA LUMBER AND WOOD PRODUCTS INDUSTRY

Coefficients	Nonhomothetic[a]	Homothetic[a]	Homogenous[a]
α_o	10571(3.01)**	8658.647(2.525)**	-9734.684(-3.72)**
α_Q	-58.067(-1.13)	-54.854(-1.57)	-162.867(-4.19)**
α_{QQ}	-0.084(0.49)	-0.141(-0.73)	
α_t	-10.796(-3.00)**	-8.903(-2.54)**	10.201(3.80)**
α_{tt}	0.003(2.99)**	0.002(2.54)**	-0.002(-3.89)**
β_L	-61.844(-2.00)*	-104.578(-4.405)**	-1.704(-1.08)
β_{RM}	62.844(2.04)*	105.578(4.45)**	2.704(1.71)
α_K	99.529(2.72)**	82.739(2.76)**	26.679(0.997)
γ_{LL}	-1.902(-2.32)**		-0.009(-0.56)*
γ_{RMRM}	-0.912(-2.27)**		-0.004(-0.56)
γ_{LRM}	1.823(2.27)**		0.009(0.561)
γ_{KK}	0.223(1.143)	0.177(2.151)*	0.220(2.33)**
δ_{LQ}	-0.456(-2.27)**		-0.056(-2.3)**
δ_{RMQ}	0.456(2.27)**		0.056(2.3)**
δ_{tQ}	0.030(1.18)	0.029(1.592)	0.084(4.22)**
δ_{KQ}	-0.059(-0.106)		-0.601(-3.07)**
δ_{tL}	0.029(1.80)	0.053(4.42)**	0.001(1.48)
δ_{tRM}	-0.029(-1.80)	-0.053(-4.42)**	-0.001(-1.487)
δ_{tK}	-0.050(-2.76)**	-0.42(-2.75)**	-0.012(-0.936)
δ_{LK}	0.426(2.01)*	-0.053(-4.42)**	-0.038(-2.81)**
δ_{RMK}	-0.426(-2.01)*	0.053(4.426)**	0.038(2.81)**

[a] t values are shown in parenthesis,
* and ** indicate significance at the 10% and 5 % level, respectively.

Parameter estimates for the nonhomothetic, the homothetic and the homogenous models are presented in Table 3.4. Mispecification test was conducted for these three models and for the additional model that restricted the parameters of the variable t^2 and Q^2 to equal zero.

Based on the statistical test results, homotheticity was rejected. Because we are using time series and many of the explanatory variables, including output, time, and factor prices, are trended, it may be impossible to distinguish economies of scale from technological change in a full translog model (de Borger and Buongiorno). The remainder of the discussion, therefore, is confined to the homogenous model (column 3 of Table 3.4). This model implies that input substitution and constant elasticity of cost with respect to output characterizes the FPI.

Own and cross –price elasticities of factor demand are shown in Table 3.5. They were calculated using the mean factor shares over the sample period and the following relationships:

Own price elasticity

$$\varepsilon_{jj} = S_j - 1 + \gamma_{ij} / S_j$$

Cross-price elasticities of factor demand

$$\varepsilon_{ij} = S_j + \gamma_{ij} / S_i, \quad i \neq j$$

All own-price elasticities have the expected negative signs. Labor displays the most elastic demand (-0.75) although it is only significant at the10 percent level. Its value is close to those reported in the literature for the pulp and paper industry but considerably greater than values reported for the solid wood and softwood industries (see section

2.2.1). On the other hand, the own price elasticity of raw materials was found to be in harmony with those reported in the literature (see section 2.2.1). Following Banskota, Phillips and Williamson, a low own price elasticity value for raw materials suggests the "basic good" nature of raw materials which explains the low responsiveness to price change.

TABLE 3.5

OWN AND CROSS-PRICE DEMAND ELASTICITIES, OKLAHOMA LUMBER AND WOOD PRODUCTS INDUSTRY

	Inputs	
	Labor	Raw materials
Labor	-0.7513**	0.2125
Raw Materials	0.8476*	-0.1884*

** and * indicate significance at the 10% and 5 % level, respectively

For the industry, estimated cross-price elasticities of factor demand suggest substantial substitution possibilities between labor and materials. For instance, if price of labor increases by one percent, the demand for materials increases by 0.84 percent. However, cross effect between materials and labor is not significantly different from zero.

The Allen-Usawa partial elasticity of substitution between factors *i* and *j* is given by

$$\sigma_{ij} = \gamma_{ij}/S_i S_j + 1, \; i \neq j$$

The Allen-Usawa partial elasticity of substitution between labor and raw materials is 1.038, calculated at the mean factor shares. Labor and raw materials are found to be substitutes. The strength of the substitution relation is more closely compared to those found for the paper and allied industry (see, Vincent at el.). For the solid wood, lumber, and panels industries, elasticities of substitution range from 0.38 to 0.67. For the pulp and paper industry values between 1.09 and 1.33 are reported. Our results seem to suggest substitution of labor for raw materials in the Oklahoma forest products industry.

A measure of the degree of short-run returns to scale may be defined as the inverse of the elasticity of cost with respect to output:

$$C_{VCQ}^{-1} = \left[\frac{\partial CV}{\partial Q}\frac{Q}{VC}\right]^{-1}$$

Because in our analysis homotheticity was statistically rejected we can only approximate elasticity of scale with the inverse of the elasticity of cost with respect to output. We estimate a value of 0.96679 that is not significantly different from one at the five- percent level. This indicates that constant returns to scale is the more likely case for the Oklahoma forest products industry.

The parameter γ_{it} $\forall i = L, RM$ is used to determine technical change. If it is not statistically significant from zero then technical change is Hicks neutral. Technical change is biased against (for) factor *i*, if γ_{it} <0 (>0). In our analysis, P-values for the null hypothesis $\gamma_{Lt} = 0$ and $\gamma_{RMt} = 0$ were 0.167 and 0.168, respectively. Thus, we fail to reject the assumption that technical change in the Oklahoma forest products industry is Hicks neutral.

The empirical results of this analysis should be viewed with caution for two reasons. First, the capital stock data constructed for the years 1964-68 did not possess the benefit of a consistent lag-series of new capital expenditures as required by the perpetual inventory method. The original Annual Survey of Manufactures data contains information on new investment spending, but does not measure the total capital stock for the industry. The 2-digit data are estimated for years prior to 1968 assuming that the industry-asset type flows are the same as for the benchmark year, 1978. Under this assumption, however, we are not considering the effects of strong investment during the late 1970's.

Second, the translog cost function employed in this analysis requires the assumption that Oklahoma lumber and wood products industries are price takers in factor markets. We acknowledge exceptions for several industries, i.e., plywood industry, hence a bias is introduced into our analysis. Hseu and Buongiorno, used non-parametric analysis and found cost minimization to be a valid assumption for the U. S. Pulp and Paper Industries. For the other segments of the FPI, high capital intensity suggests firms minimize variable cost of production, at least in the short run; however, it does not preclude the assumption of factor price-taking. If the firm is price-setting (i.e., for price of stumpage), the assumption of cost minimization may be invalid.

CHAPTER IV

REGIONAL COMPUTABLE GENERAL EQUILIBRIUM MODEL

On pursuing modeling for regional analysis, the standard competitive CGE framework allows us to expand beyond the questionable assumptions of input-output based models. By relaxing the assumption of fixed prices, which in I-O models implies that increased demand is always met with no price increase due to excess production capacity and limitless supply of labor and other factors, we have a more realistic empirical model of regional analysis. The competitive CGE framework allows demand and supply of commodities and resources to depend on prices. Furthermore, resources may be substitutable in production.

However, the competitive regional CGE modeling has two very important limitations. First, it does not consider the presence of imperfect competitive market structure and, second, it ignores production technologies characterized by increasing returns to scale (IRS). Chapter II emphasized the need for overcoming these limitations.

In this chapter, the regional CGE model used for empirical simulation on the Oklahoma FPI is presented. The chapter is organized in a theoretical presentation followed by an outline on monopsony market structure. Then the model specification and data requirements are indicated.

4.1 Theoretical Background

General equilibrium models have been widely used to capture the effects of policies and economic shocks at the national level. Most of these models have been developed on the basic assumption that all the industries in production are facing constant returns to scale. However, the assumption of constant returns to scale keeps the *CGE* models detached from reality as quite often industries face increasing or decreasing returns to scale. Here a brief theoretical background on imperfect competitive CGE models is presented.

4.1.1. Increasing Returns, Non-convexity, and Competitive CGE Models

The term returns to scale refers to the response of output when proportional increases in all inputs are carried out (scale of operation). If output increases by a smaller proportion, then the technology is said to exhibit decreasing returns to scale (diseconomies), but if it increases by a greater proportion than the inputs it exhibits increasing returns to scale (economies). If output increases by the same proportion as the inputs, we refer to this technology as constant returns to scale.[7]

The existence of increasing returns to scale (IRS) relies on the non-convexity of the production set. Non-convexity is explained by the fact that the *additivity* and *divisibility* hypotheses on production do not hold. The additivity assumption says that if two production plans are technologically feasible, a new production plan consisting of the sum of these two will also be possible. Divisibility, on the other hand, states that if a production plan is feasible, then any production plan consisting of a reduction in scale

[7] Mathematically, if $f(m\mathbf{X}) = m^k f(\mathbf{X})$, $k>1$ implies increasing returns, $k<1$ decreasing returns, and $k=1$ constant returns when X is a vector of inputs, $f(\mathbf{X})$ is the production technology, and m is a scaler.

will also be feasible. Failure of the *divisibility* assumption is argued as the main source of non-convexities in production (see, Villar).

But what is the problem of non-convexity of the production set? To begin with, it undermines the assumptions used in *fixed-point* proof of existence of general equilibrium: the convexity of preferences and of consumption and production sets. For the standard competitive general equilibrium, the equalization of prices and marginal rates of transformation is a necessary, and under the assumption of convex preferences and choice sets (and complete markets), a sufficient condition for optimality. This is not the case when non-convexity is present. To understand why, we may use the following line of thought. The presence of IRS leads to large-scale firms because at some price p^0 above minimum average cost, profits increase indefinitely with the scale of operation. This is a direct result of average cost always being greater than marginal cost under IRS. Thus, as firms increase the scale of operation the market becomes more and more concentrated which in turn leads to fewer and fewer firms (even one) in the industry and possible collusion of prices. Theoretically, the price mechanism loses its efficiency characteristics and we have lost the optimality and efficiency dichotomy that attracts us to competitive general equilibrium. Indeed, firms with IRS are not consistent with the hypothesis of perfect competitive markets.

Stated, the presence of returns to scale imposes serious questions to mainstream neoclassical economics. It brings questions about the efficiency of competitive equilibrium and its existence[8]. In the core of these questions is the proven incompatibility of profit maximizing behavior at given prices and increasing returns to scale. Hence, theoretical work for modeling IRS has followed a broader market behavior than profit maximization, known as the *pricing rule approach* to general equilibrium theory.

I follow Villar in the exposition of the price rule approach in what follows. Define an equilibrium for the economy as a price vector, a list of consumption allocations, and a list of production plans such that: (a) consumers maximize their preferences subject to their budget constraints; (b) each individual firm is in equilibrium at those prices and production plans; and (c) the markets for all goods clear. This is the Walrasian equilibrium. However, if IRS is assumed for some firms, then (b) can't be produced by profit maximization behavior. To model consistently the behavior of non-convex firms, we associate the equilibrium of firms with the *notion of a pricing* rule rather than to the notion of a supply correspondence. In other words, we allow individual firms to affect prices and indirectly optimize with respect to the price variable. Thus, a price rule is a mapping from each firm's set of efficient production plans to the price space. It includes all the price-production pairs that a firm finds acceptable. The pricing rule notion allows

---

[8] Heals paper on the economics of increasing returns is an excellent source for understanding the welfare consequences of increasing returns and its incompatibility with perfect competition behavior.

modeling of different types of behavior as well as provides grounds for using again the fixed-point argument in order to obtain the existence of a unique equilibrium[9]

Of course, the presence of IRS is not the only case that precludes the benefits of competitive equilibrium. Imperfect competition, for example, may be a direct consequence of limitations to entering to the market or of a firm's exclusive right to use a resource granted by the regional, federal, or local government. We concentrate in modeling increasing returns and imperfect competition while motivating the reader to investigate the extensions of our modeling description.[10]

---

[9] Mercenier argues nonuniqueness of equilibrium is a potentially serious problem in CGE forumulation with IRS and imperfect competition.

[10] Several issues are still not totally clear on theoretical grounds. First, the selection of the numeraire has no implication for the competitive CGE framework; however, this issue is still controversial when imperfect competition is involved (see, Ginsburgh, Rasmussen). Furthermore, the possibility of non-uniqueness of equilibrium is "a potentially serious problem" for applied general equilibrium models with imperfect competition and economies of scale (Mercenier). Finally, regional CGE modeling has adapted concepts and specifications from the national and/or trade CGE literature; however, the implications of its implementation at the regional level has been greatly criticized (i.e., the Armington assumption on product differentiation).

4.1.2. Modeling Increasing Returns and Imperfect Competition

Harris' (1984) work is considered by many as the first successful and compelling general equilibrium model to incorporate both imperfect competition and increasing returns to scale. His work deals with a small open economy and formulates for first time the modeling of IRS using the dual approach (see below). After Harris's work, imperfect competitive general equilibrium models have been extensively used, especially in trade liberalization issues.

Imperfect market structures that characterize the product side of the production system have been the major focus of the great majority of theoretical and empirical work. Monopolistic competition and monopoly competition, for example, have extensively been modeled in trade models. However, market imperfections related to the factor (input) side of the production system remain unexplored. The reason, at least in the opinion of these authors, is the international trade focus of most national CGE models where factor market imperfections are of less concern: i.e., how strong is the case for monopsony modeling when commodities are traded nationally and internationally?

However, at the regional level and particularly for agriculture and other natural resource based sectors, one may argue for a strong need for modeling input side market distortions, i.e. monopsony and cooperative behavior (see Rogers and Sexton). Thus, the state of the art of CGE is very promising for output distortions of markets but less promising for distortions of input markets.

4.1.2.1 Increasing Returns -- the Dual Approach

The modeling of IRS at regional levels is adopted from literature on international trade and national CGE formulations. Its implementation/adaptation to regional CGE models has been, with some few exceptions identified by Partridge and Rickman, limited. Harris' basic approach is used here. The main characteristic of the approach is the use of the dual formulation of increasing returns to scale. Duality is less restrictive in modeling and allows treatment of the assumption of convex input requirement sets.

Under constant returns to scale, marginal costs are assumed to be constant and equal to average variable cost (VC_i / X_i, where VC_i is for variable costs and X_i is output for the i^{th} sector). Under increasing returns to scale, average cost is a monotonically decreasing function[11]:

$$(4.1) \quad AC = \frac{FC}{X} + MC$$

where FC is fixed costs and MC and AC are marginal and average cost, respectively. We assume that marginal costs are governed by the preferred constant returns to scale production function, but a subset of inputs are committed *a priori* to production and these costs must be covered regardless of the output level. Thus, increasing returns to scale takes the form of unrealized economies of scale in production. There is no customary procedure in defining fixed costs. Fixed costs may involve the same mix of inputs as marginal costs or, alternatively, fixed costs may be assumed to involve a different set of

---

[11] An alternative specification states average cost equals $AC = X^{\Theta-1} f(w)$ where $f(w)$ represents the cost function for a homogenous bundle of primary and intermediate inputs. This alternative formulation is used to specify scale economies due to returns from specialization.

inputs. However, the specification of the fixed costs has important consequences for the calibration procedure (to be discussed).

As a measure of unrealized scale economies it is customary to use the concept of cost disadvantage ratio (*CDR*). The *CDR* provides an estimate of unrealized economies of scale (de Melo and Tarr). Depending on the value of this ratio, an industry may be facing economies/diseconomies of scale or it may be operating at the minimum efficient scale. The *CDR* is calculated as:

$$CDR = 1 - \frac{1}{S}$$

where $S = \frac{AC}{MC}$

and *AC* and MC are average cost and *MC* marginal cost, respectively. Thus, if $CDR > 0$, there are *Economies of Scale*, if $CDR < 0$, there are *Diseconomies of Scale*, and if $CDR = 0$, the firm is operating at the *Minimum Efficient Scale*[12].

4.1.2.2 Increasing Returns -- the Primal Approach

The primal approach in modeling increasing returns to scale has been infrequently used by CGE modelers. The reason is the indeterminacy under increasing returns to scale. Kilkenny, however, argues that "when factor markets are geographically segmented and the pool of labor is limited" factor costs will rise for an industry, which is

---

[12] For multi-product scale economies we carry out the following modification: $S = \frac{C(\mathbf{Y})}{(\sum Y_i \cdot \frac{dC}{dY_i})}$ where C and Y_i are, respectively, cost and output of the i^{th} product.

expanding operation using unexploited increasing returns to scale. Thus, existence of an optimal output level is thus obtained.

In the primal approach, increasing returns to scale are much easier to model. We adjust, for example, the coefficients of a Cobb-Douglas production function to exhibit increasing returns to scale: doing $\sum_f \alpha_f > 1$, where f states for factor index and α is the exponential (share) parameters in the Cobb-Douglas technology specification.

4.1.3 Market Power

Before modeling market power we require specification of the degree of product differentiation used in the model. We assume Armington preferences at the regional level. Thus, substitution in purchases is allowed between domestically produced consumer goods and out-of-region produced consumer goods. Traded goods are imperfect substitutes by origin and goods produced domestically are imperfect substitutes for imports. Also, goods supplied on the domestic regional market are imperfect substitutes for goods supplied for export. Armington specifications also apply to sectors with IRS. In those sectors, goods are produced by N_i identical firms implying goods produced for domestic sales in these sectors are perfect substitutes.

4.1.3.1 Contestable pricing

Two pricing hypotheses are considered for the IRS sectors. First, we assume low-cost entry and exit such that the threat of entry forces firms to price at average cost. This is called the contestable pricing behavior:

(4.2) $PX = AC$

where PX is the weighted sum of the unit sales prices on the regional (PD) and export (PE) markets. Firms in a perfectly contestable market will be forced to operate as efficiently as possible, and to charge as low a price as long-run financial survival permits.

This pricing rule represents only a small departure from the competitive pricing rule because price also equals average cost in the long-run equilibrium of the competitive model (de Melo and Tarr). Another advantage of contestable pricing is that it is very easy to calibrate. According to de Melo and Tarr, the calibration process is complete by just equating output price to average cost.

4.1.3.2 From monopoly to oligopoly

In the second alternative, we assume that each (identical) firm behaves in the regional market as if it is facing a downward-sloping demand curve. The equilibrium condition for each firm is given by:

$$(4.3) \qquad \frac{PD-MC}{PD}=\frac{1+\theta}{N\varepsilon}$$

where ε is the endogenous elasticity of aggregate sectoral demand, N is the number of firms, and θ is the representative firm's conjecture about the response of competitors to its output decision. This alternative is the conjectural variation specification where one may or may not have entry/exit assumptions.

In long-run equilibrium, entry/exit ensures zero profits. If N represents the number of firms, then as $N \to \infty$ we expect $\theta \to 0$; thus, firms behave competitively. Why should the representative firm's conjecture banish as the number of firms increase? Two explanations are given. First, collusion among firms is more difficult to coordinate if more firms arrive to the market, and second, more firms imply greater availability of varieties. A conjecture formulation that accounts for both product variety and effects on collusion of firms is given by:

$$(4.4) \quad \theta = \Delta Q_{-j} / \Delta Q_j = N^{-1}$$

where ΔQ_{-j} is the change in aggregate output of other firms due to a change in the j^{th} firm, and N is an arbitrary number normalized to unity in the calibration.

On the other hand, with barriers to entry it is possible to have supernormal profit because firms sell in the domestic regional market at a price $\tilde{P}D > PD$. If we define an exogenous rate of profit (ψ) per unit of regional sales, then the mark-up pricing equation (4.2) is replaced by:

$$(4.5) \quad PX \cdot (\tilde{P}D, PE) = AC \cdot (1+\psi)$$

This equation is the same for contestable market scenario when $\psi = 0$. In the conjectural variation case, we have $\pi = \psi$.

The empirical example applies all of these modeling techniques to the Oklahoma region. In addition to the high concentration of the industry, Oklahoma foresters have limited options on where to sell their timber because of costly transportation and long distances between processing centers. All of this propitiates some kind of imperfect structure for the timber market (raw material market) in which wood processing industries are capable of affecting the price paid for timber. Such an industry structure may result in imperfect competition not only in the buying side but also in the selling side of the market. For example, high concentration in the pulp manufacturing industry increases the likelihood of lower outputs and higher price than under a competitive structure. As well, it's actions may distort the timber market, thus affecting the welfare of both forest land owners and consumers (Tillman,1985).

Peterson, Hertel, and Stout, on the other hand, assessed the limitations of static, deterministic, reduced form, supply-demand (SD) models of agricultural trade. They believe that there is more to gain in better detailed partial equilibrium analysis (i.e., SD models) than extending efforts in more complex dynamics and uncertainty issues. In their final comments, the authors admitted that to obtain an accurate assessment of the effects of agricultural policy liberalization, a general equilibrium closure is not crucial when one is interested in the farm-level effects of liberalization. However, again their argument is based on the competitive environment. De Melo and Tarr argue that inter-industry linkages are best captured in a general equilibrium framework. It is argued, partial equilibrium yields accurate estimates for particular sectors, however, estimates of aggregate costs of regional policies across sectors, for example, require a general equilibrium model to account for region-wide budget and resource constraints.

