

REGIONAL ECONOMIC ADJUSTMENT TO THE DEPLETION  
OF GROUNDWATER AND PETROLEUM: HIGH  
PLAINS OF OKLAHOMA AND TEXAS

By

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## TABLE OF CONTENTS

Chapter	Page
I. INTRODUCTION . . . . .	1
Study Area and Problem Setting . . . . .	1
Objectives . . . . .	5
Organization of Study . . . . .	6
II. MODELS OF REGIONAL ECONOMIC ADJUSTMENT . . . . .	7
Theories of Regional Economic Adjustment and Growth . . . . .	8
Empirical Regional Economic Models . . . . .	13
The High Plains Simulation Model - An Overview . . . . .	16
III. ECONOMIC INFORMATION SYSTEM FOR THE HIGH PLAINS OF OKLAHOMA AND TEXAS . . . . .	22
Interindustry Transactions Matrix . . . . .	22
Input-Output Methodology . . . . .	23
National and Regional Input-Output Studies . . . . .	28
Changes in Coefficients . . . . .	34
The High Plains Transactions Matrix . . . . .	35
Capital Account . . . . .	56
Concepts and Definitions . . . . .	56
Capital Coefficient Matrix . . . . .	58
Capital-Output Ratios . . . . .	59
Capital Stock . . . . .	64
Depreciation Coefficients . . . . .	64
Human Resources Account . . . . .	64
Population . . . . .	65
Employment . . . . .	66
Employment-Output Ratios . . . . .	68
Labor Productivity Projections . . . . .	70
Income-Output Ratios . . . . .	74
IV. PROJECTIONS OF AGRICULTURAL AND PETROLEUM OUTPUTS . . . . .	75
Agricultural Crop Output . . . . .	75
Alternative Water and Yield Assumptions . . . . .	76
Crop Output Determination . . . . .	82
Agricultural Livestock Output . . . . .	84
Petroleum Output . . . . .	85

Chapter	Page
V. AN ECONOMIC SIMULATION MODEL FOR THE HIGH PLAINS OF OKLAHOMA AND TEXAS . . . . .	90
Estimating Final Demand . . . . .	100
Capital Formation . . . . .	100
Household Purchases . . . . .	105
Exports . . . . .	108
Government Purchases . . . . .	110
Total Final Demand . . . . .	113
Estimating Sector Output Subject to Agricultural and Petroleum Output Projections . . . . .	114
Supply Output . . . . .	114
Demand Output . . . . .	116
Estimating Employment, Population, Income and Value Added . . . . .	120
Employment . . . . .	120
Population . . . . .	121
Income . . . . .	122
Value Added . . . . .	123
VI. RESULTS OF HIGH PLAINS SIMULATION MODEL . . . . .	125
Base Projection . . . . .	126
Population . . . . .	126
Sectoral Output . . . . .	131
Employment . . . . .	136
Household Income . . . . .	138
Alternate Groundwater Projection . . . . .	140
Population . . . . .	140
Sectoral Output . . . . .	142
Employment . . . . .	143
Household Income . . . . .	146
Alternate Petroleum Output Projection . . . . .	146
Population . . . . .	147
Sectoral Output . . . . .	149
Employment . . . . .	149
Household Income . . . . .	150
Variations in Selected Parameters . . . . .	150
Yields Per Acre . . . . .	151
Employment-Output Ratios . . . . .	151
Feedlot Livestock Growth Adjustment Factor . . . . .	154
VII. PLANNING AND POLICY IMPLICATIONS . . . . .	156
Regional Development . . . . .	157
Water Policies . . . . .	158
Exports of Demand Output Sectors . . . . .	158
Agricultural Productivity . . . . .	161
Import Substitution . . . . .	162
Public Service Provision . . . . .	163

## CHAPTER I

### INTRODUCTION

This study investigates the long-run adjustment of a regional economy to the depletion of its major exhaustible natural resources: groundwater, petroleum, and natural gas. The information developed is relevant for decision-making by planners in agriculture, industry, and government.

#### Study Area and Problem Setting

The study area is composed of 25 counties of the northern Texas Panhandle and the three counties of the Oklahoma Panhandle. This region will be referred to as the High Plains (Figure 1). The High Plains is basically rural with one standard Metropolitan Statistical Area (SMSA), Amarillo, which serves as a regional trade center. The Amarillo SMSA includes Potter and Randall counties. There was a total population in the High Plains of 357,095 in 1970 (93, 96). This represented a decrease of 4.4 percent from the 1960 population (92, 95). Forty percent of the region's population was located in the Amarillo SMSA in both 1960 and 1970. The study area delineation is based on the location of water formations and trade areas within a political boundary constraint determined by the sources of funding for the project of which this study is a part.

Agricultural production of wheat, grain sorghum, and cattle and

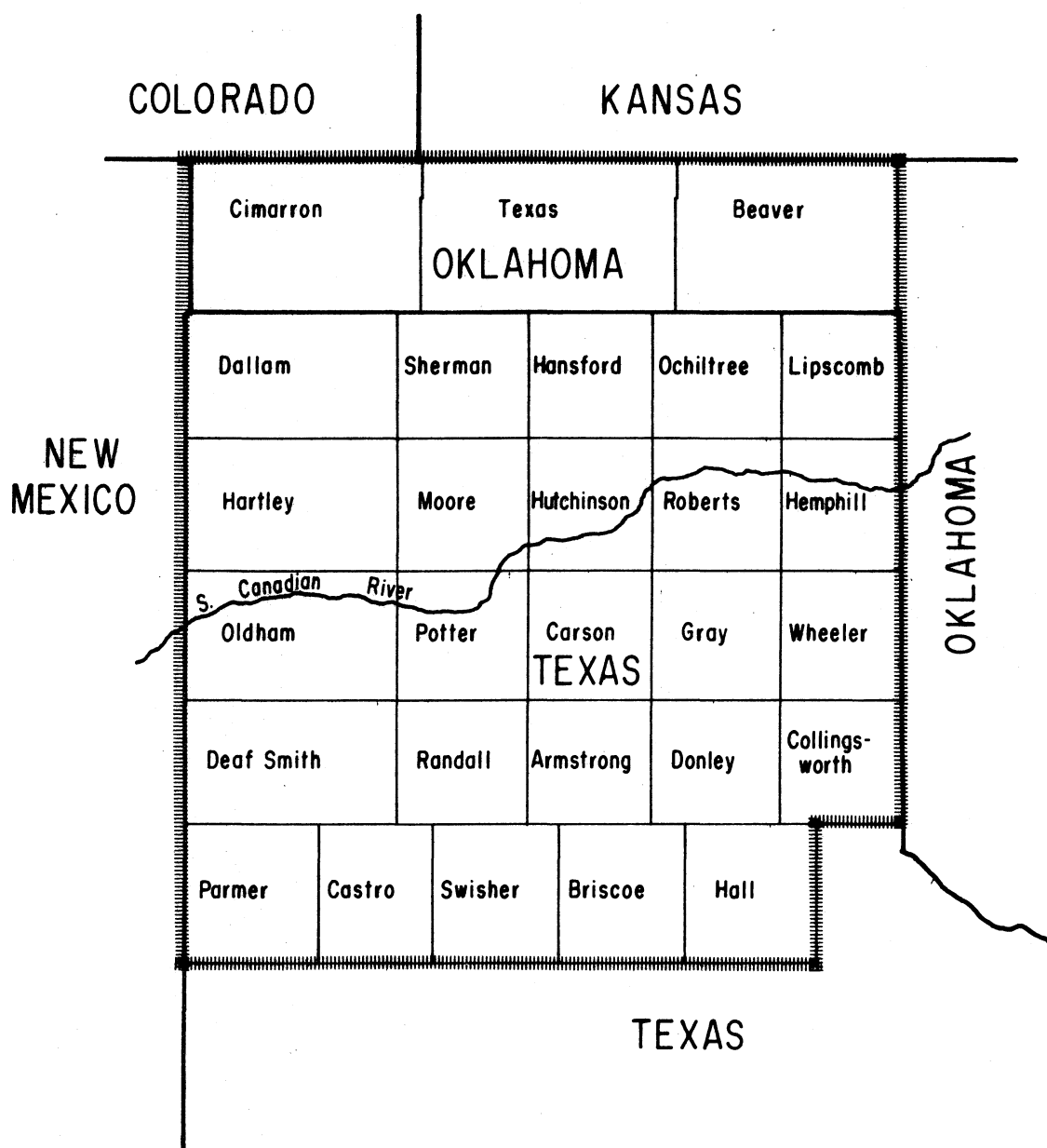


Figure 1. High Plains of Oklahoma and Texas

mining production of crude petroleum, natural gas, and natural gas liquids (hereafter referred to as petroleum) are the principal activities at the base of the regional economy. In 1967, twenty-four percent of the income of regional households came directly from agricultural and mining production while these activities directly accounted for sixty-three percent of the dollar value of the region's exports. Agricultural and petroleum production in the High Plains are dependent on the withdrawal of exhaustible natural resources.

Depletion of the petroleum resources in the High Plains has reached the point where annual production of oil has been decreasing for several years and where annual production of natural gas has leveled off and is predicted to begin decreasing in the next few years. However, recent price increases may alter these trends. In the Texas portion of the High Plains proved reserves of oil in 1971 were 200,246 thousand barrels as compared to 362,264 thousand in the peak year, 1955, and proved reserves of natural gas in 1971 were 9,824,738 million cubic feet as compared to 26,188,090 million in 1945 (3). If no additions are made to current oil and gas reserves, there would be less than ten years of production possible at current annual production rates.

The High Plains is a semi-arid region where irrigation significantly increases crop yields. Water is pumped from groundwater formations, principally the Ogallala aquifer. Since the recharge of water into the aquifer is very small relative to current and projected rates of withdrawal, the groundwater resource is exhaustible (5). In the area of the High Plains south of the South Canadian River (Lower High Plains), irrigation development began about twenty years before development in the area north of the river (Upper High Plains) and has already reached the