4.2 Oklahoma Regional CGE Model

The economy is small and open in the sense that prices of tradable commodities and tradable intermediate inputs are determined exogenously in the national market place. The model consists of six sectors. Non-manufacturing activities include the agriculture(A), mining (M), and services (S) sectors. The forest complex consists of two sectors: the forest products industry (P) and forestry (RM). The last sector is manufacturing (MA) which integrates manufacturing industries except for forest products industry. There are three primary factors of production, capital (K), labor (L), and land (T). Land and capital are assumed to be in fixed supply in the short run but only land in the long run is fixed. Labor supply is affected by migration flows as well as capital in the long run. The regional CGE model includes one household group, one government level, enterprise and investment (capital formation) account.

The model allows substitution between imported and regionally produced commodities through a constant elasticity of substitution (CES) function and substitution between exports and regional markets through a constant elasticity of transformation (CET) function. The basic data for CGE is a social accounting matrix for the State of Oklahoma developed for the year 1993 based on data obtained from Minnesota IMPLAN Group (MIG) Inc. (see table 4.1). In our model, households possess endowments of labor, land and capital. The assumption of competitive market with full information and agents characterized by profit and/or utility maximizing behavior is maintained in 5 sectors (A, M, MA, RM, S). A sector is an aggregation of many producers, but the sector is treated as a single firm in the model. Similarly, many similar households are treated as a single household.

Exogenous parameters used in the model include elasticities of substitution, elasticities of transformation, elasticities of labor and capital migration. 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 price of one. The regional market price of the composite good is a weighted average of the imported and domestic good prices, except for the timber sector, which only has one regional (domestic) price. Import prices are exogenous to the region whereas regional prices are endogenous.

Production functions are characterized at two (nested) levels. At the first level, each of six production sectors produces only one homogeneous commodity using intermediate and primary inputs. Technology assumes no substitution between composite intermediate inputs and composite primary factors nor between intermediate inputs produced by different sectors. This is the Leontief input-output production function technology. At the second level, substitution among primary factors of labor, capital and land is represented by a decreasing returns to scale Cobb-Douglas (C-D) production function for agriculture (A) and the forestry sector (RM) (land is fixed in both sectors). Cobb-Douglas production function with labor and capital is used for the other sectors (P, MA, M, and S).

Demand for the composite and individual intermediate inputs is derived from the Leontief input-output production relationship whereas primary factor demand is determined from the C-D production relationship by profit maximizing for each sector. The model assumes that full employment is always attained by adjustment of the wage rate and the rates of return to land and capital for a given time period. Land is used only in agriculture and forestry and is assumed fixed in supply ($\overline{T}$) for each. Labor migration is a function of the ratio of regional and out-of-region wage rate, the elasticity of labor migration, and base year labor supply. Similarly, capital migration is a function of the domestic/out-of-region capital price ratio, the elasticity of capital migration, and base year capital supply.

Intermediate inputs are treated as a mix of regional and imported products. Quantity of the intermediate input demanded is described by a constant elasticity of substitution (CES) function between regional and imported components. The elasticities of substitution are exogenously specified. However, we don't allow the raw material (timber) input to be transported from Oklahoma to other regions or from other regions to Oklahoma. Therefore, the quantity of raw material intermediate input ($V_{RM} = X_{RM}$) is determined in the region by a derived demand of the forest product industry (P). In general, the regional intermediate input demand is obtained from first order conditions of cost minimization subject to a given level of composite intermediate input defined by the CES function. Relative prices of regionally produced and imported inputs and the elasticity of substitution parameter determine regional intermediate input demand.

Similarly, each sector produces for both export and regional markets, except in the case of raw material input where forestry (RM) sector only produces for the regional market. A constant elasticity of transformation (CET) function describes this transformation process. The regional supply function for goods is derived from the first order conditions for maximizing revenue subject to a given output level with the CET function. Relative prices of regional goods to exported goods and the constant elasticity of transformation parameter determine regional supply and export supply for market goods except for the forest product sector (P) where we assume that the regional supply is filled first and then the rest of production is exported[13].

---

[13] This raises two further issues: if the sector presents increasing returns, the

Household annual income is determined by the level of ownership of the primary factors (labor, land, and capital), factor prices, and government transfers. Government transfers are assumed fixed in this analysis.

Consumer demand functions are derived from maximization of utility. The Stone-Geary utility function is used which results in a linear expenditure system (LES) that satisfies the assumption of a diminishing marginal rate of substitution. The demand system derived from this utility function satisfies the general properties required; homogeneity of degree zero in all prices and income, symmetry of cross-substitution effects, adding up condition, and negativity of direct substitution effects. Household consumption is modeled at two levels. The first level determines consumption of the composite market goods derived from utility maximization subject to prices and full income. The average budget shares are calculated from the SAM data.

The second level determines the optimal combination of imported and regional consumer goods. The optimal combination is the result of first order conditions for cost minimization subject to the level of composite commodity obtained from the first level which is expressed as a CES function of imported and regionally produced components. Relative prices and the elasticity of substitution determine the optimal combination.

---

representative firm (as modeled here) may have unlimited exports; if the raw material supply is not elastic enough, how could the firm exploit their economies of scale. We model these issues by assuming that the industry is at, or is near the minimum efficient scale.

Government revenues include indirect business taxes, factor taxes, and household and corporate income taxes. Their expenditures include commodity consumption, transfers to household, and payment to labor. Quantity of commodity consumption is held constant, but as regional prices change total government expenditure changes. The proportion of regional relative to imported commodities specified by a CES function changes as discussed above for the household.

Total saving is composed of household savings, retained earnings for enterprises, and net transfers (saving) from rest-of-world. Capital expenditures are for investment demand and include regional produced and imported components as specified through a CES function. Capital expenditures are the result of a fixed quantity (exogenous) and a regionally determined composite. Gross regional product is before tax factor income generated from the production activities of the region plus indirect business taxes. A monopsony structure is imposed to the raw material market. Firms are assumed to minimize cost subject to a given output level.

The different market structure studied requires modeling of industries in terms of marginal pricing rules. That is, firms are instructed to sell their outputs at prices which satisfy the necessary conditions for optimality (Villar, 1996). Non-linear programming algorithms (GAMS) are used to solve for prices and welfare effects.

4.3 Data Requirements

A social accounting matrix (SAM) was developed using the information from IMPLAN and the Bureau of Economic Analysis (BEA) for the state of Oklahoma for the year 1993. In this study, employee compensation, proprietary income and other property income were distributed to factors of labor, capital and land and indirect business taxes were allocated to government following procedures in Koh (1991), Lee (1993) and Budiyanti (1995).

The estimated social accounting matrix (SAM) for the impact region is presented in Table 4.1. We have considered the forest complex to constitute the forestry sector and the forest product industry (FPI). The forestry sector was treated as making good purchases from other sectors but only selling to the forest product industry. Thus, in the social accounting matrix, the forestry sector only reports sales to the forest product industry sector and does not export.

About 0.08 percent of FPI expenditures were spent on raw-materials from the timber sector ($44.4 million). The remaining expenditures by this sector were considered to include purchases of imported and regional produced commodities. Forestry sector, on the other hand, purchases intermediate goods from both sources: imports and regional markets. However, it is restricted to the regional market for its output.

In the calibration process, we use exogenous parameters for some elasticities: elasticity of capital/labor substitution; import price elasticities of demand; and export supply price elasticities. Table A.4 in appendix A gives these parameters and their sources.

Table 4.1 Oklahoma Social Accounting Matrix, 1993 in thousand dollars.

Receipts	Expenditures																	
	Industry							Factors				Institutions						
			Forest Complex															
	Agriculture	Mining	Forestry	FPI	Manufacturing	Services	Total	Labor	Capital	Land	Total	Enterprise	Households	Governments	Capital	Total	Exports	Row Total
Industry																		
Agriculture	670862	8116	4936	2668	820923	34800	1542305						147210	12863	9780	169853	2591601	4303759
Mining	122579	2180942	891	65705	1192412	881343	4443872						1587998	231250	19097	1838345	5807568	12089785
Forest Complex																		
Forestry				40400			40400											40400
FPI	9839	72630	1264	6026	179590	206456	475805						138648	96782	248026	483456	826339	1785600
Manufacturing	147584	1318071	984	109769	3299584	3746744	8622736						2517437	1757284	4503431	8778152	15003939	32404827
Services	379945	1317332	1597	275341	4996845	9752027	16723087						30727365	1477994	557652	32763011	9629092	59115190
Sub-total Industry	1330809	4897091	9672	499909	10489354	14621370	31848205						35118658	3576173	5337986	44032817	33858539	109739561
Factors																		
Labor	426998	1622806	6244	188400	7389027	20767388	30400863						107070	6981839		7088909		37489772
Capital	566973	2713109	4387	525780	3499379	12042709	19352337											19352337
Land	701385		7681				709066											709066
Sub-total	1695356	4335915	18312	714180	10888406	32810097	50462266						107070	6981839		7088909		57551175
Institutions																		
Enterprise									12510953		12510953							12510953
Households								31363057	7848069	683300	39894426	1734234		11490516		13224750	760825	53880001
Governments	95405	666971	896	85720	101159	4318042	5268193	6126715	-1006686	25766	5145795	1699623	6976571	8477813		17154007	4375095	31943090
Capital												9077096	-3869320			5207776	2789519	7997295
Sub-total Intitutions	95405	666971	896	85720	101159	4318042	5268193	37489772	19352336	709066	57551174	12510953	3107251	19968329		35586533	7925439	106331339
Imports																		
Agriculture	574915	5160	4955	1230	377192	41300	1004752						181550	20097	10447	212094		1216846
Mining	11222	1274869	628	16247	294847	385272	1983085						141662	29912	15759	187333		2170418
Forest Complex																		
Forestry																		
FPI	27620	23552	2742	19243	436987	143637	653781						299232	43146	128560	470938		1124719
Manufacturing	414296	427425	2171	350537	8028706	2606708	11829843						5414473	780700	2326243	8521416		20351259
Services	154136	458802	1024	98534	1788176	4188764	6689436						9510103	542893	178299	10231295		16920731
Sub-total	1182189	2189808	11520	485791	10925908	7365681	22160897						15547020	1416748	2659308	19623076		41783973
Column Total	4303759	12089785	40400	1785600	32404827	59115190	109739561	37489772	19352336	709066	57551174	12510953	53879999	31943089	7997294	106331335	41783978	315406048

CHAPTER V

IMPLEMENTATION OF THE REGIONAL CGE MODEL

5.1 The Oklahoma Forest Products Industry Under Monopsony Structure

This section presents the modification to the perfect competitive model needed to accommodate monopsony market structure between the raw material seller (timber producer) and the raw material buyers (Forest Product Industry).

Oklahoma's forest products industry (*P*) is modeled by a single-representative-firm that uses an intermediate input composite made of raw material intermediate input ($V_{RM,P}$) and other intermediate inputs ($V_{i,P} \quad \forall i \neq RM$). The industry also uses a primary factor composite ($VA_p = f(L_P, K_P)$) of labor and capital. Labor (L_P) and capital (K_P) are combined in a CES functional form and we design it as the value-added composite.

We assume that the firm uses both value-added and intermediate composite to produce a homogenous output (X_P). Therefore, the decision of production is carried out in two steps. First, the firm chooses intermediate and value-added levels according to the Leontief production relationship given by:

$$(5.1) \qquad X_P = Min\left[\frac{VA_P}{a_{o,P}}, \frac{V_{1,P}}{a_{1,P}}, \cdots, \frac{V_{6,P}}{a_{6,P}}\right]$$

where 1,…,6 represents the i^{th} sector (A, M, P, RM, MA, and S), $a_{0,P}$ is the composite valued added requirement per unit of output of the processing industry; $a_{1,P},...,a_{6,P}$ are the requirements of intermediate goods per unit of output of the processing industry.

At this step, the firm will not waste any input with a positive price, hence levels of value-added composite and intermediate inputs are obtained from the following relations:

$$(5.2) \quad X_P = \frac{VA_P}{a_{O,P}} = \frac{V_{i,P}}{a_{i,P}} \quad \forall i = A, M, RM, MA, P, and\ S.$$

The second step consists of choosing the labor and capital levels. Factor demands are derived from cost minimization subject to a given level of output. We use a CES function to represent the production relationship between labor and capital. The CES value-added function for the wood processing industry is given by:

$$(5.3) \quad VA_P = \phi_P^{VA}\left[\delta_P^{VA} L_P^{\rho_P^{VA}} + \left(1-\delta_P^{VA}\right) K_P^{\rho_P^{VA}}\right]^{\frac{\lambda}{\rho_P^{VA}}} \qquad \sigma_P^{VA} = \frac{1}{1-\rho_P^{VA}}$$

where ϕ_P^{VA}, δ_P^{VA}, σ_P^{VA}, and λ are shift, factor share parameters, elasticity of substitution, and returns to scale parameter, respectively. We assume constant returns to scale based on the empirical results of chapter III.

Allen partial elasticities of substitution and elasticities of size between capital and labor given by Vincent, et al were averaged to 1.0334 and 1.24, respectively. Thus, we obtain a ρ_P^{VA} value of 0.03234. The CES value-added function for P sector is given by:

$$(5.4) \quad VA_P = \phi_P^{VA} \cdot \left[\delta_P^{VA} \cdot (L_P)^{0.032} + (1-\delta_P^{VA}) \cdot (K_P)^{0.032}\right]^{\frac{1}{0.03234}}$$

Profit maximization in the Forest Products Industry is assumed. The industry represented by a single-representative firm is assumed to be a profit maximizer. It chooses the level of output so to maximize its profit function given by:

(5.5) $\pi_P = P_P X_P - PVC_P - IC_P - ibt_P X_P P_P$

where π , P , *PVC*, *IC*, and *Ibt* are profits, output price, primary variable costs, intermediate costs, and indirect business tax rate of the processing industry (P). Equation (5.5) assumes separability of intermediate and primary inputs. On this basis, we further assumed constant primary variable costs. We use the fixed coefficient technology (Leontief relationship) to express (5.5) as:

(5.6)

$$\pi_P = \overline{P}_P X_P - PVC_P(PL, PK, X_P) - P_{RM}(V_{RM,P}) \cdot V_{RM,P} - \sum_{i \neq RM} P_i \cdot V_{i,P} - ibt_P X_P \overline{P}_P$$

where *PL* and *PK*, are price of labor and capital, respectively. Three aspects are important to note in the construction of equation (5.6). First, the horizontal bar over the price of output indicates that the representative firm takes the price of their output as given: no monopoly power is guaranteed to the firm. Second, the primary variable cost component (PVC_P) is a dual to the CES value-added function defined previously, hence, its arguments are the prices of labor, capital and the level of output. Remember it is assumed that this component of the cost structure of the firm is characterized by "constant marginal cost". Finally, we note that intermediate costs are separated into two components: raw material intermediate input and other intermediate inputs. This follows a required specification of the model so the buyer market power exertion can be modeled.

Solving equation (5.2) for the intermediate and value-added variables, equation (5.6) becomes:

(5.7)

$$\pi_P = \overline{P}_P X_P - (a_{0,P} \cdot X_P)^{1/\lambda} \phi_P^{-1/\lambda} \left[(\delta_P^{VA})^{\frac{1}{1-\rho}} \cdot PL^{-\rho/1-\rho} + (1-\delta_P^{VA})^{\frac{1}{1-\rho}} \cdot PK^{-\rho/1-\rho} \right]^{\frac{1-\rho}{-\rho}}$$

$$- P_{RM}(a_{RM,P} X_P) \cdot a_{RM,P} X_P - \sum_{i \neq RM} P_i \cdot a_{i,P} X_P - ibt X_P P_p,\ \sigma = \frac{1}{1-\rho},\text{and } \lambda \succ 1$$

where ϕ, σ, δ, and, λ are the CES value-added function shift parameter, labor-capital elasticity of substitution, CES value-added function share parameter, and returns to scale parameter, respectively.

Calibration of the Forest Products Industry offers new challenges when benchmarking or calibrating production for a sector that assumes imperfect competition. In the case at hand, the forest products industry is assumed to exert monopsony profits from the raw material input market as well as possessing constant returns to scale technology.

5.2 Calibration Procedure

We assume a monopsonistic market structure where the only buyer is the processing industry. The presence of a monopsonist prescribes the possibility of profit exertion from the raw material sector (forestry sector). Thus, to calibrate a monopsony model we are required to determine profits at the base year. The profit function for the forest products industry sector was given in (5.6). The intermediate costs include the intermediate raw material coming from the forestry sector (RM) and other sectors. Because we allow for power exertion in raw material intermediate input market, the raw material intermediate input cost of equation (5.6) is expressed by:

(5.8) $P_{Rm}(V_{RM,P}) \cdot V_{RM,P}$

where the price of raw material P_{RM} is a function of the industry's demand for raw material. Next, using equalities described in (5.2) and the first order condition for profit maximization, it could be proven that the monopsony maximizes profit when:

$$(5.9)\ \overline{P}_P - \frac{\partial PVC_P}{\partial X_P} - \sum_i P_{i,P}a_{i,P} - a_{IBT,P} = a_{RM,P}P_{RM}\left(1+\frac{1}{\varepsilon^{S}_{RM,P_{RM}}}\right) \quad \forall i = A, M, P, MA, and\ S$$

where the left-hand side is the difference between the marginal revenue ($\overline{P}_P$) and the marginal cost of processing less the marginal cost of raw material intermediate input cost. The term $\varepsilon^{S}_{RM,P_{RM}}$, defined as:

$$(5.10)\quad \varepsilon^{s}_{rm,Prm} = \frac{\partial V_{RM,P}}{\partial P_{RM}}\frac{P_{RM}}{V_{RM,P}} \cong \frac{\partial X_{RM}}{\partial P_{RM}}\frac{P_{RM}}{X_{Rm}} \quad \text{where } V_{RM,P} = X_{RM}$$

is the own price supply elasticity for the forestry sector. The right-hand side of equation (5.9) indicates that for profit maximization under the monopsony market structure a price distortion occurs. Following Azzam and Schroeter, we define the proportional gap between the value of the marginal product of the raw material (net of marginal processing costs and marginal indirect business taxes) and the price of the raw material input as:

$$(5.11)\quad v = \frac{1}{\varepsilon^{S}_{RM,P_{RM}}}$$

which for the case of monopsony market defines the price supply flexibility of raw material. The parameter v connects the production technology of the forestry sector with the profit maximization behavior of the forest products industry sector.

Estimating the price distortion, we need to derive production and supply functions for the forestry sector that replicates base year data of Table 4.1. Thus we start with the production function. The forestry sector (RM) gathers under the single-representative-firm many identical (small) producers of raw material (logs, roundwood, etc.) who are precluded from affecting raw material price. Due to high costs in transportation, raw material producers are regional price-takers. We assume a representative-firm for the forestry sector that produces raw material product (X_{RM}) to be sold exclusively to processors in the forest products industry sector (*P*). At the first production, the Leontief production function is described by:

$$(5.12)\quad X_{RM} = Min\left[\frac{VA_{RM}}{a_{o,RM}}, \frac{V_{1,RM}}{a_{1,RM}}, \ldots, \frac{V_{6,RM}}{a_{6,RM}}\right]$$

Value-added composite faces increasing marginal costs because we fixed the amount of available land. The Cobb-Douglas production function is used to express the value-added relationships among the primary factors of production - land, labor, and capital. The Cobb-Douglas function is given by:

$$(5.13)\quad VA_{RM} = \phi_{RM} L_{RM}^{\alpha_{RM}^{L}} K_{RM}^{\alpha_{RM}^{K}} T_{Rm}^{\alpha_{RM}^{T}}$$

Where *T*, *K*, and *L* are land, capital and labor, respectively; ϕ_{RM} is a technical shifter; $\alpha_{RM}^{i}\ \forall\ i = L, K, T$, are share parameters obtained from the expenditures of the forestry sector in Table 4.1. Calibration of the value added production function yields:

$$(5.14)\quad VA_{RM} \cong 2.926 \cdot L_{RM}^{0.34} K_{RM}^{0.24} T_{RM}^{0.42}$$

In the short run, we assume land to be fixed, therefore the industry optimizes over labor and capital levels. The restricted value added function becomes:

$$(5.15)\quad VA_{RM}(L, K / \overline{T}) \cong 124.74 \cdot L_{RM}^{0.34} K_{RM}^{0.24}$$

Using equation (5.2) for the forestry sector (*RM*), we calibrated the coefficient parameters of equation (5.12). These are:

$$a_{O,RM} = 0.453,\ a_{A,RM} = 0.245,\ a_{M,RM} = 0.037,\ a_{P,RM} = 0.099,\ a_{MA,RM} = 0.078,\ a_{S,RM} = 0.065,\ a_{IBT,RM} = 0.022$$

To obtain the total regional supply function for raw material intermediate input (V_{RM}) we used the relationship $X_{RM} = \frac{VA_{RM}}{a_{O,RM}}$, and the fact that no out of the region supply is allowed. We used results of Beattie and Taylor (page172) to obtain the supply function given by:

$$(5.16)\quad X_{RM}^{S} = 44.198\cdot(P_{RM})^{1.384}\left[124.74\left(\frac{0.34}{PL}\right)^{0.34}\left(\frac{0.24}{PK}\right)^{0.24}\right]^{2.38}$$

where PL and PK are price of labor and capital, respectively. From (5.16) we obtained $v = 0.7225$ which yields profits in the base year of 29.2 million dollars ($v \times P_{RM} \times V_{RM,P}$) where the price of raw material input has been normalized to unity and the level of raw material supply is 40.400 physical units (see, SAM data in Table 4.1).