point where the increased cost of groundwater recovery has resulted in a reduced number of irrigated acres (78, 79, 81, 82, 83, 84). In the Lower High Plains the number of irrigated acres increased from 460,804 in 1949 to 1,380,978 in 1959 but, by 1969, the number of acres had decreased to 1,324,224. Projections by hydrologists and agricultural economists (see Chapter IV) indicate this decline will continue. In the Upper High Plains the number of irrigated acres has increased from 12,591 in 1949 to 1,230,435 in 1969. Projections indicate the number of irrigated acres in the Upper High Plains will continue to increase until about 1990, after which there will be a decline in irrigated acres. Correspondingly, the terminal year, 2010, of the study is selected to allow analysis of the effect of this decline on the High Plains economy.

The dependence of the High Plains economy on these mined resources, water and petroleum, is at the root of the problem under consideration in this study: the long-term structural adjustments of the regional economy as its exhaustible resources are depleted. The estimation of the magnitude of these structural adjustments is essential to public and private planners who make decisions each day which affect the economic growth and quality of living in the High Plains. These planners often find it difficult to determine the best of alternative policies and programs to meet various objectives due to the complexity of the interrelationships in the regional economy and the lack of detailed information on the impact in various economic sectors of expected resource depletion.

Estimation of output, employment, population, and income changes provide the information base for government planners to develop policies

aimed at mitigating the adverse economic effects of mined resource depletion (e.g., planning and managing the use of groundwater and/or promoting industrial development) and to assess the impact of projected regional change on the existing system for provision of public services (e.g., public schools, transportation, public health). The private sector of the economy will find this analysis of value in examining long-range investment opportunities, the basic economic structure and marketing conditions for an industry, and the demand for basic materials, energy, and labor.

### Objectives

The objective of this study is to develop an economic information system and a simulation model which determine the regional impact of declining water and petroleum supplies and apply these to the High Plains of Texas and Oklahoma. Estimates of agricultural and petroleum output from previous, related research are utilized in the simulation model to determine the impact of the declining exhaustible resource base on the regional economy. The simulation model provides a dynamic analysis based on interindustry relationships.

Specific objectives are to:

1. Develop a quantitative information system which provides data necessary to analyze structural adjustment in the High Plains economy with a simulation model. The information system includes the following accounts:
  - A. Interindustry transactions matrix;
  - B. Capital account; and
  - C. Human resources account.

2. Develop estimates of agricultural and petroleum output to the year 2010 which are based on declining reserves of depletable resources and are consistent with the specification of the interindustry transactions matrix.
3. Determine the long-term structural adjustment of the High Plains economy to the depletion of its exhaustible resources by developing a simulation model which generates dynamic changes in the regional economic structure subject to estimated agricultural and petroleum output. The simulation model will describe the long-run structural adjustments to the year 2010 in terms of sectoral output and employment and regional income, employment, and population.

### Organization of Study

The following chapter develops the theoretical bases and reviews other studies relevant for the analysis presented in this study. It then presents a brief overview of the simulation model and relates the model to those presented in other studies. Chapter III develops the economic information system and Chapter IV develops the projections of agricultural crop and petroleum output. In Chapter V, the economic simulation model is specified in detail. The empirical results are presented in Chapter VI, utilizing the data developed in Chapters III and IV and the model specified in Chapter V. Implications of the simulation results with regard to public service provision and with regard to regional development are investigated in Chapter VII. The summary and evaluation of the study are contained in Chapter VIII.

## CHAPTER II

### MODELS OF REGIONAL ECONOMIC ADJUSTMENT

Models which analyze the way an exogenous change in a regional activity results in changes in other regional activities have been a mainstay of regional economic research. Typically, these have been comparative static models and have dealt with short-run phenomena. These models are generally referred to as "impact" models (63, pp. 141-156). While these models are valuable for analysis of short-run regional business cycles, the most important regional problems tend to be those of long-run structural adjustment and growth. Likewise, policy tools available to state and local governments also relate to long-run structural adjustment rather than to countercyclical activity.

Regional models that analyze long-run economic development have typically been referred to as regional forecasting or projection models (63, pp. 157-194 and 27, pp. 54-87). Both comparative static and dynamic models are represented in the recent literature. In a study of the West Virginia economy, Miernyk (44) applied both comparative static and dynamic models and compared the results. Ideally, a long-run development model would be an empirical representation of "the theory of regional growth". However, as Richardson (64, p. 14) has stated: "The state of the art of regional growth theorizing is very primitive".

The simulation model developed for the High Plains economy is designed to measure the impact on the regional economy of declining

groundwater and petroleum resources as an exogenous or primary change. However, this "impact analysis" of mined resources depletion is a long-run phenomenon and an accurate analysis requires that the impact be measured in a projections model framework. Thus, a hybrid of impact and projections models, a "regional economic adjustment model", is used in simulating the High Plains economy. The first section of this chapter will review pertinent theories of regional economic adjustment and growth. The following sections review selected empirical regional economic models and present an overview of the High Plains simulation model.

### Theories of Regional Economic Adjustment and Growth

Theories of regional economic growth have typically emphasized one of two factors as the primary motivating force. One is the demand for the region's output, the other is the region's supply of inputs for the production process. Hoover (31, p. 221) has emphasized that "both approaches are relevant and necessary parts of an adequate theory of regional change and development."

Exemplar of the emphasis on demand for the region's output is the simple export base theory which designates export demand as the primal force in regional development. In its most simplistic, aggregate form, this theory distinguishes only two sectors in a regional economy: (1) the basic sector which includes the exporting industries which are held to be the stimuli for a region's growth and (2) the nonbasic sector which includes those industries which supply the local requirements of the basic sector and of themselves. In its traditional form, as

specified by Romanoff (65, pp. 121-122).

$$X_T = X_N + X_B \quad (2.1)$$

where subscripts T, N, and B represent total, non-basic, and basic industries, respectively, and the  $X_i$  represent respective aggregate outputs. By assumption,  $X_N = A X_T$  so that

$$X_T = A X_T + X_B \quad (2.2)$$

and the reduced form solution is

$$X_T = (1-A)^{-1} X_B. \quad (2.3)$$

Thus, given output of the sectors which sell outside the region,  $X_B$ , total output of all sectors in the regional economy,  $X_T$ , is determined through the "regional multiplier",  $(1-A)^{-1}$ . In more sophisticated forms, other aspects of demand (e.g., investment and consumption) are included in the aggregate demand for a region's output as is the case in the standard input-output analysis. The demand approach has been used frequently in regional impact analysis through the use of a variety of "multipliers".