Next, we adjust the base year capital factor retribution in Table 4.1 by the amount of profits. Therefore, the level of capital used in calibration of the value added function of the FPI sector is $496.6 million instead of the $525.78 million originally assumed. The $29.2 million monopsonist's profits are then allocated to enterprise which then passes it to institutions.

Then to calibrate share parameters of the CES value-added function, we use:

$$(5.17)\quad \delta_{P}^{VA} = \left[1 + \left(\frac{L_P}{K_P}\right)^{\rho_P^{VA}-1}\left(\frac{PK}{PL}\right)\right]^{-1}$$

We normalized prices of labor and capital to unity and used the new capital level. We calibrated the share parameter for labor to be 0.2813344 and the share parameter for capital to be 0.718665.

The primary variable cost function (PVC_P) is a dual to (5.4), the CES value-added function. By solving the following cost minimization problem

$$(5.18)\quad \begin{aligned} &\underbrace{MIN}_{L,K}\ PL\cdot L_P + PK\cdot K_P \\ &\text{s.t.}\ \left(\frac{VA_P}{\phi_p^{VA}}\right)^{\rho_P^{VA}} = \delta_p^{VA} L_p^{\rho_P^{VA}} + \left(1-\delta_P^{VA}\right)K_p^{\rho_P^{VA}} \end{aligned}$$

where we have assumed constant returns to scale ($\lambda = 1$), we can derive the indirect cost function in terms of factor prices and value-added composite (Beattie and Taylor, page 248):

$$(5.19)\quad \widetilde{C}(PL,PK,VA_P) = (VA_p)\cdot(\phi^{-1})\cdot\left[(\delta_P^{VA})^{\frac{1}{1-\rho}}\cdot PL^{-\rho/1-\rho} + (1-\delta_P^{VA})^{\frac{1}{1-\rho}}\cdot PK^{-\rho/1-\rho}\right]^{\frac{1-\rho}{-\rho}}$$

If the share parameter and the labor-capital elasticity of substitution are substituted into (5.19), primary variable cost function takes the form:

$$(5.20)\quad \widetilde{C}(PL,PK,VA_P) = (VA_p)\cdot(\phi^{-1})\cdot\left[(0.28)^{1.03}\cdot PL^{-1.03/1-0.03} + (0.72)^{1.03}\cdot PK^{-0.03/1-0.03}\right]^{\frac{1-0.03}{-0.03}}$$

Then, one may use the SAM data to solve equation (5.20) for the shift parameter. This because we have normalized the price of the factor to unity, therefore, one will expect the total expenditure in primary factors to be given by the expression $PL\cdot L_P + PK\cdot K_P$. This expression is obtained from our SAM data . We calibrate the shift parameter ϕ_P^{VA} by using the expression:

$$(5.21)\quad \phi_P = \left[\frac{X_P\cdot a_{0,P}\cdot\left[(\delta_P^{VA})^{\frac{1}{1-\rho}}\cdot PL^{-\rho/1-\rho} + (1-\delta_P^{VA})^{\frac{1}{1-\rho}}\cdot PK^{-\rho/1-\rho}\right]^{1-\rho/_{-\rho}}}{0.3836}\right]^{v}$$

This yields a shift parameter of 1.801.

Next, we notice that under CRS technologies and perfect competitive markets, the average cost (AC) and marginal cost (MC) of an industry are exchangeable terms. However, the assumption of monopsony market implies that average revenue is greater than marginal cost in our base year data. How much do they differ? They differ by the amount of the average profits. To see this, recall that the firm maximizes profits by choosing the output level that maximizes equation (5.7). Note that this equation is completely a function of the output variable (X_P). The marginal profit function is given by:

$$(5.22)\quad \frac{\partial \pi_P}{\partial X_P} = \overline{P}_P - \frac{\partial PVC_P}{\partial X_P} - \sum_{i \neq RM} P_i a_{i,P} - \frac{\partial P_{RM} V_{RM,P}}{\partial X_P} - a_{IBT,P} = 0$$

$$(5.23)\quad \frac{\partial \pi_P}{\partial X_P} = \overline{P}_P - X_P a_{0,P} \phi_P^{-1} \left[(\delta_P^{VA})^{\frac{1}{1-\rho}} \cdot PL^{-\rho/1-\rho} + (1-\delta_P^{VA})^{\frac{1}{1-\rho}} \cdot PK^{-\rho/1-\rho} \right]^{\frac{1-\rho}{-\rho}}$$
$$- a_{RM,P} P_{RM} (1 + \tfrac{1}{\varepsilon}) - \sum_{i \neq RM} P_i \cdot a_{i,P} - a_{IBT,P} = 0$$

This marginal profit function equals zero if the industry maximizes its profits. Both expressions of the marginal profit represent the same concept, only that equation (5.23) has the expression for the derivatives. It is also important to indicate the fact that the partial of the primary variable cost function is for the expression with gross output variable as an argument, not the value added composite. Thus, it is close to the partial of equation (5.20).

Next, we solve (5.23) for the marginal primary variable costs component and substitute prices and values derived from our SAM. Those are obtained from equation (5.2):

$$a_{O,P} = 0.3836,\ a_{A,P} = 0.0021,\ a_{M,P} = 0.0459,\ a_{P,P} = 0.0141,$$
$$a_{MA,P} = 0.2577,\ a_{S,P} = 0.2093,\ a_{IBT,P} = 0.048$$

Thus, profit maximization can now be expressed by the unit profit function obtained when equation (5.5) is divided by total output (X_P):

$$(5.24)\quad \frac{\pi}{X_P} = P_P - \frac{PVC_P}{X_P} - \sum_i \frac{P_i V_{i,P}}{X_P} - \frac{ibt_P}{X_P}$$

Substituting our calibration results in (5.24) is a test of the accuracy of the procedure. Because we normalize prices to unity, this equation holds for our data. The validated model is given in Appendix B, in addition to the equation description of the model in Appendix A.

CHAPTER VI

EVALUATING A PRO-COMPETITIVE SHOCK IN THE RAW MATERIAL MARKET

If the raw material market structure changes from a monopsony market to a perfect competitive market, we will be able to examine effects of the pro-competitive shock. This pro-competitive environment is justified in terms of possible value-added processing incursions by cooperatives, the arrival of other firms, or a new technological strategy that makes transportation of raw material less restrictive.

The way we have modeled monopsony market structure allows us to simulate a pro-competitive movement in the raw material market. To see how, observe equation 5.11 where the supply elasticity is given. We notice that if the raw material supply is infinitely elastic, the industry will not be able to reap monopsonistic profits no matter how high the degree of concentration and/or collusion. By redefining the value of the supply elasticity and solving the model for new equilibrium prices we see the effects a pro-competitiveness scenario bears in the regional economy.

Table 6.1 shows short-run simulation results for major endogenous variables. An index greater (less) than unity implies positive (negative) change in percentage terms with respect to base year values. The most significant changes accrue to the forest complex: forestry and forest products industry. Raw material price increases 2.55% and the sector output increases by 1.33%. This implies a price elasticity of 0.52 for raw materials sector. Although, marginal output increases from 40.4 million to 40.94 million, the total revenue from raw material increases from $40.4 million to $42.0 million, representing additional income of a little less than 1.1 million dollars for raw material producers.

In addition to the revenue change, we observe the way costs for the forestry sector changed. The new competitive structure of the raw material market affects the retribution to factors: both capital, and land have higher returns (3.9 % see Table 6.1), however, the price of labor is almost intact (0.01% see table 6.3). Prices for regional intermediate inputs are almost unchanged as the first column of Table 6.1 shows. With respect to factor usage, labor demand in the forestry sector increases 3.9 %. Total value added then increases by 1.3%. Whether raw material producers will receive additional factor incomes depends on the regional factor ownership. If we assume regional land ownership, then raw material producers are compensated 3.95% more for their land endowment. Using the base year data, this implies that land compensation increases by $303,000 thousand dollars.

On the other hand, FPI output increases 1.32% and the sector receives a 0.23% lower price for its product (see Table 6.1). That translates to additional revenues of $19.54 million for the FPI. However, pure monopsony profits have disappeared. This sector also has a higher return to capital (4.9%). According to simulation results, the FPI will sell most of its increase in output to the export market (2% increase) and regional intermediate market (0.7% increase): little change happens to the final demand for FPI (Table 6.1, columns IQ). Outside the forest complex, changes in variables are small, less that 0.01%. This is not surprising considering that the entire forestry sector output is less that 0.03% of the total output for the region.

TABLE 6.1 SHOR-RUN SIMULATION RESULTS. INDEXES REPORTED FOR MAJOR ENDOGENOUS VARIABLES

	IP	IPR	IPX	IX	IEXP	IIMP	IR	IVA	IL	IK	IT	IPK	IPT	IQ	IQR	IQM
AGR	1.00001	1.00001	1.00000	0.99996	0.99994	1.00001	0.99999	0.99996	0.99984	1.00000	1.00000	0.99998	0.99998	0.99974	0.99973	0.99975
MIN	1.00005	1.00007	1.00003	0.99995	0.99985	1.00006	1.00004	0.99995	0.99987	1.00000		1.00002		0.99970	0.99970	0.99973
RM		1.02550	1.02550	1.01326				1.01326	1.03938	1.00000	1.00000	1.03953	1.03953			
FPI	0.99802	0.99573	0.99772	1.01326	1.02001	0.99465	1.00742	1.01326	1.04904	1.00000		1.04920		1.00173	1.01217	0.99690
MAN	1.00002	1.00003	1.00002	0.99992	0.99987	1.00020	0.99997	0.99992	0.99989	1.00000		1.00003		0.99973	0.99965	0.99977
SER	1.00005	1.00007	1.00006	0.99990	0.99986	1.00005	0.99991	0.99990	0.99984	1.00000		0.99999		0.99970	0.99967	0.99980

where P, PR, PK, and PT stands for composite, regional, capital and land prices. X, EXP, L, VA, R, IMP, Q, QR, and QM stand for regional output, exports, labor demand, value added, regional production consumed in the region, imports, final composite demand for commodities, final regional demand for comodities, and imported final demand for commodities, respectively.

TABLE 6.2 LONG-RUN SIMULATION RESULTS. INDEXES REPORTED FOR MAJOR ENDOGENOUS VARIABLES

	IP	IPR	IPX	IX	IEXP	IIMP	IR	IVA	IL	IK	IT	IPK	IPT	IQ	IQR	IQM
AGR	1.00015	1.00025	1.00010	0.99881	0.99842	0.99986	0.99940	0.99881	0.99852	0.99756	1.00000	1.00142	0.99897	0.99975	0.99956	0.99991
MIN	1.00097	1.00131	1.00068	0.99795	0.99599	0.99979	0.99976	0.99795	0.99856	0.99759		1.00142		0.99893	0.99888	0.99953
RM		1.06612	1.06612	1.09566				1.09566	1.17089	1.16976	1.00000	1.00142	1.17142			
FPI	0.98584	0.97064	0.98486	1.09566	1.14630	0.96320	1.05139	1.09566	1.09643	1.09537		1.00142		1.01426	1.08934	0.97998
MAN	1.00017	1.00038	1.00020	0.99912	0.99854	1.00180	0.99963	0.99912	0.99943	0.99847		1.00142		0.99972	0.99881	1.00015
SER	1.00050	1.00067	1.00056	0.99981	0.99942	1.00125	0.99989	0.99981	1.00017	0.99920		1.00142		0.99940	0.99908	1.00042

where P, PR, PK, and PT stands for composite, regional, capital and land prices. X, EXP, L, VA, R, IMP, Q, QR, and QM stand for regional output, exports, labor demand, value added, regional production consumed in the region, imports, final composite demand for commodities, final regional demand for comodities, and imported final demand for commodities, respectively.

Long-run simulation results for a pro-competitive change in the raw material market are presented in Table 6.2. Again forest complex gathers the more significant changes. Forestry sector increases output by 9.5% and receives a 6.61% higher price. Total revenue increases almost 6.79 million dollars. Factor prices differ to those obtained in the short run. For capital, the percentage change is 1.7%, for land is 17% and for labor 0.04 %. Labor and capital demand increase similarly, 17.01% and 16.97%, respectively. Price of land increase is 11% more that the short-run increase. This is because the only fixed factor now is land.

On the other hand, FPI output increases 9.5% but receive1.52% less per unit of output. Total exports of the sector increase by 14.6% and demand for labor and capital increases 9.64% and 9.54%, respectively. It appears that capital mobility allows the forest products manufacturing sector to better respond to the pro-competitive shock. To see this, one may argue that the lower return to capital faced in the long run compared to the short-run, makes the FPI demand more capital relative to labor and thus, allowing more flexibility to adjust to the new economic environment.

Table 6.3 shows regional indexes for the pro-competitive short-run and long run simulation. In general, changes for Oklahoma economic indexes are very small. This finding was expected due to the nature and size of the forest complex. The gross regional product increases by 0.05% and 0.15% in the short-run and long run scenario, respectively. Also, total exports of the region increases by 0.03% and 0.19% in the short-run and long run scenarios, respectively. Interesting aspect to notice from Table 6.3 is the change in the household income index. In the short-run household income index decreased lightly 0.02% but in the long run scenario the household income index increased to 0.04% inverting the effect of the short-run. Other indexes concerning original household income and adjusted household income show similar behavior as well as do the household saving index. A possible explanation for this phenomenon is the effect that the assumption concerning monopsony profit distribution has in the model. Since monopsony profit where distributed to household group in a direct way, when the new solution (simulation) in found, the model has subtracted the entire profit from the household budget. In the short run, the compensation increase that households obtained for their endowments (land, capital, and labor endowments) is not enough to compensate the lost of monopsony profit in their budget. However, in the long run scenario compensation is greater.

An alternative to direct monopsony profit distribution would have been to incorporate profit into a capital account. Then, by assuming that capital rent are past to regional household and out-of-region household, retained earnings, enterprise income distributed to household, and enterprise taxes could be estimated from this new definition of capital account. With monopsony profit specified through a capital account rather than directly to household, an increase in the household income index in the short-run scenario will be likely.

There are two important observations on the magnitude of values reported in Table 6.3. Although, these represent changes of small magnitude, when we take in consideration the fact that forestry and FPI are located in a sub-region (eastern Oklahoma) instead of spread throughout the state, we get a better perspective of the

TABLE 6.3 REGIONAL INDEXES FOR THE PRO-COMPETITIVE SIMULATION

INDEX	Short-run	Long-run	DESCRIPTION
ITX	1.00014	1.00096	Total Output index
ITE	1.00036	1.00195	Total Export index
ITL	1.00014	1.00041	Total labor demand index
IPL	1.00015	1.00045	Wage rate index
TLSRAT.L	1.00000	1.00000	lab supply ratio
ITK	1.00127	1.00272	Total Capital use index
ITT	1.00041	1.00084	Total Land use index
IGRP	1.00058	1.00146	Gross region product index
ITVA	1.00010	1.00081	Total Value added index
ITR	1.00003	1.00046	Total Reg. supply index
ITM	0.99998	1.00037	Total Import index
IAYH	0.99978	0.99998	Index for adjusted hh income
IYH	0.99988	1.00031	Household (in the region) income index
ITYH	0.99988	1.00031	Total household income index
IAYHTRA	0.98177	0.98203	djusted Household income net of TRANSFER
IYGOV	1.00008	1.00044	Government revenue index
IGOVEXP	1.00008	1.00024	Government expenditure index
ILS	1.00000	1.00000	Labor supply index
IDYH	0.99988	1.00031	Disposable income index
IHSAV	0.99988	1.00031	Household saving index
IAHEXP	0.99988	1.00031	adj. Household expenditure index
CAPCOMP	2.75597	8.43670	Capital Compensation
NETGOV	0.00894	6.57539	Net Revenue for government
TAYH			Total Adjusted hh income
YHCH	-13.60451	-5.50069	Change in hh income
AYHCH	-12.11226	-0.93715	Change in Adjusted Household income
GRPCH	36.18752	91.56268	Change in Gross regional product
LANDCOMP	0.09255	0.28340	Land Compensation

significance of those changes. Second, because we assume that at the base year monopsony profits are passed to households and not sent out of the region, we may have under-specified the pervasive effects of buyer market power in the raw material market.

Finally, by comparing columns IPR and IX in Tables 6.1 and 6.2, we observe that sectors with an increase in price were not able to increase their production except for the raw material sector. Forest products industry, however, match the decrease of output price with an increase of output supply. Chen and Lent, and Kinnucan and Sullivan studies, although using different framework of analysis, have reported the possibility of simultaneous price and output increases when imperfect competition is assumed. We believe that our results extend their findings to the CGE framework.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Monopsony power-exertion in agricultural commodity markets is likely to be present in many rural economies. Using the monopsony structure of the raw material market in Oklahoma, the necessary modifications to the standard computable general equilibrium model were introduced. Successfully, a calibrated and validated monopsony model for Oklahoma was implemented in a computable general equilibrium framework. A pro-competitive shock in the market structure of the raw material market was simulated using the monopsony regional CGE model. Changes in the state and household income, disposable income, commodity exports, commodity imports, commodity prices, wage rate, and rates of return to capital were estimated.

Simulation results indicate that changes at the state level are not of big magnitude. However, when the redistribution of revenues between forest products industry and the forestry industry are considered, a case for increased competition in the raw material sector appears to have been brought out. Under the hypothesis that CGE gives more accurate and realistic estimates compared to alternative methods i.e., partial equilibrium, CGE modeling allows a better understanding of what is happening in the regional economy. For example, results suggest forestry sector benefits from a pro-competitive shock in the raw material market structure; however, other factors will affect the level of welfare change, i.e., forest-land ownership.

Two contributions of this research should be emphasized; one concerns economic policy, the other modeling techniques available to regional scientists. First, with the example of the forest product industry we have brought evidence of welfare gains when competition is inserted in raw material (first-handler) markets. A policy oriented to improve the competition in the raw material market by, for example, promoting value-added processing cooperatives in the forestry region of eastern Oklahoma, will result in a redistribution of the monopsonistic profit assumed in the base year. Thus, raw material producers will increase their total revenue by 27 million dollars, which could be interpreted as an increase in the rate of return to land by almost 2%. On the other hand, it is argued that research results will be more significant for a CGE model implemented for a smaller area, i.e., an eighteen timber-producer-counties area (eastern Oklahoma). Areas with an economy connected to a specific industry will be affected strongly by the monopsonistic structure of markets.

Secondly, the procedure used here to calibrate our monopsony CGE model offers new possibilities for regional scientists interested in modeling imperfect market structures. No CGE model has been reported in the literature that incorporates monopsony market in the general equilibrium framework. The method presented in Chapter 5 " Implementation of the Regional CGE Model" must be considered, however, preliminary.

A further step to incorporate imperfect market structure in CGE is the oligopsony case. This requires further modification to the models, especificaly the introduction of a variable for number of firms and an explicit specification of supply elasticities.

The contributions of this research may be affected by the assumption of constant returns to scale and the static nature of the modeling technique used. An examination of how these assumptions affect the validation of our analysis would be highly desirable. Nevertheless, the direct allocation of monopsony profits to regional households may also limit the validation of our analysis.

REFERENCES

Abt, Robert C. "An Analysis of Regional Factor Demand in the U.S. Lumber Industry". Forest Science 33(1)1987:164-173.

Ahearn, Mary, Jet Yee, Eldon Ball, and Richard Nehring. "Agricultural Productivity in the United States". *Agricultural Information Bulletin Number 740*, ERS, United States Department of Agriculture, February 1998, pp. 21.

Aruna, P.B., Frederick Cubbage, Karen J.Lee, and Clair Redmond. "Regional Economic Contribution of the Forest-based Industries in the South". *Forest Products Journal* 47(July/August 1997):35-45.

Azzam, Azzeddine M. and John R. Schroeter. "The Tradeoff Between Oligopsony Power and Cost Efficiency in Horizontal Consolidation: An Example from Beef Packing". *Amer. J. Agr. Econ.* 77(November 1995):825-836.

Basu, S., and J.G. Fernald. "Are Apparent Productive Spillovers a Figment of Specification Error?" NBER Working Paper Series No.5073, March 1995.
Beattie, Bruce R. and C. Robert Taylor. "*The Economics of Production*". Krieger Publishing Company, Malabar, Florida:1992.

Berck, P., E. Golan, B. Smith, J. Barnhart and A. Dabalen. *Dynamic Revenue Analysis for California*. Agricultural and Resource Economics, University of California at Berkeley, Smith and Barnhart:California Department of Finance, 1996.

Brocker, J. "Chamberlinian Spatial computable General Equilibrium Modeling: A Theoretical Framework". *Economic Systems research* 7(1995):137-149.

Budiyanti, R. (1996). Application of General Equilibrium Modeling for Measuring Regional Economic and Welfare Impacts of Quality Changes in Sport Fishing in Oklahoma. Unpublished Ph.D. Dissertation, Oklahoma State University, Oklahoma.

Buongiorno, J., and H. Lu. "Effects of costs, Demand, and Labor Productivity on the Prices of Forest Products in the United State, 1958-1984". Forest Science. 35(June 1989):349-363.

Burniaux, J.M. and J. Waelbroeck. "Preliminary Results of Two Experimental Models of General Equilibrium with Imperfect Competition". *Journal of Policy Modeling* 14(1992):65-92.

De Borger, Bruno and Joseph Buongiorno. "Productivity growth in the Paper and Paperboard Industries: a Variable cost Function Approach". Can. J. For. Res. 15(1985):1013-1020

De Melo, Jaime and Tarr, David . "*A General Equilibrium Analysis of US Foreign Trade Policy.*" London, England: The MIT Press, Cambridge, Massachussetss:1992.

Everett, B. Peterson, Thomas W. Hertel, and James V. Stout. "A Critical Assessment of Supply-Demand Models of Agricultural Trade". *Amer. J. Agr. Econ.* 76(November 1994):799-721.

Francois, Joseph F. "Scale Economies and Imperfect Competition in the GTAP Model". *GTAP Technical Paper No.14*. September:1998.

Ginsburgh, V. "In the Cournot-Walras General Equilibrium Model, There May be 'More to Gain' by Changing the Numeraire than by Eliminating Imperfections: A Two-Good Economy Example". In *Applied General Equilibrium Analysis and Economic Development,* eds. J. Mercenier and T. N. Srinivasan. Ann Arbor: University of Michigan Press.

Harris, Richard. "Applied General Equilibrium Analysis of Small Open Economies with Scale Economies and Imperfect Competition". *The American Economic Review* 74(December 1984):1016-1032.

Hertel, Thomas W. "Partial vs. General Equilibrium Analysis and Choice of Functional Form: Implications for Policy Modeling". *Journal of Policy Modeling* 7(1985):281-303.

Hertel, Thomas W., and Timothy D. Mount. "The pricing of Natural Resources in a Regional Economy". *Land Economics* 61 (August 1985):229-243.

Hoff, K., Nona Fisher, Sandra Miller, and Alan Webb. "Sources of competitiveness for Secondary Wood Products Firms: A Review of Literature and Research Issues". Forest Products Journal, 47(February 1997):31-37.

Hoffman, Susan H., and Jeffrey S. Royer. "Evaluating the competitive Yardstick Effect of cooperatives on Imperfect Markets: A Simulation Analysis" Working paper, Department of Agricultural Economics, University of Nebraska-Lincoln.

Hseu, Jiing-Shyang, and Joseph Buongiorno. "Producer Behavior and Technology in the Pulp and Paper Industries of the United States and Canada: A Nonparametric Analysis". Forest Science 41(February 1995):140-156.

Hseu, Jiing-Shyang, and Joseph Buongiorno. "Output Supply and Input Demand in the Pulp and Paper Industry: A Nonparametric Model for the United States and Canada". Forest Science 43(1)1997:35-45.

Hughes, M. (1991). General Equilibrium of a Regional Economy with a Financial Sector-Part I: An Accounting Framework with Budget and Balance Sheet Linkages. Journal of Regional Science, 31(4):385-396.

Kant, Shashi, Wafa Al-Ameen, and J.C. Nautiyal. "The Canadian Forest Product Sector: a Sectoral Econometric Model" *Can. J. For. Res.* 26(1996):1122-34.

Kenkel, Phil and Lyford, Conrad (1997). 'The Potential for "New Wave" Cooperatives in Oklahoma". *Oklahoma Current Farm Economics,* 70(3),39-45.

Kilkenny, M. "Agricultural Liberalization in Segmented or Integrated Markets, with Scale Economies". *Journal of Economic Integration* 8(1993b):201-218

Kilkenny, M. "Rural/Urban Effects of Terminating Farm Subsidies". *Amer. J. Agr. Econ.* 75(November 1993):968-980

Kim, Jinill. "The Sources of Increasing Returns to Scale". *Finance and Economics Discussion Series*, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, Washington, D.C.:1997-18.

Klemperer, W. David. *Forest Resource Economics and Finance*. McGraw-Hill, Inc. 1996.

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

Koh, Young-Kon. (1991). *Analysis of Oklahoma's Boom and Bust Economy by Means of a CGE Model.* Unpublished Ph.D. Dissertation, Oklahoma State University, Oklahoma, 1991.

Kraybill, D. Computable General Equilibrium Analysis at the Regional Level. In D.M. Otto and T.G. Johnson (eds). *Microcomputer-Based Input-Output Modeling.* Boulder, Co: Westview Press.

Krugman, P. "Increasing Returns and Economic Geography". *Journal of Political Economy* 99(1991):483-499.

Krugman, P. "On the Number and Location of Cities". *European Economic Review* 37(1993):293-298.

Krugman, P. *Development, Geography, and Economic Theory.* Cambridge, MA: MIT Press. 1995

Lewis, D. K. and Goodier, Jeffrey P. (1990). "The South's Fourth Forest: Oklahoma." Agricultural Experiment Station, Division of Agriculture, Oklahoma State University, MP-130, July 1990.

Marcouiller, D. W. "Development and Use of a Supply-determined Social Accounting Matrix to Evaluate Economic Impacts of Forest Productivity on Distribution of Regional Factor Income". Unpublished Thesis, Oklahoma State University.

May, Dennis M.(1986). *Oklahoma Forest Industries, 1984*. Resource Bulletin SO-109, August, Southern Forest Experiment Station.

McWilliam, Bruce and George Goldman. The Forest Products Industry in California: Their Impact on the State Economy. University of California, Division of Agriculture and Natural Resources, Berkerley: CA 1994.

Mead, Walter J. *Cometition and Ologopsony in the Douglas Fir Lumber Industry,* Berkeley and Los Angeles: University of California Press, 1966.

Mercenier, Jean. "Nonuniqueness of Solutions in Applied General Equilibrium Models With Scale Economies and Imperfect Competition". Research Department Staff Report 183, Federal Reserve Bank of Minneapolis:October 1994.

Merrifield, David E. and William R. Singleton. "Production function Analysis and Market Adjustments: an Application to the Pacific Northwest Forest Product Industry". Forest Science 29(4)1983:813-822.

Merrifield, David E. and William R. Singleton. "A Dynamic cost and Factor Demand analysis for the Pacific Northwest Lumber and Plywood Industries". Forest Science 32(1)1986:220-233.

Nautiyal, J. C., and B.K. Singh. "Using Derived Demand Techniques to Estimate Ontario roundwood Demand." Can. J. Fore. Res. 13(1983):1174-1184.

Neil, J.K., B.K. Singh, and J.C. Nautiyal. "Short-run Leat-Cost Productivities of Variable Inputs for the British Columbia Interior Softwood Lumber Industry". *Forest Science* 34(March 1988):88-101.

Neil, J.K. and J.C. Nautiyal. "An intraregional economic analysis of production structure and factor demand in major Canadian softwood lumber producing regions". *Can. J. For. Res.* 18(1988):1036-1048.

Nguyen, T. T., and R. M. Wigle. "Trade Liberalization with Imperfect Competition: The Large and the Small of It". *European Economic Review* 36 (1992):17-35

Partridge, Mark D. and Dan S. Rickman. "Regional Computable General Equilibrium Modeling: A Survey and Critical Appraisal". *International Regional Science Review* ()

Plaut, T. R. "An Economic Model for Forecasting Regional Population Growth". *International Regional Science Review*, 6(1981):53-70

Rasmussen, Bo Sandemann. "Imperfect Competitive Factor Markets and Price Normalization". To appear in the Journal of Economics.

Raunikar, Robert. 1960. The Processing Industry for Forest Products in Eastern Oklahoma: Structure, Efficiency, Capacity and Potential Impact on the Rural Economy. Oklahoma State University, Science Serving Agriculture, Experiment Station.

Richards, Timothy J., Albert Kagan, Pamela Mischen, and Richard Adu-Asamoah. "Marketing Order Suspensions and Fresh Lemon Retail-Fob Margins". *Journal of Agricultural and App. Economics*. (December, 1996):263-277.

Richardson, J. D. "Empirical Research on Trade Liberalization with Imperfect Competition: A Survey". *OECD Economic Studies* 12(1989):7-50.

Rockel, Mark L. and Joseph Buongiorno. "Derived Demand for Wood and Other Inputs in Residential Construction: A Cost Function Approach". Forest Science 28(2)1982:207-219.

Rogers, Richard T. and Richard J. Sexton. "Assessing the importance of Oligopsony Power in Agricultural Markets". *Amer. J. Agr. Econ.* 76(December 1994):1143-1150.

Sadoulet, E., and de Janvry, A. (1995). *Quantitative Development Policy Analysis.* Baltimore, MR: The Johns Hopkins University Press.

Schallau, Con. "The contribution of the Forest Products Industry to Rural Economies of the Southern Appalachian Region". Forest Resources Technical Bulletin, American Forest and Paper Association, Washington:DC 1994.

Schooley, D. C., and J. Greg Jones. *An Input-output Model for Measuring Impacts of the Oklahoma Forest Products Industry on the State's Economy.* Research Report P-838, Agricultural Experiment Station, Division of Agriculture, Oklahoma State University, July 1983.

Schooley, Daniel C. (1981). *The Impacts of the Forest Products Industry on the Economy of Oklahoma.* Unpublished thesis. Oklahoma State University.
630.976608
R 432, No. 838

Schreiner, F. D., Lee, H., Koh, Y., & Budiyanti, R. (1996). "Rural development: Toward and integrative policy framework". The Journal of Regional Analysis and Policy, 26(2):53-72.

Stevens, James A. "Heterogeneous Labor Demand in the Western Washington Sawmill Industry". Forest Science 41(February 1995):181-193.

Stier, Jeffrey C. "Technological Adaptation to Resource Scarcity in the US Lumber Industry". Western Journal of Agricultural Economics 5(December, 1980):165-175.

Stier, Jeffrey C. "Implications of Factor Substitution, Economies of Scale, and Technological Change for the Cost of Production in the United States Pulp and Paper Industry". Forest Science 31(4)1985:803-812.

Stier, Jeffrey C. and David N. Bengston. "Technical Change in the North American Forestry Sector: A Review". Forest Science 38(February 1992):134-159.

Stout, James V. "Direct Comparison of General Equilibrium and Partial Equilibrium Models in Agriculture". Agriculture and Trade Analysis Division, Economic Research Service, U.S. Department of Agriculture. *Technical Bulletin*, No. 1799 (September 1991).

Sullivan, Jay and J. Keith Gilless. "Cumulative Employment Effects on Northern california's Wood Products Industries from National forest Timber Harvests". Forest Science 35(3)1989:856-862.

Tillman, A. D. (1985). *Forest Products Advanced Technologies and Economic Analyses*. Orlando, Fl: Academic Press, Inc.

Toms, Wade Martin. 1987. Characterization of Oklahoma's Forest Harvesting Industry. Unpublished Master Thesis. Oklahoma State University.

Treyz, F. and J. Bumgardner. "Monopolistic Competition Estimates of Interregional Trade Flows in Services". *REMI mimeograph.* Amherst, MA:Regional Economic Models, Inc. 1996

Varian, Hal R. *Microeconomic Analysis*. Third Ed., W.W. Norton & Company, New York:London 1992.

Villar, Antonio (1996). "*General Equilibrium with Increasing Returns*." (Lecture Notes in Economics and Mathematical Systems, 438) Berlin, Germany: Springer-Verlag. PP164

Vincent, Jeffrey R., William J. Lange, and Hyun-Deok Seok. "Labor Demand by Forest Products Industries: A review". USDA, Forest Service, Forest Products Laboratory, Research Paper FPL-RP-510 March 1992.

USDA, Forest Service (1988). The South's Fourth Forest: alternatives for the Future. Forest Resources Report No. 24. Washington, D.C.:USDA Forest Service, 512 pp.

Wann, Joyce J. and Richard J. Sexton. "Imperfect Competition in Multiproduct Food Industries with Application to Pear Processing". *Amer. J. Agr. Econ.* (November, 1992):980-90.

Wear, David N. "Structural Change and Factor Demand in Montana's Solid Wood Products Industries". Can. J. For. Res. 19:645-650.

Whalley, J. and I. Trela. "Regional Aspects of Confederation". Buffalo: University of Toronto Press. 1986

APPENDIX A

INDICES, VARIABLES, AND EQUATIONS

TABLE A.1

EQUATIONS OF THE MONOPSONISTIC CGE MODEL

Equation	Description Equations	No. of Equations	Endogenous Variables	Exogenous Variables	Parameters
PRODUCTION SYSTEM					
1. $LAB_i = \frac{\alpha_i^L PN_i X_i}{PL}$	*Labor demand*	n	LAB_i PN_i PL X_i		α_i^L
2. $CAP_i = \frac{\alpha_i^K PN_i X_i}{PK_i}$	*Capital demand*	n	CAP_i PN_i PK_i X_i		α_i^K
3. $LAND_i = \frac{\alpha_i^T PN_i X_i}{PT_i}$	*Land demand*	n	$LAND_i$ PN_i PT_i X_i		α_i^T
4. $VA_i = a_{0i} X_i$	*Composite factor demand*	n	VA_i X_i		a_{0i}
5. $V_{ji} = a_{ji} X_i$	*Intermediate input demand*	n x n	V_{ji} X_i		a_{ji}
6. $VA_i = \phi_i^{VA} LAB_i^{\alpha_i^L} CAP_i^{\alpha_i^K} LAND_i^{\alpha_i^T}$	*Net product production function*	n	VA_i LAB_i CAP_i $LAND_i$		ϕ_i^{VA} α_i^L α_i^K α_i^T
7. $V_{ji} = \phi_{ji}^V \left[\delta_{ji}^V VM_{ji}^{\rho_j^V} + (1-\delta_{ji}^V) VR_{ji}^{\rho_j^V} \right]^{\frac{1}{\rho_j^V}}, \sigma_j^V = \frac{1}{1-\rho_j^v}$	*CES for intermediate input demand*	n x n	V_{ji} VM_{ji} VR_{ji}		ϕ_{ji}^V δ_{ji}^V ρ_j^V σ_j^V

TABLE A.1 (Continued)

Equation	Description Equations	No. of Equations	Endogenous Variables	Exogenous Variables	Parameters
8. $TV_i = \sum_j V_{ij}$	*Total intermediate demand*	n	$TV_i\ V_{ij}$		
9. $VR_{ji} = VM_{ji}\left[\left(\frac{1-\delta_{ji}^V}{\delta_{ji}^V}\right)\left(\frac{PM0_j}{PR_j}\right)\right]^{\sigma_j^V}$	*Regional produced intermediate input demand*	n^2	$VM_{ji}\ VR_{ji}\ PR_j$	$PM0_j$	$\delta_{ji}^V\ \sigma_j^V$
10. $TVR_i = \sum_j VR_{ji}$	*Total intermediate regional demand*	n	$TVR_i\ VR_{ji}$		
11. $TVM_i = \sum_j VM_{ji}$	*Total intermediate imported demand*	n	$TVM_i\ VM_{ji}$		
<u>COMMODITY MARKETS</u>					
12. $X_i = \phi_i^x\left[\delta_i^x EXP_i^{\rho_i^x} + \left(1-\delta_i^x\right)R_i^{\rho_i^x}\right]^{\frac{1}{\rho_i^x}}, \sigma_i^X = \frac{1}{\rho_i^X - 1}$	*Regional supply*	n	$X_i\ EXP_i\ R_i$		$\phi_i^x\ \delta_i^x\ \rho_i^x\ \sigma_i^x$
13. $R_i = EXP_i\left[\left(\frac{1-\delta_i^x}{\delta_i^x}\right)\left(\frac{PE0_i}{PR_i}\right)\right]^{-\sigma_i^x}$	*Regional supply for regional demand*	n	$R_i\ EXP_i\ PR_i$	$PE0_i$	$\phi_i^x\ \delta_i^x\ \sigma_i^x$

TABLE A.1 (Continued)

	Equation	Description Equations	No. of Equations	Endogenous Variables	Exogenous Variables	Parameters
13.	$R_{rm} = X_{rm}$	*Regional supply for regional demand of forestry sector*	*n*	$R_i\ EXP_i\ PR_i$	$PE0_i$	$\phi_i^x\ \delta_i^x\ \sigma_i^x$
25.	$Q_i = \left(\frac{\beta_i}{P_i} \cdot AHEXP\right)$	*Composite household demand*	*n*	$Q_i\ P_i\ HEXP_j$		β_i
26.	$Q_i = \phi_i^Q \left[\delta_i^Q QM_i^{\rho_i^Q} + \left(1-\delta_i^Q\right) QR_i^{\rho_i^Q}\right]^{\frac{1}{\rho_i^Q}}, \quad {}_i^Q = \frac{1}{1-\rho_i^Q}$	*CES for household demand*	*n*	$Q_i\ QM_i\ QR_i$		$\phi_i^Q\ \delta_i^Q\ \rho_i^Q \sigma_i^Q$
27.	$QR_i = QM_i \left[\left(\frac{1-\delta_i^Q}{\delta_i^Q}\right)\left(\frac{PM0_i}{PR_i}\right)\right]^{\frac{1}{1-\rho_i^Q}}$	*Regionaly produced household demand*	*n*	$QR_i\ QM_i\ PR_i$	$PM0_j$	$\delta_i^Q\ \rho_i^Q$
32.	$QGOV_i = QGOV0_i$	*State / Local gov commodity demand*	*n*	$QGOV_i$	$QGOV0_i$	

TABLE A.1 (Continued)

Equation	Description Equations	No. of Equations	Endogenous Variables	Exogenous Variables	Parameters
34. $QGOVR_i = QGOVM_i \left[\left(\frac{1-\delta_i^{GOV}}{\delta_i^{GOV}}\right)\cdot\left(\frac{PM0_i}{PR_i}\right)\right]^{\frac{1}{1-\rho_i^{GOV}}}$	*State / Local government demand for regional good*	*n*	$QGOVR_i$ $QGOVM_i$ PR_i	$PM0_i$	δ_i^{GOV} ρ_i^{GOV}
33. $QGOV_i = \phi_i^{GOV}\left[\delta_i^{GOV} QGOVM_i^{\rho_i^{GOV}} + \left(1-\delta_i^{GOV}\right) QGOV_{R_i}^{GOV}\right]^{\frac{1}{\rho_i^{GOV}}}$	*government domestic and import demand substitution*	*n*	$QGOV_i$ $QGOVM_i$ $QGOVR_i$		ϕ_i^{GOV} δ_i^{GOV} ρ_i^{GOV} σ_i^{GOV}
37. $QINV_i = QINV0_i$	*Investment demand*	*n*	$QINV_i$	$QINV0_i$	
36. $QINV_i = \phi_i^{INV}\left[\delta_i^{INV} QINVM_i^{\rho_i^{INV}} + \left(1-\delta_i^{INV}\right) QINVR_i^{\rho_i^{INV}}\right]^{\frac{1}{\rho_i^{INV}}}$	*Investment demand substitution between region and import*	*n*	$QINVi$ $QINVMi$ $QINVRi$		ϕ_i^{INV} δ_i^{INV} ρ_i^{INV} σ_i^{INV}
38. $QINVR_i = QINVM_i \left[\left(\frac{1-\delta_i^{INV}}{\delta_i^{INV}}\right)\cdot\left(\frac{PM0_i}{PR_i}\right)\right]^{\frac{1}{1-\rho_i^{INV}}}$	*Investment demand for regional good*	*n*	$QINVR_i$ $QINVM_i$ PR_i	$PM0_i$	δ_i^{INV} ρ_i^{INV}

TABLE A.1 (Continued)

	Equation	Description Equations	No. of Equations	Endogenous Variables	Exogenous Variables	Parameters
41.	$PN_i = PR_i - \sum_j a_{ji} P_j - ibtax_i PR_i \quad \forall i \neq RM$	*Net price*	*n*	$PN_i\ PR_i\ P_i$		$a_{ij}\ ibtax_I$
42.	$PN_{rm} = PRR_{rm} - \sum_j a_{jrm} P_j - ibtax_{rm} PR_{rm} - a_{rn,p} P_{rm} \cdot (1 - \frac{1}{\text{esup}})$	*Net price for monopsony*	*1*	$PN_{irm} PRrm\ P_{irm}$		$a_{ij}\ ibtax_{I,}, esup$
42.	$P_i = \frac{PR_i R_i + PM0_i M_i}{R_i + M_i}$	*Composite price*	*n*	$P_i\ PR_i\ R_i\ M_i$	$PM0_i$	
42.	$PROF_{FPI} = \frac{V_{RM,FPI} * PR_{RM}}{e\,\text{sup}}$	*Monopsony Profit*	*1*	$PROF,\ PR_{iRM} V_I$	$PM0_I$	*esup*
44.	$P_{rm} = PR_{rm}$	*Composit monop. price*	*1*	P_{rm}, PR_{RM}		
43.	$PX_i = \frac{PR_i R_i + PEO_i EXP_i}{R_i + EXP_i}$	*Composite output price faced by producers*	*n*	$PR\ \ PX_i\ R_i\ M_i$	PEO_i	