There have been a number of objections to the heavy use of demand-oriented models in regional analysis (31). An explicit incorporation of the region's supply of inputs for the production process is needed. As stated by Pratt (61, p. 141):

In order for the demand oriented multiplier analysis to be valid, certain implicit assumptions must be made concerning supply conditions in the economy. The supply side of the analysis is as important as the demand side.

Recent theoretical models incorporate the more balanced approach of considering both supply and demand factors in regional growth. Examples include the works of Siebert (70), Romans (66), and Borts and Stein (7).

These models extend the closed economy, neoclassical models to the open regional economy.

A regional neoclassical model, as presented by Richardson (64, p. 26) is as follows:

$$y_i = a_i k_i + (1-a_i)l_i + t_i \quad (2.4)$$

$$k_i = s_i/v_i + \sum_j k_{ji} \quad (2.5)$$

$$l_i = n_i + \sum_j m_{ji} \quad (2.6)$$

$$k_{ji} = f(R_i - R_j) \quad (2.7)$$

$$m_{ji} = f(W_i - W_j) \quad (2.8)$$

where  $y$ ,  $k$ ,  $l$ , and  $t$  are growth rates in output, capital, and technical progress in region  $i$ ,  $a$  is capital's share in income,  $s$  is the saving/income ratio,  $v$  is the capital/output ratio,  $k_{ji}$  is the annual net flow of capital from region  $j$  to region  $i$  divided by the capital stock of region  $i$ ,  $n$  is the rate of natural increase in population,  $m_{ji}$  is the annual net flow of migrants from region  $j$  to region  $i$  divided by the population of region  $i$ ,  $R$  is the rate of return on capital, and  $W$  is the wage rate. Equation (2.4) is the standard growth equation for output in which the influence of the supply of inputs on the growth rate is explicit. Equations (2.5) and (2.6) are definitional, stating that the growth of factor inputs is composed of two elements: local inputs and net imported inputs (equation (2.6) assumes a constant labor force participation rate). In equations (2.7) and (2.8) the growth rate of the inputs is dependent on the rate of return on capital and the wage rate. These will be a function of the demand for the region's output. Thus, this model emphasizes the interplay of supply and demand in regional growth.

The complex process of regional economic adjustment to these two motive forces, demand for output and supply of inputs, is determined by the relationships between sectors within the regional economy. If a sector purchases inputs from other sectors and/or sells its output to other processing sectors, the growth of the sector increases the demand for inputs from other sectors and/or increases the supply of its output to other sectors. Through this process, changes in one sector will have an impact on the development of other sectors in a regional economy. In the extreme contrast, if a self-sufficient sector which sells to final users expands its output, there is no growth stimulated in other sectors because there is no purchase of inputs from other sectors nor sale of output to other processing sectors. These relationships among sectors are referred to as structural linkages. Linkages are classified into two categories: forward and backward. As explained by Bharadwaj (6, p. 315):

An activity absorbs inputs from others and, as such, whenever it operates on a positive output level, it provides stimulus for the expansion (or initiation) of production of the input-providing industries. This has been termed the backward linkage effect. Secondly, an activity provides inputs to other industries and, in so doing, either through the cheapening of its products or through greater availabilities stimulates the setting up of or increasing the output levels of the output absorbing industries. These have been called the forward linkage effects.

Studies of regional growth that have emphasized the demand for a region's outputs also emphasize backward linkages of activities in the region. Backward linkages refer to sales of a sector that are induced by an increase in output of a sector that is at a later stage in the production process. For example, sales of the electric service sector might be increased due to an increase in the output of the cotton

ginning sector. A "chain-letter" demand for output among regional industries is generated which is eventually terminated by leakages to imports and saving. Generally, this type of analysis assumes that with the increased demand for regional industry output, input supplies are perfectly elastic, imposing no constraint on regional growth.