TABLE A.1 (Continued)

Equation	Description Equations	No. of Equations	Endogenous Variables	Exogenous Variables	Parameters
40. $M_i = TVM_i + TQM_i + QGOVM_i + QINVM_i$	*Import*	*n*	M_i TVM_i TQM_i $QGOVM_i$ $QINVM_i$		
44. $X_i + M_i = TV_i + TQ_i + QGOD_i + QINV_i + EXP_i$	*Commodity market equilibrium*	*n*	X_i M_i TV_i TQ_i $QGOV_i$ $QINV_i$ EXP_i		
FACTOR MARKETS AND INCOMES					
28. $LS = LS0$	*Household labor supply*	*1*	LS	$LS0$	
29. $ALS = LS \cdot \text{Adj}L$	*Adjusted labor supply*	*1*	LS ALS		
14. $LY = PL(TLAB + LHHH0 + LGOV0) + \text{PLROC0} \cdot \left(\sqrt{\text{LMIG}^2} - \text{LMIG}\right)^2 \cdot 0.5 - PL \cdot \left(\sqrt{\text{LMIG}^2} + \text{LMIG}\right)^2 \cdot 0.5$	*Labor income*	*1*	LY PL $TLMig$ $TLAB$	$PLROC0$ $LHHH0$ $LGOV0$	
46. $LMIG_h = LS0 \cdot log\left(\frac{PL}{PLROC0}\right)\eta^L$	*Labor migration*	*1*	$LMIG$ PL	LSO $PLROC0$	η^L

TABLE A.1 (Continued)

Equation	Description Equations	No. of Equations	Endogenous Variables	Exogenous Variables	Parameters
15. $KY = \sum_i \left(CAP_i PK_i\right) + PKROC0 \cdot \left(\sqrt{KMIG^2} - KMIG\right) \cdot 0.5 - PK("Agr") \cdot \left(\sqrt{KMIG^2} + KMIG\right) \cdot 0.5$	*Capital income*	1	$KY\ CAP_i\ Pk_i$ KMiG	*PKROC0*	
49. $KMIG = \sum_i KO_i \cdot \log\left(\frac{PK("Agr")}{PKROC0}\right) \cdot \eta^K$	*Capital migration (long run equilibrium)*	1	*KMIG PK*	$K0_i$ *PRROC0*	η^K
16. $YENT = KY + PROF - \left(1 - Ktax\right)$	*Enterprise income*	1	*YENT KY PROF*		*ktax*
17. $TY = \sum_i \left(LAND_i PT_i\right)$	*Land income*	1	$YT\ LAND_i\ PT_i$		
18. $ALY = PL \cdot \left(\sum_i LAB_i + LHHH0 + LGOV0\right)$	*Adjusted labor income*	1	AYL, PL, LAB_i	*LHHH0* *LGOV0*	
19. $adjL = \frac{LS0_h + LMig_h}{TLS0}$	*Household adjustment factor*	1	*LMig* *AdjL*	*LS0* *TLS0*	

TABLE A.1 (Continued)

	Equation	Description Equations	No. of Equations	Endogenous Variables	Exogenous Variables	Parameters
20.	$YH = PL \cdot (LS + lMIG) \cdot (1 - SStax) + TY \cdot (1 - ttax) + (Yent - retrKY - etKY) + REMIT0 + adjL \cdot TRGOV - \left[\sqrt{Mratio^2 - Mratio} \right] 0.5 + \left[TY \; (1 - ttax) + (YENT\text{-}RETENT - et \cdot KY) \right] + REMIT0$	*Household income*	1	*PL LMIG TY MRATIO YENT RETENT KY LS*	*TRGOV0 LHTRHO*	*retr ltr ttax*
21.	$DYH = YH \; (1 - hhtax)$	*Disposable income*	1	*DYH YH*		*hhtax*
22.	$HSAV = mpsYH$	*Household saving*	1	*HSAV YH*		*mps*
39.	$INV = \sum_{i} QINV_i P_i$	*Total investment*	1	$INV \; QINV_i \; P_i$		
23.	$GSP = YL + YK + YT + \sum_i ibtax_i X_i$	*Gross state product*	1	$GSP \; YL \; YK \; YT \; X_i$		$ibtax_i$
24.	$AHEXP = DYH - HSAV - PL \cdot LHHH0$	*Household expenditure*	1	*HEXP DYH HSAV PL*	*LHHH0*	

TABLE A.1 (Continued)

	Equation	Description Equations	No. of Equations	Endogenous Variables	Exogenous Variables	Parameters
30.	$YGOV = \left(\sum_i ibtax_i PR_i X_i\right) + (sstax \cdot LY) + (ktax \cdot KY) + et \cdot KY + ttax \cdot TY + hhtax \cdot YH + GOVBOR0 + GOVITR0$	Government revenue	1	$YGOV$ PR_I X_I LY KY TY YH	$GOVBOR0$ $GOVLITRO$	$ibtax_i$ $sstax$ $ktax$ $ttax$ $hhtax$
31.	$GOVEXP = \sum_i QGOV_i P_i + adjL \cdot TRGOV0 + PL \cdot LGOV0 + GOVITRO$	Government expenditures	1	$QGOV_i$ $GOVEXP$ P_i PL	$LGOV0$ $TRGOV0$ $GOVITR0$	
35.	$SAV = \sum_h (HSAV_h * AdjL) + retrYK + ROWSAV0$	Total Saving	1	SAV $HSAVh$ YK $YENT$	$ROWSAV0$	$depr$ $retr$
45.	$\sum_i LAB_i + LHHHO + LGOV0 = LS + LMIG$	Labor market equilibrium	1	LS $LMIG$ LAB_i	$LHHH0$ $LGOV0$	
47.	$CAP_i = KS0_i$	Capital market equilibrium (short run equilibrium)	n	CAP_i	$KS0_i$	
48.	$\sum_i CAP_i = \sum_i KS0_i + KMIG$	Capital market equilibrium (long run equilibrium)	1	CAP_i $KMIG$	$KS0_i$	
50.	$LAND_i = TS0_i$	Land market equilibrium	1	$LAND_i$ $TS0_i$		

TABLE A.2

SUBSCRIPT NOTATION

INDEX	DESCRIPTION
i,j	Sectors and commodities
ag(i)	Agricultural sectors
nag(i)	Nonagricultural sectors
e(i)	Sectors with exported
mk(i)	Sectors with imported and regional produce demand
we(i)	Export sectors
nwe(i)	No export sectors
ci(i)	Regional consumed goods
f	Factors
fl(f)	Factors no land
g	Government

TABLE A.3

SUMMARY OF ENDOGENOUS VARIABLES

VARIABLES	DESCRIPTION	NUMBER
Z	Objective Function Value	1
PROF	Profits of the monopsonist	1
PL	Wage rate	1
PK(i)	Cap rate1	1 or 6
PT(i)	Land rent	2
PN(i)	Net output price	6
PR(i)	Regional price	6
P(i)	Composite price	6
PX(i)	Composite price faced by consumers	6
LAB(i)	Labor demand	6
CAP(i)	capital demand	6
LAND(ag)	Land demand	2
TCAP	Total Capital Demand	1
TLAB	Total Labor Demand	1
TLAND	Total land demand	1
LS	Labor supply	1
TLSrat	lab supply ratio	1
ALS	Adj labor supply	1
LMIG	Labor migration	1
Mratio	Migr compared to initial lab supply	1
KMIG	Capital migration	1
VA(i)	Value added	6
V(j,i)	Composite intermediate good demand	6
VM(j,i)	Imported int good demand	36
VR(j,i)	Reg int good demand	36
R(i)	Regional supply	6
X(i)	Output	6
EXP(ie)	Export	5
M(im)	Import	5
TVM(i)	Imported int good total demand	5
TVR(i)	Reg int good total demand	5
TV(i)	Compos. intermediate good total demand	6
adjL	Labor adjustment	1
adjK	Capital adjustment	1
LY	Labor income (original hhs)	1

TABLE A.3 (CONTINUED)

VARIABLES	DESCRIPTION	NUMBER
ALY	Adjusted labor income	1
KY	capital income (original capital stock)	1
TY	Land income	1
YENT	Enterprise income	1
RETENT	Retained Earnings by enterprises	1
TYH	Total household income	1
YH	Income of hh staying in the region	1
AYH	Adjusted hh income	1
AYHtra	Adj. hh income net of transfers	1
DYH	Disposable household income	1
HSAV	Household saving	1
SAV	Total saving	1
ROWSAV	Saving from rest-of-world	1
INV	Investment	1
YGOV	gov revenue	1
GOVBOR	gov borrowing	1
IBTX	Indirect business tax	1
GRP	Gross region product	1
HEXP	Household expenditure	1
AHEXP	Adjusted household expenditure	1
Q(i)	Demand for comp consump good	5
QM(i)	Demand for imp consump good	5
QR(i)	Demand for reg consump good	5
ADQ(i)	Adj demand for comp consump good	5
AQM(i)	Adj demand for imp consump good	5
AQR(i)	Adj demand for reg consump good	5
TQ(i)	Total demand for comp consump good	5
TQM(i)	Total demand for imp consump good	5
TQR(i)	Total demand for reg consump good	5
GOVEXP	gov expend	1
QGOV(i)	gov demand for comp good	5
QGOVM(i)	gov demand for imported good	5
QGOVR(i)	gov demand for reg good	5
QINV(i)	Invest gov demand for comp good	5
QINVM(i)	nvest gov demand for imported good	5
QINVR(i)	nvest gov demand for reg good	5

TABLE A.4

EXOGENOUS PARAMETER ESTIMATES AND THEIR SOURCES

Parameter	Parameter Value	Source
Elasticities of Substitution $\left(\sigma^{V},\sigma^{Q},\sigma^{GOV},\sigma^{INV}\right)$		De Melo and Tarr (1992)
Agriculture	1.42	
Mining	0.50	
Manufacturing	3.55	
Forest Product Industry	3.55	
Forestry	1.42	
Services	2.00	
Elasticities of Transformation (σ^{X})		De Melo and Tarr (1992)
Agriculture	3.90	
Mining	2.90	
Manufacturing	2.90	
Forest Products Industry	2.90	
Services	0.70	
Labor Migration Elasticity (z)	0.92	Plaut(1981)
Capital Migration Elasticity (z)	0.92	Plaut(1981)

APPENDIX B

GAMS INPUT FILE FOR THE REGIONAL CGE MODEL

```
$TITLE REGIONAL CGE MODEL FOR OKLAHOMA (1993)(CRS.GMS)
$OFFSYMLIST OFFSYMXREF OFFUPPER

*#:) Note        1.      SET DECLARATION: Consist of declaring and specifying the
*                        index to be used. It is the same as the indexes use in the
*                        equations of the model.

SETS
i    Sectors        /AGR  agriculture,
                          MIN  mining,
                          FPI  forest products industry,
                          RM  forestry,
                          MAN  manufacture
                          SER  construction/

ag(i)  Agricultural sectors   / AGR, RM /
nag(i)  Nonagricultural market sectors   /FPI, MIN, SER, MAN/
ie(i)  Sectors which products are exported /AGR, MIN, FPI, SER, MAN/
mk(i)  Market goods reg. and import intermediate demand   /Agr,Min, RM, FPI, SER, Man/
mk1(i)  Market goods /AGR, MIN, SER, MAN/
we(i)  Export sectors /AGR, MIN, FPI, SER, MAN/
nwe(i)  No export sectors /RM/
ci(i)  Reg cons goods  /Agr,Min, FPI, SER,Man/
f     Factors      /L   labor,K   capital, T   land/
fl(f)  Factors no land / L, K/
g     Government    /GOV/
ALIAS(IE,IM);
ALIAS(i,j);
ALIAS(i,i1);
ALIAS(j,j1);
ALIAS(ci,cj);
ALIAS(mk,ml);
ALIAS(mk1,mj);

*#################################################################*
*                                       *
*    SECTION ONE: BASE YEAR DATA                  *
*                                       *
*#################################################################*

*#:) Note 2.      BASE YEAR DATA: Base year variables base upon
*                       the Social Accounting Matrix (SAM) are distinguished
*                       by "0" as a suffix, i.e., L0(i) state for base year labor.

*#:) Note 3.      DECLARATION AND ASSIGNMENT OF BASE YEAR DATA: We declarate
*                       the base year variables as parameter. GAMS requires a
*                       declaration of the parameter and an assignment of values to
*                       it. In spite of the flexible arrangements allow for GAMS, we
*                       recommend firstly declare (initiate) all the parameters, then
*                       use tables to enter data and finally, to assign the values.


*#####-- DECLARATION OF BASE YEAR VARIABLES (AS PARAMENTERS)
```

PARAMETERS

```
*#:) Note 4.    DECLARATION: We consider four blocks of variables for better
*                       readability. They are, price, production, income and expenditure
*                       blocks.

*@Price block
 PL0            Wage rate
 PLROC0         Wage rate of rest-of-country
 PKROC0         Cap rate of rest-of-country
 PK0(i)         cap rate
 PT0(ag)        Land rent
 PE0(i)         Export price
 PM0(i)         Import price
 PR0(i)         Reg price
 P0(i)          Composite price
 PN0            Net price
 PX0(i)         Composite price face by producers
 prof0          Profits for fpi sector
*@Production block
 L0(i)          Labor demand
 LS0            Labor supply by hh
 LHHH0          Labor employed by high-income hh group
 LGOV0          Labor employed by gov
 K0(i)          capital demand
 T0(ag)         Land demand
 KS0            Supply of pri capital
 TKS0           Total pri capital supply
 TS0            Supply of land
 VA0(i)         Value added
 V0(j,i)        Composite intermediate good demand
 TV0(i)         Composite intermediate good total demand
 VR0(j,i)       Reg int good demand
 VM0(j,i)       Imported int good demand
 TVR0(i)        Reg int good total demand
 TVM0(i)        Imported int good total demand
 IBT0(I)        Indirect business taxes
 X0(i)           Sector output
 E0(i)          Export of reg product
 M0(i)          Import
 R0(i)          Reg supply of reg product

*@Income block
 LY0            Labor income
 KY0            capital income
 TY0            Land income
 YENT0          Gross Enterprise income
 LLTRH0         Transfer from low to low hh
 LMTRH0         Transfer from med to low hh
 LHTRH0         Transfer from high to low hh
 YH0            Household income
 TYH0           Total Household income
 DYH0           Disposable hh income
 HSAV0          Household saving
 SAV0           Total saving
 ROWSAV0         Saving from rest-of-world
```

TRGOV0 Gov transfer to hh
RETENT0 Capital retented by enterprises
REMIT0 Remittance from outside the reg to hh
FLY0 Labor income distrib to hhs
FTY0 Land income distrib to hhs
YGOV0 Gov revenue
YFed0 Fed gov revenue
ENTY0 Enterprise income distrib to hhs
GOVITR0 Inter gov transfer
GOVBOR0 Government Borrowing
GRP0 Gross region product
* SUB0 Subsidy to enterprise
*@Expenditure block
HEXP0 Household expend
QR0(i) Demand for reg consump good
QM0(i) Demand for imp consump good
Q0(i) Demand for comp consump good
TQR0(i) Demand for reg consump good
TQM0(i) Demand for imp consump good
TQ0(i) Demand for comp consump good
GOVEXP0 government expenditure
QGOVR0(i) government demand for reg good
QGOVM0(i) government demand for imported good
QGOV0(i) government demand for comp good
QInvR0(i) Invest gov demand for reg good
QInvM0(i) Invest gov demand for imported good
QInv0(i) Invest gov demand for comp good
INV0 Total invest

*#:) Note 5. The following variables are defined as "logical variables". A logical
* variable takes the value of 1 if the condition stated is true and "0"
* We use these variables when defining an equation or when value
* if not. Assignment to a particular variable depend on the "true" or
* "false" condition of a specific condition, i.e.,

****

*Regional		x	x	0	0	0=zero, x=not zero
*Import	x	0	x	0		
*						
*NZV		T	F	F	F	T=TRUE, F=FALSE
*ZVR		F	F	T	F	
*ZVM		F	T	F	T	

****

ZVM(i,J) non-imported intermediate demand with-or-without regional interm. demand
ZVR(i,J) only imported intermediate demand
NZV(i,J) both imported intermediate demand and regional demand

ZQM(i) non-imported final demand and either none or some regional final demand
ZQR(i) only imported final demand
NZQ(i) both imported final demand and regional final demand

ZGOVM(i)
ZGOVR(i)
NZGOV(i)

```
 ZInvM(i)
 ZInvR(i)
 NZInv(i)


*#####-- DECLARATION OF PARAMETERS TO BE CALIBRATED.

PARAMETERS

*#:) Note 6.        These parameters are those specified in Table 5.5.

*@Production block
 a0(i)              composite value added req per unit of output i
 a(j,i)             req of interm good j per unit of good i
 Alpha(i,f)         value added share param
 Ava(i)             value added shift param
 RHOv(i)            interm input subs param
 deltav1(j,i)
 deltav(j,i)        interm input share param
 Av(j,i)            interm input shift param
 RHOx(i)            output transformation param
 deltax1(i)
 deltax(i)          output share param
 Ax(i)              output shift param

*@Income block
 ktax               capital tax rate
 sstax               factor income tax rates for labor
 ttax               factor income tax rates for land
 retr               rate of retained earnings fr ent inc
 et                   enterprise tax rate
 hhtax              income tax rate for hh
 ltr                Household Income Transfer Coefficient
 mps                saving rate
 ibtax(i)           indirect business tax
 beta(i)            param calc fr elast of comm demand wrt inc

*@Expenditure block
 RHOq               consumer demand subs param
 deltaq1(i)
 deltaq(i)          consumer demand share param
 Aq(i)              consumer demand constant eff param
 RHOgov             gov demand subs param
 deltagov1
 deltagov           gov demand share param
 Agov               gov demand constant eff param
 RHOinv             inv gov demand subs param
 deltainv1
 deltainv           inv gov demand share param
 Ainv               inv gov demand constant eff param
 drs                decreasing returns to scale coefficient for raw material sector
 esup               elasticity of product supply for Raw materials sector
 ;

*### DATA: Data come from our SAM (Table 2.1)
```

Table IOR(i,j) Input-output regional matrix

	Agr	MIN	RM	FPI	MAN	SER
Agr	670.862	8.116	4.936	2.668	820.923	34.800
Min	122.579	2180.942	0.891	65.705	1192.412	881.343
RM				40.400		
FPI	9.839	72.630	1.264	6.026	179.590	206.456
Man	147.584	1318.071	0.984	109.769	3299.584	3746.744
Ser	379.945	1317.332	1.597	275.341	4996.845	9752.027

;

Table IOM(i,j) Input-output import matrix

	AGR	MIN	RM	FPI	MAN	SER
Agr	574.915	5.160	4.955	1.230	377.192	41.300
Min	11.222	1274.869	0.628	16.247	294.847	385.272
RM						
FPI	27.620	23.552	2.742	19.243	436.987	143.637
Man	414.296	427.425	2.171	350.537	8028.706	2606.708
Ser	154.136	458.802	1.024	98.534	1788.176	4188.764

;

Table VAD(i,f) Value added matrix

	L	k	t
AGR	426.998	566.973	701.385
MIN	1622.806	2713.109	
RM	6.244	4.387	7.681
FPI	188.400	496.5906105	
MAN	7389.027	3499.379	
SER	20767.388	12042.709	

;

Table HHCONR(i,*) Household consumption demand for regional goods

	HOUSE
AGR	147.210
MIN	1587.998
RM	
FPI	138.648
MAN	2517.437
SER	30727.365

;

Table HHCONM(i,*) Household consumption demand for imported goods

	HOUSE
AGR	181.550
MIN	141.662
RM	
FPI	299.232
MAN	5414.473

```
SER      9510.103
;

Table GOVCONR(i,*)  Government consumption demand for regional goods


          GOV
AGR     12.863
MIN     231.250
RM
FPI     96.782
MAN     1757.284
SER     1477.994
;

Table GOVCONM(i,*) Government consumption demand for imported goods
          GOV
AGR     20.097
MIN     29.912
RM
FPI     43.146
MAN     780.700
SER     542.893;

Table FYDIST(*,f)  Factor income distribution
                 L              K          T
HH       31363.057      0.00       683.300
;

TABLE ParamA(*,i)   BASE YEAR VALUES FOR INDUSTRY

            AGR          MIN          RM       FPI       MAN           SER

PT0           1.00         1.00                  1.0    1.0           1.00          1.00
PK0           1.00         1.00                  1.0      1.0         1.00          1.00
PR0           1.00         1.00         1.0      1.0      1.00           1.00
P0          1.00         1.00           1.0      1.0      1.00           1.00
PM0           1.00         1.00                  1.0                  1.00          1.00
PE0           1.00         1.00                  1.0                  1.00          1.00
X0        4303.759          12089.785        40.400   1785.600           32404.827           59115.190
E0        2591.601          5807.568                  826.339            15003.939           9629.092
R0        1712.158          6282.217         40.400   959.261            17400.888           49486.098
M0        1216.846          2170.418                  1124.719           20351.259           16920.731
IBT0     95.405             666.971          0.896    85.720             101.159             4318.042
QINVR09.780                 19.097                    248.026            4503.431            557.652
QINVM010.447                15.759                    128.560            2326.243            178.299
SIGMAv          1.42        0.50             1.42     3.5                3.55       2.00
SIGMAx          3.90        2.90                      2.90               2.90       0.70
SIGMAq          1.42        0.50                      3.55               3.55       2.00
SIGMAgov         1.42        0.50                     3.55               3.55       2.00
SIGMAinv         1.42        0.50                     3.55               3.55       2.00

;

TABLE ParamB(f,*)   BASE YEAR VALUES FOR FACTORS
   WAGE0   WAGEROC0    FTAX0        RETENT0      CAP0   CAPROC0
```

```
L    1.0      1.0    6126.715        0
K                   -1006.685     9077.096        1      1
T                    25.766          0
;

TABLE ParamC (*,*)  BASE YEAR VALUES FOR HH GROUPS

            HTAX0         HSAV0          TRGOV0
HOUSE       6976.571    -3869.320       11490.516

+          REMIT0       ENTYDIS0
HOUSE      760.823       9582.303
;

TABLE ParamD(g,*)  BASE YEAR VALUES FOR GOVTS
           BOR0        GOVDR0    GOVDM0
GOV          0.0       3576.173  1416.748
;
SCALAR LHHH0  Labor used by high inc hh /  107.070/;
SCALAR LGOV0  Labor used by government  /6981.839/;
SCALAR GOVITR0 Inter-government transfer  /8477.813/;
*SCALAR YENT0    Enterprise income          /20359.022/;
SCALAR ENTTAX0  Enterprise taxes                          /1699.623/;
SCALAR ROWGOV0   Rest of world trans.to gov.  /4375.093/;
SCALAR ROWSAV0   Saving from ROW            /2789.518/;
SCALAR QINVMSUM0 Inv demand for imported goods / 2659.308/;
SCALAR etaL      Labor migr elasticity     /    .92   /;
SCALAR etaK      Capital migr elasticity    /    .92   /;
Scalar KMobil    Capital Mobility          /      1 /;

*#:) Note 7.        ASSIGNING VALUES: Here, we assign value to each of the base
*                            year variables declared previously using our data.


*@Production block
 L0(i)        =VAD(i,"L");
 K0(i)        =VAD(i,"K");
 T0(ag)        =VAD(ag,"T");
 VA0(i)        =sum(f,VAD(i,f));
 V0(j,i)      =IOR(j,i)+IOM(j,i);
 TV0(i)        =sum(j,V0(i,j));
 VM0(j,i)     =IOM(j,i);
 VR0(j,i)     =IOR(j,i);
 TVM0(i)       =sum(j,VM0(i,j));
 TVR0(i)       =sum(j,VR0(i,j));
 LHHH0          =LHHH0;
 LGOV0          =LGOV0;
 FLY0         =FYDIST ("HH","L");
 LS0          =sum(i,VAD(i,"L"))+LHHH0+LGOV0;
 X0(i)        =ParamA("X0",i);
 E0(i)        =ParamA("E0",i);
 R0(i)        =ParamA("R0",i);
 KS0(i)        =VAD(i,"K");
 TKS0          =sum(i,KS0(i));
 TS0(ag)        =VAD(ag,"T");
 IBT0(I)              =PARAMA("IBT0",I);
```

```
*@Income block
 TRGOV0      =ParamC ("HOUSE","TRGOV0");
 FTY0        =FYDIST ("HH","T");
 LY0         =sum(i,VAD(i,"L"))+LHHH0+LGOV0;
 KY0         =sum(i,VAD(i,"K"));
 TY0         =sum(ag,VAD(ag,"T"));
 REMIT0      =ParamC ("HOUSE","REMIT0");
 YH0         =sum(f,FYDIST("HH",f))+ParamC("HOUSE","ENTYDis0")+TRGOV0
             +REMIT0;
 TYH0        =YH0;
 DYH0        =YH0 -ParamC ("HOUSE","HTAX0");
 HSAV0       =ParamC ("HOUSE","HSAV0");
 HEXP0       =DYH0-HSAV0-LHHH0;
 SAV0        =ParamB("K","RETENT0")+ ParamC ("HOUSE","HSAV0")+ROWSAV0;
 ROWSAV0     =ROWSAV0;
 YGOV0       =sum(i,ParamA("IBT0",i))+sum(f,ParamB(f,"FTAX0"))
             +ParamC("HOUSE","HTAX0")+ENTTAX0+ROWGOV0+GOVITR0;
 ENTY0       =ParamC("HOUSE","ENTYDis0");
 GOVBOR0     =ParamD("GOV","BOR0");
 GRP0        =LY0+KY0+TY0+sum(i,ParamA("IBT0",i));

*@Expenditure block
 QR0(i)      =HHCONR(i,"HOUSE");
 QM0(i)      =HHCONM(i,"HOUSE");
 Q0(i)       =QM0(i)+QR0(i);
 TQR0(i)     =QR0(i);
 TQM0(i)     =QM0(i);
 TQ0(i)      =Q0(i);
 GOVEXP0     =ParamD("GOV","GOVDR0")+ParamD("GOV","GOVDM0")
             +ParamC("HOUSE","TRGOV0")+LGOV0+GOVITR0;
 QGOVR0(i)   =GOVCONR(i,"GOV");
 QGOVM0(i)   =GOVCONM(i,"GOV");
 QGOV0(i)    =QGOVM0(i)+QGOVR0(i);
 QINVR0(i)   =ParamA("QINVR0",i);
 QINVM0(i)   =ParamA("QINVM0",i);
 QINV0(i)    =QINVM0(i)+QINVR0(i);
 INV0        =sum(i,QINV0(i));
 M0(i)       =ParamA("M0",i);

*@Price block
 PL0         =ParamB("L","WAGE0");
 PK0(i)      =ParamA("PK0",i);
 PLROC0      =ParamB("L","WAGEROC0");
 PKROC0      =ParamB("K","CAPROC0");
 PT0(ag)     =ParamA("PT0",ag);
 PE0(i)      =ParamA("PE0",i);
 PM0(i)      =ParamA("PM0",i);
 PR0(mk)     =ParamA("PR0",mk);
 P0(i)       =ParamA("P0",i);
 PX0(ci)     =(PR0(ci)*R0(ci)+PM0(ci)*M0(ci))/(R0(ci)+M0(ci));

*--------------------------------------------------
* Regional    x x 0 0    0=zero, x=not zero
* Import      x 0 x 0
*
```

```
* NZV       T F F F    T=True, F=False
* ZVR       F F T F
* ZVM       F T F T
*-----------------------------------------------------

 ZVM(i,j)    =(VM0(i,j) eq 0);
 ZVR(i,j)    =(VR0(i,j) eq 0) and (VM0(i,j) ne 0);
 NZV(i,j)    =(VR0(i,j) ne 0) and (VM0(i,j) ne 0);

 ZQM(ci)   =(QM0(ci) eq 0);
 ZQR(ci)   =(QR0(ci) eq 0) and (QM0(ci) ne 0);
 NZQ(ci)   =(QR0(ci) ne 0) and (QM0(ci) ne 0);

 ZGOVM(i)    =(QGOVM0(i) eq 0);
 ZGOVR(i)    =(QGOVR0(i) eq 0) and (QGOVM0(i) ne 0);
 NZGOV(i)    =(QGOVR0(i) ne 0) and (QGOVM0(i) ne 0);

 ZInvM(i)    =(QInvM0(i) eq 0);
 ZInvR(i)    =(QInvR0(i) eq 0) and (QInvM0(i) ne 0);
 NZInv(i)    =(QInvR0(i) ne 0) and (QInvM0(i) ne 0);

*#:) Note 8.      SAM: We have already assigned the values to our
*                      base year variables (parameters). Next, we define some new
*                      parameter to check for accurasy of our assignment. If it is
*                      correct we should get our SAM and a block of unity prices.
*                      The DISPLAY comment of GAMS allows the modeler to
*                      easily see the assignment with the following statement:
*                          DISPLAY PK0, PT0, L0, K0, ....., TSO;
*                      However, we prefer to define new parameters as above, so
*                      the output will be easier to read and better presented.

PARAMETER SAM SOCIAL ACOUNTING MATRIX -BASE YEAR PRICES-;
SAM(I,"PK")=PK0(I);
SAM(ag,"PT")=PT0(ag);
SAM(I,"PE0")=PE0(I);
SAM(I,"PM0")=PM0(I);
SAM(I,"PR0")=PR0(I);
SAM(I,"P0")=P0(I);
SAM(I,"PR0")=PR0(I);
SAM(I,"L0")=L0(I);
SAM(I,"K0")=K0(I);
SAM(I,"KS0")=KS0(I);
SAM(ag,"T0")=T0(ag);
SAM(I,"TS0")=TS0(I);
SAM(I,"VA0")=VA0(I);
SAM(I,"TVR0")=TVR0(I);
SAM(I,"TVM0")=TVM0(I);
SAM(I,"TV0")=TV0(I);
SAM(I,"IBT0")=IBT0(I);
SAM(I,"X0")=X0(I);
SAM(I,"M0")=M0(I);
SAM(I,"R0")=R0(I);
SAM(I,"E0")=E0(I);
SAM(I,"Q0")=Q0(I);
SAM(I,"QR0")=QR0(I);
SAM(I,"QM0")=QM0(I);
```

```
SAM(I,"TQ0")=TQ0(I);
SAM(I,"TQR0")=TQR0(I);
SAM(I,"TQM0")=TQM0(I);
SAM(I,"QGOV0")=QGOV0(I);
SAM(I,"QGOVR0")=QGOVR0(I);
SAM(I,"QGOVM0")=QGOVM0(I);
SAM(I,"QINV0")=QINV0(I);
SAM(I,"QINVR0")=QINVR0(I);
SAM(I,"QINVM0")=QINVM0(I);

OPTION DECIMALS=3;
DISPLAY SAM;

DISPLAY V0,VM0,VR0,LS0,TKS0,PL0, PLROC0,LHHH0,LGOV0,LY0,KY0,TY0,
REMIT0,YH0,DYH0,YGOV0,GRP0,HSAV0,HEXP0,GOVEXP0,SAV0,ROWSAV0,
TRGOV0,FLY0,FTY0,ENTY0,ENTTAX0,GOVBOR0, ZVM, ZVR, NZV, ZQM, ZQR,
 NZQ, ZGOVM, ZGOVR, NZGOV, ZInvM, ZInvR, NZInv;


*#############################################################*
*                                        *
*    SECTION TWO: PARAMETER CALIBRATION              *
*                                        *
*#############################################################*


*#####-- CALIBRATION

*#:) Note 9.     This is where we calibrate our paramenters. The calibration procedure
*                    was introduced in section 2.3. We have put in parentesis the equation
*                    of the text that is used in the calibration; e.i.,
*                          *(3.1.2)
*                          a0(i)   = VA0(i)/X0(i);
*                    means that the calibration of a0(i) aggree with the equation (3.1.2) of
*                    our text.

*@Production block
* (3.1.2)
 a0(i)         =VA0(i)/X0(i);
 a(j,i)        =V0(j,i)/X0(i);
* (3.1.11)
 alpha(ag,"K")  =VAD(ag,"K")/VA0(ag);
 alpha(ag,"T")  =VAD(ag,"T")/VA0(ag);
 alpha(ag,"L")  =1-alpha(ag,"K")-alpha(ag,"T");
 alpha(nag,"K")  =VAD(nag,"K")/VA0(nag);
 alpha(nag,"L")  =1-alpha(nag,"K");
* (3.1.3)
 Ava(ag)       =VA0(ag)/Prod(f,VAD(ag,f)**alpha(ag,f));
 Ava(nag)       =VA0(nag)/PROD(fl,VAD(nag,fl)**alpha(nag,fl));
* (3.1.16)
 RHOv(i)       =1-1/ParamA("SIGMAv",I);
* (3.1.17)
 deltav1(j,i)
  $(NZV(j,i))  =(VR0(j,i)/VM0(j,i))**(1-RHOv(j))*(PR0(j)/PM0(j));
 deltav(j,i)
  $(NZV(j,i))  =1/(1+deltav1(j,i));
```

```
* (3.1.19)
 Av(j,i)
  $(NZV(j,i))  =V0(j,i)/(deltav(j,i)*VM0(j,i)**RHOv(j)
          +(1-deltav(j,i))
          *VR0(j,i)**RHOv(j))**(1/RHOv(j));
* (3.2.1)
 RHOx(WE)       =1+1/ParamA("SIGMAx",we);
* (3.2.3)
 deltax1(WE)    =(R0(we)/E0(we))**(1-RHOx(we))*(PR0(we)/PE0(we));
 deltax(WE)     =1/(1+deltax1(we));
* (3.2.4)
 Ax(WE)         =X0(we)/(deltax(we)*E0(we)**RHOx(we)+(1-deltax(we))
          *R0(we)**RHOx(we))**(1/RHOx(we));
*@Income block
 sstax          =ParamB("L","FTAX0")/LY0;
 ktax           =ParamB("K","FTAX0")/KY0;
 ttax           =ParamB("T","FTAX0")/TY0;
 retr           =ParamB("K","RETENT0")/sum(i,VAD(i,"K"));
 ibtax(mk)      =ParamA("IBT0",mk)/(PR0(mk)*X0(mk));
 et                        =ENTTAX0/KY0;
 hhtax              =ParamC("HOUSE","HTAX0")/YH0 ;
 mps                =ParamC("HOUSE","HSAV0")/YH0 ;

*@Expenditure block
* (3.2.17)
 RHOq(ci) = 1-1/ParamA("SIGMAq",ci);
* (3.2.19)
 deltaq1(ci)$NZQ(ci) = (QR0(ci)/QM0(ci))**(1-RHOq(ci))*(PR0(ci)/PM0(ci));
 deltaq(ci)$NZQ(ci) =1/(1+deltaq1(ci));
* (3.2.20)
 Aq(ci)$NzQ(ci)                 =                  Q0(ci)/(deltaq(ci)*QM0(ci)**RHOq(ci)+(1-
deltaq(ci))*QR0(ci)**RHOq(ci))**(1/RHOq(ci));

*#:) Note 10.      For government and investment the paramenter are calibrated in a
*                           similar way as before.

 RHOgov(ci) = 1-1/ParamA("SIGMAgov",ci);
 deltagov1(ci)$NZGOV(ci)  =(QGOVR0(ci)/QGOVM0(ci))**(1-RHOgov(ci))*(PR0(ci)/PM0(ci));
 deltagov(ci)$NZGOV(ci) = 1/(1+deltagov1(ci));
 Agov(ci)$NZGOV(ci)            =            QGOV0(ci)/(deltagov(ci)*QGOVM0(ci)**RHOgov(ci)+(1-
deltagov(ci))*QGOVR0(ci)**RHOgov(ci))**(1/RHOgov(ci));
 RHOinv(ci)= 1-1/ParamA("SIGMAinv",ci);
 deltainv1(ci)$NZInv(ci) = (QINVR0(ci)/QINVM0(ci))**(1-RHOinv(ci))*(PR0(ci)/PM0(ci));
 deltainv(ci)$NZInv(ci) = 1/(1+deltainv1(ci));
 Ainv(ci)$NZInv(ci)            =              QINV0(ci)/(deltainv(ci)*QINVM0(ci)**RHOinv(ci)+(1-
deltainv(ci))*QINVR0(ci)**RHOinv(ci))**(1/RHOinv(ci));
* (3.2.14)
 beta(i) = Q0(i)*P0(i)/HEXP0;
 drs=alpha("RM","L")+alpha("RM","K");
 esup=DRS/(1-DRS);
 prof0=v0("rm","fpi")*(1/esup);
 YENT0=KY0+PROF0-ktax*KY0;
 RETENT0=retr*KY0;


PARAMETER CALIBR PARAMETER CALIBRATED;
```

```
CALIBR(I,"A0")=A0(I);
CALIBR(I,"AVA")=AVA(I);
CALIBR(I,"RHOV")=RHOv(I);
CALIBR(I,"RHOQ")=RHOQ(I);
CALIBR(I,"DELTAQ")=DELTAQ(I);
CALIBR(I,"AQ")=AQ(I);
CALIBR(I,"IBTAX")=IBTAX(I);
CALIBR(I,"RHOGOV")=RHOGOV(I);
CALIBR(I,"DELTAGOV")=DELTAGOV(I);
CALIBR(I,"AGOV")=AGOV(I);
CALIBR(I,"RHOINV")=RHOINV(I);
CALIBR(I,"AINV")=AINV(i);
CALIBR(I,"RHOX")=RHOX(i);
CALIBR(I,"DELTAX")=DELTAX(i);
CALIBR(I,"AX")=AX(i);
CALIBR(I,"BETA")=BETA(i);
DISPLAY CALIBR;
OPTION DECIMALS=3;
DISPLAY a,Av,deltav,alpha,
ktax,sstax,ttax,retr,et,mps,hhtax,drs,esup,prof0,yent0, RETENT0;


*##############################################################*
*                                   *
*    SECTION TREE: VARIABLE DECLARATION              *
*                                   *
*##############################################################*

* ENDOGENOUS VARIABLES

VARIABLES
 Z          Objective Function Value
 Prof       profits of the monopsonist
*@Price block
 PL          Wage rate
 PK(i)        cap rate
 PT(i)       Land rent
 PN(i)        Net output price
 PR(i)        Regional price
 P(i)        Composite price
 PX(i)        Composite price faced by consumers

*@Production block
 LAB(i)        Labor demand
 CAP(i)        capital demand
 LAND(ag)        Land demand
 TCAP          Total Capital Demand
 TLAB          Total Labor Demand
 TLAND                    Total land demand
 LS          Labor supply
 TLSrat        lab supply ratio
 ALS          Adj labor supply
 LMIG          Labor migration
 Mratio        Migr compared to initial lab supply
 KMIG          Capital migration
 VA(i)        Value added
```

V(j,i)	Composite intermediate good demand
VM(j,i)	Imported int good demand
VR(j,i)	Reg int good demand
R(i)	Regional supply
X(i)	Output
EXP(ie)	Export
M(im)	Import
TVM(i)	Imported int good total demand
TVR(i)	Reg int good total demand
TV(i)	Composite intermediate good total demand
adjL	Labor adjustment
adjK	Capital adjustment

*@Income block

LY	Labor income (original hhs)
ALY	Adjusted labor income (staying + in-migrating)
KY	capital income (original capital stock)
TY	Land income
YENT	Enterprise income
RETENT	Retained Earnings by enterprises
TYH	Total hh income
YH	Income of hh staying in the region (including in-migrants)
AYH	Adjusted hh income (original hh including out-migrating)
AYHtra	Adj. hh income net of transfers for original hh
DYH	Disposable hh income (staying in the region + inmigra)
HSAV	Household saving (staying +inmigrat)
SAV	Total saving
ROWSAV	Saving from rest-of-world
INV	Investment
YGOV	gov revenue
GOVBOR	gov borrowing
IBTX	Indirect business tax
GRP	Gross region product

*### Expenditure block

HEXP	Household expenditure
AHEXP	Adjusted household expenditure (spent within the region)
Q(i)	Demand for comp consump good
QM(i)	Demand for imp consump good
QR(i)	Demand for reg consump good
ADQ(i)	Adj demand for comp consump good
AQM(i)	Adj demand for imp consump good
AQR(i)	Adj demand for reg consump good
TQ(i)	Total demand for comp consump good
TQM(i)	Total demand for imp consump good
TQR(i)	Total demand for reg consump good
GOVEXP	gov expend
QGOV(i)	gov demand for comp good
QGOVM(i)	gov demand for imported good
QGOVR(i)	gov demand for reg good
QINV(i)	Invest gov demand for comp good
QINVM(i)	Invest gov demand for imported good
QINVR(i)	Invest gov demand for reg good
SLACK(i)	
SLACK2(i)	

```
POSITIVE VARIABLE   SLACK, SLACK2;

*################################################################*
*                                              *
*    SECTION FOUR: EQUATION DECLARATION                *
*                                              *
*################################################################*

*#:) Note 11.      This section declares the equations of the model
*                             which are those presented in table 5.1

EQUATIONS
 EQZ           objective function

*@Price block
 NETprice(we)     net price
 Price(im)       composite price
 Price1(ie)
 Price2(nwe)
*  Price3(nwe)      condition for the monopsony
 Profit      profits of the monopsonist
 KPrice

*@Production block
 Ldemand(mk)      labor demand
 Kdemand(mk)      capital demand
 Tdemand(ag)      land demand
 TLdem          total labor demand
 TKdem          total capital demand
 TTdem            total land demand
 VAdemand(i)      value added demand
 Vdemand(j,i)     intermediate demand
 VAprod1(nag)     value added prod fc
 VAprod2(ag)      value added prod fc
 Vces(ml,mk)      ces fc for int demand
 TVdemand(i)      intermediate total demand
 TVRdemand(i)      int reg total demand
 TVMdemand(i)      int imp total demand
 VRdem(j,i)       demand for reg int good
 VRdem0(j,i)      demand for reg int good for goods with zero import
 VMDem0(j,i)      demand for imp int good for goods with zero import
 Xcet(ie)       cet fc for reg product
 Xcet1(nwe)          cet function for regional product that are not exported
 Rsupply(ie)      reg supply of reg product
 Rsupply1(nwe)    regional supply of sectors without exports
 LSupply         labor supply
 ALSupply         adjusted labor supply
 LMIGrat         labor migration
 TLSratio        labor supply ratio
 MIGratio        migration compared to initial labor supply
 adjustL        labor migration adjustment
 KMIGrat         capital migration
 KMIGrat1
 AdjustK        capital migration adjustment

*@Income block
```

LYincome labor income
ALYincome adjusted labor income
KYincome capital income
TYincome land income
YENTincome enterprise income
RETearn Retained earning by enterprises
YHincome household income
AYHinc Adjusted hh income
AYHNtran AYH net of transfer income
TYHinc
DHYincome disposable income
HSAVings household savings
SAVings total savings
INVest total investment
YGOVincome Government income
INDtax Indirect business tax
GRProduct gross region product

*@Expenditure block
AHEXPLow adj. household expenditure
HEXPend household expenditure
Qces ces fc for consumption
Qdemand cons demand for composite good
QRdem0 cons demand for reg goods
AQdemand adj Qdemand
AQMdemand adj QMdemand
AQRdemand adj QRdemand
TQdemand total Qdemand
TQRdemand total QRdemand
TQMdemand total QMdemand
GOVEXPend Gov expenditure
QGOVces ces for st and loc gov demand
QGOVdemand st and loc gov cons
QGOVRdem0 st and loc gov reg cons
QGOVRDem1
QGOVRDem2
QGOVMDem1
QGOVMDem2
QINVces ces for invest gov demand
QINVemand invest gov cons
QINVRdem0 invest gov reg cons
QInvRdem1
QInvRdem2
QInvMdem1
QInvMdem2
Mimports import

*@Equilibrium
COMMequil(ie) comm market equilibrium
COMMequil2(nwe) forest market equilibrium
Lequil labor market equilibrium
Kequil(i) cap market equilibrium
Kequil1
Tequil(i) land market equilibrium
;

```
*##########################################################*
*                                   *
*    SECTION FIVE: EQUATION DEFINITION              *
*                                   *
*##########################################################*

*#:) Note 12.     All equation are defined following the algebraic structure
*                        of table 5.1. This section requires special attention and
*                        intense scrutiny.

 EQZ..        Z      =e= sum(i,SLACK(i)+SLACK2(i));

*@Price block

 NETprice(we)..                PN(we)              =e=      PX(we)*(1-ibtax(we))-sum(ie,A(ie,we)*P(ie))-
A("RM",we)*PR("RM")*(1+1/esup);
 Price(im)..    P(im)  =e= (PR(im)*R(im)+PM0(im)*M(im))/(R(im)+M(im));
 Price1(ie)..   PX(ie)  =e= (PR(ie)*R(ie)+PE0(ie)*EXP(ie))/(R(ie)+EXP(ie));
 price2(nwe)..  PN(nwe) =e= PR(nwe)*(1-ibtax(nwe)-sum(we,A(we,nwe)*P(we)));
 profit("fpi")..  prof("fpi")=e=V("rm","fpi")*pr("rm")/esup;


*@Production block
 Ldemand(mk)..   LAB(mk) =e= alpha(mk,"L") *PN(mk)*X(mk)/PL;
 Kdemand(mk)..   CAP(mk) =e= alpha(mk,"K")*PN(mk)*X(mk)/PK(mk);
 Tdemand(ag)..  LAND(ag)=e= alpha(ag,"T") *PN(ag)*X(ag)/PT(ag);
 TLdem..        TLAB  =e= Sum(mk,LAB(mk));
 TKdem..        TCAP  =e= Sum(mk,CAP(mk));
 TTdem..          TLAND =e= sum(ag,LAND(ag));
 LSupply ..     LS   =e= ls0;
 LMIGrat ..     LMIG    =e= etaL*LS0*LOG(PL/PLROC0);

*#:) Note 13.     When more than one household group is in play, there is need for
*                        summing up throug out income group. In our exaple, however, we only
*                        have one income group therefore you will find some retuntance in the
*                        definition of variables, e.i., LS and TLS are the same variable.

 TLSratio..     TLSrat =e= LS/LS0;
 MIGratio..     Mratio  =e= LMIG/LS0;
 adjustL..     adjL   =e= (LS0+LMIg)/LS0;
 ALSupply ..   ALS   =e= LS +LMIG ;
 KMIGrat$(KMobil)..  KMIG  =e=etaK*(SUM(mk,K0(mk))*LOG(PK("Agr")/PKROC0));
 KMIGrat1$(not KMobil).. KMIG      =e= 0;
 AdjustK..      AdjK     =e= (TKS0+KMIG)/TKS0;

*#:) Note 14.     Note that with capital mobility, price of capital
*             in all sectors are set equal to each other at equilibrium
*                        thus PK("Agr") is the overall capital price.  Under capital
*                        immobility, in or out-migration of capital is not allowed.

 VAdemand(i)..   VA(i)+SLACK(i)+SLACK2(i)=e= a0(i)*X(i);

 VAprod1(nag).. VA(nag)  =e= Ava(nag)*LAB(nag)**alpha(nag,"L")*CAP(nag)**
                    alpha(nag,"K");

 VAprod2(ag)..   VA(ag)    =e= Ava(ag)*LAB(ag)**alpha(ag,"L")*CAP(ag)**
```

```
                   alpha(ag,"K")*LAND(ag)**alpha(ag,"T");
Vdemand(j,i)..  V(j,i)  =e= a(j,i)*X(i);

TVdemand(i)..   TV(i)  =e= sum(j,V(i,j));


Vces(ml,mk)$NZV(ml,mk)..    V(ml,mk)  =e= Av(ml,mk)*(deltav(ml,mk)*VM(ml,mk)
                   **RHOv(ml)+(1-deltav(ml,mk))
                   *VR(ml,mk)**RHOv(ml))**(1/RHOv(ml));

VRdem(j,i)$NZV(j,i)..  VR(j,i) =e= VM(j,i)*((1-deltav(j,i))/deltav(j,i)*PM0(j)/PR(j))**(1/(1-RHOv(j)));
VRdem0(j,i)$ZVM(j,i)..  VR(j,i) =e= V(j,i);
VMdem0(j,i)$ZVM(j,i)..  VM(j,i) =e= 0;

TVRdemand(i)..  TVR(i)  =e= sum(j,VR(i,j));
TVMdemand(i)..  TVM(i)  =e= sum(j,VM(i,j));
Xcet(ie)..     X(ie)  =e= Ax(ie)*(deltax(ie)*EXP(ie)**RHOx(ie)+(1-
                   deltax(ie))*R(ie)**RHOx(ie))
                   **(1/RHOx(ie));
xcet1(nwe)..       X(nwe)  =e= tvr(nwe);
Rsupply(ie)..   R(ie)  =e= EXP(ie)*((1-DELTAx(ie))/DELTAx(ie)
                   *PE0(ie)/PR(ie))**(1/(1-RHOx(ie)));

rsupply1(nwe)..  R(nwe)  =e= X(nwe);

INDtax..      IBTX   =E= Sum(i,ibtax(i)*X(i));
GRProduct..    GRP    =e= ALY + Sum(mk,PK(mk)*CAP(mk))+ TY +IBTX;


*@Income block
*#:) Note 15.      ALY is defined for labor staying in the region and LY is for original hh
*                        including those out-migrated.  Out migrating labor earns out-of-region
*                        rent; in-migrating labor receives prevailing wage rate and deducted
*                        from LY.

ALYincome..     ALY      =e=  PL*(SUM(I,LAB(i))+LHHH0+LGOV0);


LYincome..    LY     =e= PL*(TLAB+LHHH0+LGOV0)+PLROC0*(SQRT(LMig**2)-LMig)*0.5
              -PL*(SQRT(LMig**2)+LMig)*0.5;

***KY is defined for initial capital stock.  Out migrating capital earns
***out-of-region rent; The rent for in-migrating capital leaves the region.

KYincome..  KY  =e= sum(mk,PK(mk)*CAP(mk))+PKROC0*(SQRT(KMIG**2)-KMIG)
             *0.5-PK("Agr")*(SQRT(KMIG**2)+KMIG)*0.5;

RETearn..    RETENT  =e= retr*KY;
TYincome..     TY     =e= sum(ag,PT(ag)*LAND(ag));
YENTincome..    YENT   =e= KY*(1-ktax)+PROF("FPI");

***Household income is defined for households in the region including
***those in-migrated. In-migrating labor also qualify for TRGOV.

YHincome ..  YH   =e= PL*(LS +LMig )*(1-sstax)
             +TY*(1-ttax)+(YENT-RETENT-et*KY)
```

```
                 +REMIT0+adjL*TRGOV0
                 -((SQRT(Mratio**2)-Mratio)*0.5)
                 *(TY*(1-ttax)+(YENT-RETENT-et*KY)
                  +REMIT0);

 TYHinc..        TYH    =e= YH;

*** Adjusted hh income is defined for original hh including out-migrating.

 AYHinc ..  AYH   =e= PL*(LS +LMig )*(1-sstax)
                   +((SQRT(LMig **2)-LMig )/2
                 -PL*(SQRT(LMig **2)+LMig )/2)*(1-sstax)
                 +TY*(1-ttax)+(YENT-RETENT-et*KY)
                  +TRGOV0 +REMIT0
                  ;


 AYHNtran ..  AYHtra   =e= PL*(LS +LMig )*(1-sstax)
                   +((SQRT(LMig **2)-LMig )/2
                 -PL*(SQRT(LMig **2)+LMig )/2)*(1-sstax)
                 +TY*(1-ttax)+(YENT-RETENT-et*KY);

***DYH, HSAV, and SAV are defined for households in the region including
***those in-migrated.

 DHYincome ..  DYH  =e= YH *(1-hhtax );
 HSAVings ..   HSAV  =e= mps *YH ;
 SAVings..     SAV    =e= HSAV +RETENT+ROWSAV;
 INVest..      INV    =e= sum(we,P(we)*QINV(we));
 YGOVincome..    YGOV    =e= Sum(mk,ibtax(mk)*PR(mk)*X(mk))
                   +sstax*PL*(TLAB+LHHH0+LGOV0)
                   +ktax*Sum(mk,PK(mk)*CAP(mk))+et*KY
                   +ttax*TY+hhtax*YH+ROWGOV0+GOVITR0;


*@Expenditure block
 AHEXPLow..  AHEXP  =e= DYH-HSAV-PL*LHHH0;
***AHEXP  represents amount spent by hh within the impact region
***it is proportional to the # of hh rather than labor supplied.

 HEXPend ..  HEXP  =e=AHEXP /adjL;

***Minimum requirement, gamma, is adjusted for migrating hh

 Qdemand(ci)..  Q(ci)   =e= beta(ci)*AHEXP/P(ci);

 AQdemand(ci).. ADQ(ci)  =e= Q(ci)/adjL;

 Qces(ci)$NZQ(ci).. Q(ci)  =e= Aq(ci)*(deltaq(ci)*QM(ci)
          **RHOq(ci)+(1-deltaq(ci))*QR(ci)**RHOq(ci))
                      **(1/RHOq(ci));
 QRdem0(ci)$NZQ(ci).. QR(ci) =e= QM(ci)*((1-deltaq(ci))/deltaq(ci)
                    *PM0(ci)/PR(ci))**(1/(1-RHOq(ci)));
 AQMdemand(ci).. AQM(ci) =e= QM(ci)/adjL;
 AQRdemand(ci).. AQR(ci) =e= QR(ci)/adjL;
 TQRdemand(ci)..  TQR(ci)  =e= QR(ci);
```

```
TQMdemand(ci)..  TQM(ci)  =e= QM(ci);
TQdemand(ci)..   TQ(ci)   =e= TQR(ci)+TQM(ci);

GOVEXPend..      GOVEXP    =e= sum(we,P(we)*QGOV(we))+adjL*
                 TRGOV0+PL*LGOV0+GOVITR0;
QGOVdemand(mk)..  QGOV(mk)  =e= QGOV0(mk);

QGOVces(mk)$NZGOV(mk)..   QGOV(mk)  =e= Agov(mk)*(deltagov(mk)
                *QGOVM(mk)**RHOgov(mk)+(1-deltagov(mk))
                *QGOVR(mk)**RHOgov(mk))**(1/RHOgov(mk));
QGOVRdem0(mk)$NZGOV(mk)..  QGOVR(mk) =e=QGOVM(mk)*((1-deltagov(mk))
        /deltagov(mk)*PM0(mk)/PR(mk))**(1/(1-RHOgov(mk)));
QGOVRdem1(mk)$ZGOVM(mk)..  QGOVM(mk) =e= 0;
QGOVMdem1(mk)$ZGOVM(mk)..  QGOVR(mk) =e= QGOV(mk);
QGOVRdem2(mk)$ZGOVR(mk)..  QGOVR(mk) =e= 0;
QGOVMdem2(mk)$ZGOVR(mk)..  QGOVM(mk) =e= QGOV(mk);

QINVemand(mk)..  QINV(mk)  =e= QINV0(mk);

QINVces(mk)$NZInv(mk)..  QINV(mk) =e=Ainv(mk)*(deltainv(mk)*QINVM(mk)
          **RHOinv(mk)+(1-deltainv(mk))*QINVR(mk)**RHOinv(mk))
             **(1/RHOinv(mk));
QINVRdem0(mk)$NZInv(mk).. QINVR(mk)=e= QINVM(mk)*((1-deltainv(mk))
          /deltainv(mk)*PM0(mk)/PR(mk))**(1/(1-RHOinv(mk)));
QInvRDem1(mk)$ZInvM(mk).. QInvM(mk)=e= 0;
QInvMDem1(mk)$ZInvM(mk).. QInvR(mk)=e= QInv(mk);
QInvRDem2(mk)$ZInvR(mk).. QInvR(mk)=e= 0;
QInvMDem2(mk)$ZInvR(mk).. QInvM(mk)=e= QInv(mk);

Mimports(im)..  M(im)   =e= TVM(im)+TQM(im)+QGOVM(im)+QINVM(im);

*@Equilibrium
COMMequil(ie).. X(ie)+M(ie)=e=TV(ie)+TQ(ie)+QGOV(ie)+QINV(ie)+EXP(ie);
commequil2(nwe).. X(nwe)=e= TV(nwe);
Lequil..      sum(mk,LAB(mk))+LHHH0+LGOV0 =e= LS+LMIG;
Kequil1$(KMobil)..     KMig         =e= Sum(mk,CAP(mk)-KS0(mk));
Kprice(mk)$(KMobil)..  PK(mk)       =e= PK("Agr");

Kequil(mk)$(not KMobil).. CAP(mk)       =e= KS0(mk);
Tequil(ag)..    LAND(ag)  =e= TS0(ag);


*##############################################################*
*                                                      *
*    SECTION SIX: INITIALIZATION OR STARTING VALUES      *
*                                                      *
*##############################################################*
*@Price block              *@Income block
PL.L      =PL0    ;
PK.L(i)  =PK0(i)   ;
PT.L(ag)   =PT0(ag)  ;       HSAV.L  =HSAV0        ;
PR.L(i)   =PR0(i)   ;       YGOV.L     =YGOV0      ;
P.L(im)    =P0(im)    ;      GOVBOR.L  =GOVBOR0    ;
PX.L(i)   = PX0(i)   ;
PN.L(mk)     = PR0(mk)-sum(ml,A(ml,mk)*P0(ml))-ibtax(mk)*PR0(mk);
```

```
*@Production block
 SLACK.L(i) =0;                    SLACK2.L(i)  =0;
 LAB.L(mk)  =L0(mk)   ;   INV.L     =INV0;
 CAP.L(mk) =K0(mk)  ;     GRP.L     =GRP0;
*                   *@Expenditure block
 LAND.L(ag) =T0(ag)   ;
 TQM.L(ci)  =TQM0(ci)   ;
 LS.L     = LS0;
 Mratio.L  =0;
 LMIG.L  =0;
 KMIG.L   =0;
 VA.L(mk)  =VA0(mk)  ;       HEXP.L  =HEXP0    ;
 VM.L(j,i)  =VM0(j,i) ;
 VR.L(j,i)  =VR0(j,i)  ;      QM.L(mk) =QM0(mk)  ;
 V.L(j,i)  =V0(j,i)  ;      TQ.L(ci)  =TQ0(ci)    ;
 TVM.L(i)  =TVM0(i)  ;       TQR.L(ci)  =TQR0(ci)   ;
 TVR.L(i)  =TVR0(i)  ;       GOVEXP.L   =GOVEXP0    ;
 TV.L(i)   =TV0(i)   ;      QGOV.L(mk)  =QGOV0(mk)   ;
 R.L(ci)   =R0(ci)   ;     QGOVM.L(mk) =QGOVM0(mk)  ;
 X.L(i)    =X0(i)    ;     QGOVR.L(mk) =QGOVR0(mk)  ;
 EXP.L(ie)  =E0(ie)   ;
 M.L(im)   =M0(im)   ;
 Q.L(ci)   =beta(ci)*HEXP0/PX0(ci);
 QR.L(ci) =QR0(ci)  ;

*@Income block
 LY.L    =LY0     ;
 KY.L     =KY0      ;
 TY.L     =TY0     ;
 adjL.L   =1    ;
 adjK.L   =1;
 YENT.L    =YENT0    ;
 YH.L    =YH0   ;
 SAV.L     =SAV0     ;
 ROWSAV.L  =ROWSAV0   ;
 DYH.L    =DYH0   ;
 QINVM.L(mk) =QINVM0(mk) ;
 QINVR.L(mk) =QINVR0(mk) ;
 QINV.L(mk)  =QINV0(mk)  ;
 PROF.L("fpi")=PROF0;

*############################################################*
*                                   *
*    SECTION SEVEN: VARIABLE BOUNDS                    *
*                                   *
*############################################################*

 PL.LO      = 0.000001;
 PT.LO(i)    = 0.000001;
 PK.LO(i)  =  0.000001;
 PR.LO(i)   = 0.000001;
 PN.LO(mk)   = 0.000001;
 P.LO(i)    = 0.000001;
 R.LO(ci)    = 0.000001;
 PX.LO(i)  =  0.000001;
```

```
QM.LO(i)$(QM0(i) ne 0)  = 0.000001;
QR.LO(i)$(QR0(i) ne 0)  = 0.000001;
Q.LO(i)$(Q0(i) ne 0)    = 0.000001;

QM.LO(i)$(QM0(i) eq 0)  = 0;
QR.LO(i)$(QR0(i) eq 0)  = 0;
Q.LO(i)$(Q0(i) eq 0)    = 0;

VR.LO(i,j)$(VR0(i,j) ne 0)  = 0.000001;
VM.LO(i,j)$(VM0(i,j) ne 0)  = 0.000001;
V.LO(i,j)$(V0(i,j) ne 0)    = 0.000001;

VR.LO(i,j)$(VR0(i,j) eq 0)  = 0;
VM.LO(i,j)$(VM0(i,j) eq 0)  = 0;
V.LO(i,j)$(V0(i,j) eq 0)    = 0;


OPTIONS ITERLIM=5000, LIMROW=0, LIMCOL=0, SOLPRINT=OFF;
*-- MODEL DEFINITION AND SOLVE STATEMENT

MODEL CGE791 /ALL/;
SOLVE CGE791 MINIMIZING Z USING NLP;

*-- SOLUTION DISPLAY STATEMENT
*-- SOLUTION VALUES OF ENDOGENOUS VARIABLES


PARAMETER VALID VALUES FOR THE VALIDATION OF THE MODEL;
VALID(i,"SLACK1") = SLACK.L(i);
VALID(i,"SLACK2") = SLACK2.L(i);
VALID(i,"PR") = PR.L(i);
VALID(i,"P") = P.L(i);
VALID(i,"PN") = PN.L(i);
VALID(i,"PK") = PK.L(i);
VALID(ag,"PT") = PT.L(ag);
VALID(i,"PX") = PX.L(i);
VALID(i,"PE") = PE0(i);
VALID(I,"PM")= PM0(I);
VALID("fpi","PROF")=PROF.L("fpi");
VALID(i,"X") = X.L(i);
VALID(i,"R") = R.L(i);
VALID(ie,"EXP") =EXP.L(ie);
VALID(im,"M") = M.L(im);
VALID(i,"VA") = VA.L(i);
VALID(i,"LAB") =LAB.L(i);
VALID(i,"CAP") =CAP.L(i);
VALID(ag,"LAND") =LAND.L(ag);
VALID(i,"TVR") =TVR.L(i);
VALID(i,"TVM") =TVM.L(i);
VALID(i,"TV") =TV.L(i);
VALID(i,"Q") =Q.L(i);
VALID(i,"QR") =QR.L(i);
VALID(i,"QM") =QM.L(i);
```

```
VALID(i,"TQ") =TQ.L(i);
VALID(i,"TQR") =TQR.L(i);
VALID(i,"TQM") =TQM.L(i);
VALID(i,"ADQ") =ADQ.L(i);
VALID(i,"AQM") =AQM.L(i);
VALID(i,"AQR") =AQR.L(i);
VALID(i,"QGOV") =QGOV.L(i);
VALID(i,"QGOVR") =QGOVR.L(i);
VALID(i,"QGOVM") =QGOVM.L(i);
VALID(i,"QINV") =QINV.L(i);
VALID(i,"QINVR") =QINVR.L(i);
VALID(i,"QINVM") =QINVM.L(i);

PARAMETER PRODUCT2 -PRODUCTION SYSTEMS VARIABLES-;
PRODUCT2(I,"AGR","V")=V.L(I,"AGR");
PRODUCT2(I,"MIN","V")=V.L(I,"MIN");
PRODUCT2(I,"MAN","V")=V.L(I,"MAN");
PRODUCT2(I,"SER","V")=V.L(I,"SER");
PRODUCT2(I,"RM","V")=V.L(I,"RM");
PRODUCT2(I,"FPI","V")=V.L(I,"FPI");
PRODUCT2(I,"AGR","VR")=VR.L(I,"AGR");
PRODUCT2(I,"MIN","VR")=VR.L(I,"MIN");
PRODUCT2(I,"MAN","VR")=VR.L(I,"MAN");
PRODUCT2(I,"SER","VR")=VR.L(I,"SER");
PRODUCT2(I,"RM","VR")=VR.L(I,"RM");
PRODUCT2(I,"FPI","VR")=VR.L(I,"FPI");
PRODUCT2(I,"AGR","VM")=VM.L(I,"AGR");
PRODUCT2(I,"MIN","VM")=VM.L(I,"MIN");
PRODUCT2(I,"MAN","VM")=VM.L(I,"MAN");
PRODUCT2(I,"SER","VM")=VM.L(I,"SER");
PRODUCT2(I,"RM","VM")=VM.L(I,"RM");
PRODUCT2(I,"FPI","VM")=VM.L(I,"FPI");

PARAMETER OTHER1 MARKET CLEARING VALEUES OF VARIABLES;
OTHER1("OBJECTIVE") = Z.L;
OTHER1("PL") = PL.L;
OTHER1("LMIG")=LMIG.L;
OTHER1("KMIG")=KMIG.L;
OTHER1("TCAP")=TCAP.L;
OTHER1("TLAB")=TLAB.L;
OTHER1("TLAND")=TLAND.L;
OTHER1("LS")=LS.L;
OTHER1("TLSRAT")=TLSRAT.L;
OTHER1("ALS")=ALS.L;
OTHER1("MRATIO")=MRATIO.L;
OTHER1("ADJL") = ADJL.L;
OTHER1("ADJK")=ADJK.L;
OTHER1("LY")=LY.L;
OTHER1("ALY")=ALY.L;
OTHER1("KY")=KY.L;
OTHER1("TY")=TY.L;
OTHER1("YENT") = YENT.L;
OTHER1("RETENT")=RETENT.L;
OTHER1("TYH")=TYH.L;
OTHER1("YH")=YH.L;
OTHER1("AYH")=AYH.L;
```

```
OTHER1("PL") = PL.L;
OTHER1("AYHTRA")=AYHTRA.L;
OTHER1("DYH")=DYH.L;
OTHER1("HSAV")=HSAV.L;
OTHER1("SAV")=SAV.L;
OTHER1("ROWSAV")=ROWSAV.L;
OTHER1("INV") = INV.L;
OTHER1("YGOV")=YGOV.L;
OTHER1("GOVEXP")=GOVEXP.L;
OTHER1("GOVBOR")=GOVBOR.L;
OTHER1("IBTX")=IBTX.L;
OTHER1("GRP")=GRP.L;
OTHER1("HEXP")=HEXP.L;
OTHER1("AHEMP")=AHEXP.L;

option decimals=3;

DISPLAY VALID, OTHER1;


****************************
* HERE STARTS SIMULATION   *
****************************


esup=20000;
model simul1 /all/;
solve simul1 minimizing z using nlp;

OPTION SOLPRINT=OFF;

*-- SOLUTION DISPLAY STATEMENT
*-- SOLUTION VALUES OF ENDOGENOUS VARIABLES


PARAMETER SIMUL VALUES FOR THE SIMULATION;
SIMUL(i,"SLACK1") = SLACK.L(i);
SIMUL(i,"SLACK2") = SLACK2.L(i);
SIMUL(i,"PR") = PR.L(i);
SIMUL(i,"P") = P.L(i);
SIMUL(i,"PN") = PN.L(i);
SIMUL(i,"PK") = PK.L(i);
SIMUL(ag,"PT") = PT.L(ag);
SIMUL(i,"PX") = PX.L(i);
SIMUL(i,"PE") = PE0(i);
SIMUL(I,"PM")= PM0(I);
SIMUL(i,"X") = X.L(i);
SIMUL(i,"R") = R.L(i);
SIMUL(ie,"EXP") =EXP.L(ie);
SIMUL(im,"M") = M.L(im);
SIMUL(i,"VA") = VA.L(i);
SIMUL(i,"LAB") =LAB.L(i);
SIMUL(i,"CAP") =CAP.L(i);
SIMUL(ag,"LAND") =LAND.L(ag);
SIMUL(i,"TVR") =TVR.L(i);
```

```
SIMUL(i,"TVM") =TVM.L(i);
SIMUL(i,"TV") =TV.L(i);
SIMUL(i,"Q") =Q.L(i);
SIMUL(i,"QR") =QR.L(i);
SIMUL(i,"QM") =QM.L(i);
SIMUL(i,"TQ") =TQ.L(i);
SIMUL(i,"TQR") =TQR.L(i);
SIMUL(i,"TQM") =TQM.L(i);
SIMUL(i,"ADQ") =ADQ.L(i);
SIMUL(i,"AQM") =AQM.L(i);
SIMUL(i,"AQR") =AQR.L(i);
SIMUL(i,"QGOV") =QGOV.L(i);
SIMUL(i,"QGOVR") =QGOVR.L(i);
SIMUL(i,"QGOVM") =QGOVM.L(i);
SIMUL(i,"QINV") =QINV.L(i);
SIMUL(i,"QINVR") =QINVR.L(i);
SIMUL(i,"QINVM") =QINVM.L(i);
SIMUL("fpi","PROF")=PROF.L("fpi");

PARAMETER PRODUCT2 -PRODUCTION SYSTEMS VARIABLES-FOR SIMULATION;
PRODUCT2(I,"AGR","V")=V.L(I,"AGR");
PRODUCT2(I,"MIN","V")=V.L(I,"MIN");
PRODUCT2(I,"MAN","V")=V.L(I,"MAN");
PRODUCT2(I,"SER","V")=V.L(I,"SER");
PRODUCT2(I,"RM","V")=V.L(I,"RM");
PRODUCT2(I,"FPI","V")=V.L(I,"FPI");
PRODUCT2(I,"AGR","VR")=VR.L(I,"AGR");
PRODUCT2(I,"MIN","VR")=VR.L(I,"MIN");
PRODUCT2(I,"MAN","VR")=VR.L(I,"MAN");
PRODUCT2(I,"SER","VR")=VR.L(I,"SER");
PRODUCT2(I,"RM","VR")=VR.L(I,"RM");
PRODUCT2(I,"FPI","VR")=VR.L(I,"FPI");
PRODUCT2(I,"AGR","VM")=VM.L(I,"AGR");
PRODUCT2(I,"MIN","VM")=VM.L(I,"MIN");
PRODUCT2(I,"MAN","VM")=VM.L(I,"MAN");
PRODUCT2(I,"SER","VM")=VM.L(I,"SER");
PRODUCT2(I,"RM","VM")=VM.L(I,"RM");
PRODUCT2(I,"FPI","VM")=VM.L(I,"FPI");

PARAMETER OTHER1 MARKET CLEARING VALEUES OF VARIABLES FOR SIMULATION;
OTHER1("OBJECTIVE") = Z.L;
OTHER1("PL") = PL.L;
OTHER1("LMIG")=LMIG.L;
OTHER1("KMIG")=KMIG.L;
OTHER1("TCAP")=TCAP.L;
OTHER1("TLAB")=TLAB.L;
OTHER1("TLAND")=TLAND.L;
OTHER1("LS")=LS.L;
OTHER1("TLSRAT")=TLSRAT.L;
OTHER1("ALS")=ALS.L;
OTHER1("MRATIO")=MRATIO.L;
OTHER1("ADJL") = ADJL.L;
OTHER1("ADJK")=ADJK.L;
OTHER1("LY")=LY.L;
OTHER1("ALY")=ALY.L;
OTHER1("KY")=KY.L;
```

```
OTHER1("TY")=TY.L;
OTHER1("YENT") = YENT.L;
OTHER1("RETENT")=RETENT.L;
OTHER1("TYH")=TYH.L;
OTHER1("YH")=YH.L;
OTHER1("AYH")=AYH.L;
OTHER1("PL") = PL.L;
OTHER1("AYHTRA")=AYHTRA.L;
OTHER1("DYH")=DYH.L;
OTHER1("HSAV")=HSAV.L;
OTHER1("SAV")=SAV.L;
OTHER1("ROWSAV")=ROWSAV.L;
OTHER1("INV") = INV.L;
OTHER1("YGOV")=YGOV.L;
OTHER1("GOVEXP")=GOVEXP.L;
OTHER1("GOVBOR")=GOVBOR.L;
OTHER1("IBTX")=IBTX.L;
OTHER1("GRP")=GRP.L;
OTHER1("HEXP")=HEXP.L;
OTHER1("AHEMP")=AHEXP.L;

option decimals=3;

DISPLAY SIMUL,PRODUCT2, OTHER1;



* Parameters AS INDEX WITH 1993=1.000
PARAMETERS
* -- Price block
 IPL         Wage rate index
 IPK(i)      Rent to  capital index
 IPT(i)      Land rent index
 IPR(i)      Regional price index
 IP(i)       Composite price index

* -- Production block
 IL(i)       Labor demand index
 ITL         Total labor demand index
 ILS         Labor supply index
 IK(i)       capital demand index
 ITK         Total Capital use index
 ITT         Total Land use index
 IT(i)       Land demand index
 IVA(i)      Value added index
 IX(i)       Output index
 ITVA        Total Value added index
 ITX         Total Output index
 ITE         Total Export index
 ITR         Total Reg. supply index
 ITM         Total Import index

 IVM(j,i)    Imported intermediate demand index
 IVR(j,i)    Regional interm demand index
 IR(i)       Regional supply index
 IEXP(ie)    Export index
```

```
IIMP(IM)          Import index

* -- Income block
 ITYH          Total household income index
 IYH          Household (in the region) income index
 YHch          Change in hh income
 AYHch          Change in Adjusted Household income
 IAYH          Index for adjusted hh income
 TAYH          Total Adjusted hh income
 IAYHtra          Adjusted Household income net of TRANSFER index
 IDYH          Disposable income index
 IHSAV          Household saving index

 IYGOV          Government revenue index
 NETGOV          Net Revenue for government
 IGRP          Gross region product index
 GRPch          Change in Gross regional product
 CapComp          Capital Compensation
 LandComp          Land Compensation
 Rconsup          Resident angler consumer surplus loss
 NRconsup          NonResident angler consumer surplus loss
* -- Expenditure block
 IAHEXP          adj. Household expenditure index
 IGOVEXP          Government expenditure index
 IQ(we)          Commodity demand index
 IQM(we)          Imported commodity demand index
 IQR(we)          Regional commodity demand index
;

*-- EQUATIONS FOR CALCULATION OF INDEX WITH 1993=1.000

*### Price block
 IPL     = PL.L/PL0;
 IPK(mk)          = PK.L(mk)/PK0(mk);
 IPT(ag)  = PT.L(ag)/PT0(ag);
 IPR(i)   = PR.L(i)/PR0(i);
 IP(i)    = P.L(i)/P0(i);
*#* Production block
 IL(mk)          = LAB.L(mk)/L0(mk);
 ITL     = (Sum(mk,LAB.L(mk))+(LHHH0+LGOV0))
           /(Sum(mk,L0(mk))+LHHH0+LGOV0);
 ILS     = LS.L /LS0 ;
 IK(mk)  = CAP.L(mk)/K0(mk);
 ITK          = Sum(mk,PK.L(mk)*CAP.L(mk))/Sum(mk,K0(mk));
 IT(ag)  = LAND.L(ag)/T0(ag);
 ITT     = Sum(ag,PT.L(ag)*LAND.L(ag))/sum(ag,T0(ag));
 IVA(mk)  = VA.L(mk)/Va0(mk);
 ITVA          = Sum(mk,VA.L(mk))/Sum(mk,Va0(mk));
 IX(i)   = X.L(i)/X0(i);
 ITX     =Sum(i,X.L(i))/Sum(i,X0(i));
 ITR     =Sum(ci,R.L(ci))/Sum(ci,R0(ci));
 ITM     =Sum(IM,M.L(IM))/Sum(IM,M0(IM));
 IVM(i,j)$nzv(i,j)= VM.L(i,j)/VM0(i,j);
 IVR(ml,mk)$nzv(ml,mk)= VR.L(ml,mk)/VR0(ml,mk);
 IR(ci)  = R.L(ci)/R0(ci);
 IEXP(ie)  = EXP.L(ie)/E0(ie);
```

```
 ITE      =Sum(ie,EXP.L(ie))/Sum(ie,E0(ie));
*## Income block
 IYH      = YH.L /YH0 ;
 ITYH     =YH.L/YH0;
 IAYHtra  = AYHtra.L /(YH0 -TRGOV0);
 IDYH     = DYH.L /DYH0 ;
 IHSAV    = HSAV.L /HSAV0 ;
 IGRP     = GRP.L/GRP0;
 GRPch    = GRP.L-GRP0;
*#Expenditure block
 IAHEXP   = AHEXP.L /HEXP0 ;
 IQ(we)   = ADQ.L(we)/Q0(we);
 IQM(we)  = AQM.L(we)/QM0(we);
 IQR(we)  = AQR.L(we)/QR0(we);
 IIMP(im) = M.L(im)/M0(im);
 YHch           = YH.L -adjL.L*YH0 ;
 AYHch          = AYH.L -YH0 ;
 IAYH     = AYH.L /YH0 ;
 TAYH     = AYH.L;
 IYGOV    = YGOV.L/YGOV0;
 IGOVEXP  = GOVEXP.L/GOVEXP0;
 NETGOV   = YGOV.L-GOVEXP.L;
 CapComp  = KY.L*(1-ktax)*Mratio.L;
 LandComp = TY.L*(1-ttax)*Mratio.L;

*##- SOLUTION VALUES OF INDEX
option decimals=5;

PARAMETER INDEX INDEXES FOR THE SIMULATION;
INDEX(I,"IPR")=IPR(I);
INDEX(I,"IX")=IX(I);
INDEX(ie,"IEXP")=IEXP(ie);
INDEX(I,"IL")=IL(I);
INDEX(I,"IK")=IK(I);
INDEX(I,"IPK")=IPK(I);
INDEX(ag,"IPT")=IPT(ag);
INDEX(ag,"IT")=IT(ag);
INDEX(I,"IVA")=IVA(I);
INDEX(I,"IR")=IR(I);
INDEX(im,"IIMP")=IIMP(im);
INDEX(we,"IQ")=IQ(we);
INDEX(we,"IQR")=IQR(we);
INDEX(we,"IQM")=IQM(we);
INDEX(I,"IPR")=IPR(I);
INDEX(I,"IPR")=IPR(I);

DISPLAY INDEX;
DISPLAY ITX,ITE,ITL,IPL,TLSrat.L,
      ITK,CapComp,ITT, LandComp,
      IGRP,GRPch,ITVA,ITR,ITM, YHch,
      AYHch,IAYH,TAYH,IYH,ITYH,IAYHtra, IYGOV,IGOVEXP,NETGOV,
      ILS,IDYH,IHSAV,IAHEXP,IVM,IVR;
```

APPENDIX C

DATA SERIES COLLECTED FOR THE OKLAHOMA FPI

TABLE C.1 DATA SERIES USED IN THE ECONOMETRICS STUDY

YEAR	CAPITAL STOCK Millions	WAGES million	PRICE OF LABOR	PRICE INDEX FOR LUMBER (1982)	Cost of materials[2] (million dollars)	PPI (1982=100)	Value of shipments[3] (million dollars)	OUTPUT (value-shipments/ppi)	TOTAL VARIABLE COST	Share of Labor in total capital cost	Raw Materials share
1962	3.64			31.40		32.20			0.00		
1963	4.03	5.82	1.56	31.30		32.80			5.82		
1964	3.98	6.03	1.65	31.30	14.60	33.50	27.50	82.07	20.63	0.29	0.71
1965	4.15	6.36	1.64	31.90	12.65	33.70	24.97	74.09	19.01	0.33	0.67
1966	4.39	6.82	1.66	35.00	15.50	35.20	29.18	82.88	22.32	0.31	0.69
1967	4.89	6.80	1.94	35.00	15.40	35.10	27.60	78.63	22.20	0.31	0.69
1968	5.88	8.00	2.67	39.80	20.80	39.80	35.50	89.20	28.80	0.28	0.72
1969	8.27	9.60	2.67	44.10	20.30	44.00	41.60	94.55	29.90	0.32	0.68
1970	8.81	7.00	2.33	40.10	14.60	39.90	31.40	78.70	21.60	0.32	0.68
1971	20.62	10.00	2.56	46.90	32.60	44.70	52.10	116.55	42.60	0.23	0.77
1972	32.58	21.40	3.10	53.00	90.10	50.70	160.50	316.57	111.50	0.19	0.81
1973	37.87	22.10	3.35	65.70	79.40	62.20	153.80	247.27	101.50	0.22	0.78
1974	47.36	20.20	3.48	64.50	85.60	64.50	131.20	203.41	105.80	0.19	0.81
1975	58.18	18.40	3.76	61.30	86.30	62.10	126.10	203.06	104.70	0.18	0.82
1976	62.31	18.90	3.78	76.00	92.10	72.20	139.00	192.52	111.00	0.17	0.83
1977	69.48	27.60	4.45	91.80	175.50	83.00	260.10	313.37	203.10	0.14	0.86
1978	79.82	28.90	5.25	106.50	187.50	96.90	250.50	258.51	216.40	0.13	0.87
1979	82.63		0.00	113.40		105.50		0.00	0.00	0.00	0.00
1980	84.47		0.00	104.00		101.50	284.60	280.39	0.00	0.00	0.00
1981	84.85		0.00	102.00		102.80	330.50	321.50	0.00	0.00	0.00
1982	83.69	37.60	6.96	100.00	234.40	100.00	334.30	334.30	272.00	0.14	0.86
1983	81.74	36.10	6.69	111.90	240.10	107.90	343.70	318.54	276.20	0.13	0.87
1984	79.32	31.00	6.46	111.90	218.60	108.00	331.40	306.85	249.60	0.12	0.88
1985	78.10	23.80	6.10	105.20	185.60	106.60	268.00	251.41	209.40	0.11	0.89
1986	73.31	21.20	6.42	104.90	132.70	107.20	239.90	223.79	153.90	0.14	0.86
1987	69.66	37.70	7.54	114.10	170.60	112.80	289.10	256.29	208.30	0.18	0.82
1988	63.36	37.60	7.23	112.40	156.90	118.90	265.60	223.38	194.50	0.19	0.81
1989	64.11	45.40	7.09	108.00	216.10	126.70	319.70	252.33	261.50	0.17	0.83
1990	63.21	42.10	7.26	111.20	213.30	129.70	328.80	253.51	255.40	0.16	0.84
1991	65.91	45.90	7.06	111.00	215.70	132.10	382.60	289.63	261.60	0.18	0.82
1992	67.31	43.20	8.64	130.60	217.40	146.60	369.70	252.18	260.60	0.17	0.83
1993	69.62	53.20	9.17	168.80	243.10	174.00	396.10	227.64	296.30	0.18	0.82
1994	73.53	49.20	8.20	182.60	296.60	180.00	475.00	263.89	345.80	0.14	0.86
1995	100.77	58.10	9.08	166.90	257.20	178.10	441.10	247.67	315.30	0.18	0.82
1996	141.40	60.10	8.59	177.90	243.30	176.10	477.50	271.15	303.40	0.20	0.80
1997				201.20		183.80					

VITA

ELIECER E. VARGAS

Candidate for the Degree of

Doctor of Philosophy

Thesis: MONOPSONY MARKETS IN REGIONAL CGE MODELING: THE OKLAHOMA FOREST PRODUCTS INDUSTRY CASE

Major of Field: Agricultural Economics

Biographical:

Personal Data: Born in Heredia, Costa Rica, May 3, 1967.

Education: Graduated from University of Costa Rica in 1987 in Agricultural Economics, with a degree of Agronomy Engineering; worked for 2 years as a private consultant for several institutes and entities; received a scholarship from the U.S A.I.D. to come to the United States to study for the masters; then, received a research assistantship to continue Ph.D. work at Oklahoma State University; completed requirements for the Doctor of Philosophy degree at O.S.U. in July, 1999.

Professional Experience: Research assistant for four years in the Department of Agricultural Economics at Oklahoma State University. Private consulting in trade, natural resources and project appraisal for four years in Costa Rica. Teacher of a graduate course for the summer of 1999. Course title: Computable General Equilibrium.

Professional Membership: Mid-Continent Regional Science Association, Southern Agricultural Economics Association, and American Agricultural Economics Association.