When the supply of inputs is emphasized in explaining regional growth, forward linkages of activities are of primary importance in the structural change of the regional economy. Forward linkages refer to sales of a sector that are induced by an increase in output of a sector at an earlier stage in the production process. For example, increased output of natural gas could induce increased output by the pipeline transportation sector. In a manner symmetrical to the backward linkage process, a "chain" of output increases is generated by sectors which treat as inputs the increased output of the earlier stages of production. The induced output increases are limited by leakages of outputs to exports or final use. Generally, this type of analysis assumes that with increased supply by a regional industry, demand for output is perfectly elastic, imposing no constraint on regional growth.

Thus, the supply of inputs and the demand for outputs operate through the backward and forward linkages to explain the process of regional economic adjustment and growth. Further complicating this process are the many "feedback loops". For example, as the relation of supply of inputs and demand for outputs changes for a given sector of the regional economy, output changes are transmitted through backward and forward linkages to other sectors of the economy. The result is a different "output mix" for the regional economy. Given that different sectors of the regional economy have different labor and capital

requirements, different consumption and investment situations are fed back into the interplay of input supply and output demand.

To adequately describe the process of regional economic adjustment, both demand for regional output and supply of regional inputs must be included as well as the corresponding linkage and feedback mechanisms. A "general" theory of regional development, incorporating all of these aspects of the regional growth process, has not been specified. In the High Plains simulation model, all of these aspects of the regional growth process are utilized in an ad hoc analysis of the region's adjustment to the depletion of mined resources.

#### Empirical Regional Economic Models

Input-output and simulation models have been the major approaches in the analysis of interrelationships in regional economies in recent years. Since the model presented in this research for the High Plains of Oklahoma and Texas is a simulation model formulated around an input-output model, it is appropriate to make a brief review of some of the principal input-output and simulation models of regional economies that have been developed in recent years. Of special interest are those models which have had a direct influence on the High Plains simulation model.

One of the most cited regional models of recent years is the Susquehanna River Basin Model developed by H. R. Hamilton, et al. (27) at the Batelle Memorial Institute. This model describes the "real world" by a set of simultaneous differential equations that are referred to as a "dynamic simulation model." Demographic and employment sectors are tied together by feedback loops. Data from the two sectors are

fed into a water resource sector, a "technical sector", to determine water quality and quantity variables. However, the water sector's feedback on the demographic and employment sectors was not considered critical and was not included in the model. Economic activity is specified in terms of employment rather than such variables as income, value added, or output and relies on the export-base theory of regional growth. The main features of the employment sector are best described by Hamilton, et al. (27, pp. 128-129):

The principal "driving force" of the model is Market Area Demand operating through export industry employment. The growth of these export industries is determined by (1) the relative attractiveness of the subregion to industry in relation to other areas where it might locate and (2) the demand for goods in relevant market areas that can be supplied economically from the subregion. Attractiveness is treated explicitly through a relative cost concept embodying transportation and labor costs. Market area demand is specified exogenously.

The methodology for export employment determination is shift-share analysis formulated in a projections framework. Other employment is determined by its relationship to export industry employment and to population.

Kelso, Martin, and Mack (37) have studied the problem of water availability on the Arizona economy. Income losses from declining irrigated agriculture production are estimated using static multipliers developed from an input-output model for the state. In addition to the standard backward linkage effects, forward linkage effects are also analyzed. A comparative static analysis was used to explore the effect of alternative hypothetical patterns of sectoral growth on the demand for water. The analysis is used to

describe what changes in the structure of the state's economy will be required and how drastic they must be if we are to

live within our water budget. Or, we may estimate how large the importations of water or development of new internal supplies must be, as among the several structural alternatives, if we are to get the projected rate of overall economic growth. (37, p. 49)

The impact of groundwater and petroleum depletion on the economy of the Texas Panhandle is being investigated by James Osborn (57) at Texas Tech University. Osborn has used hydrological projections of annual groundwater pumpage for agricultural purposes to estimate agricultural crop output to the year 2020. Crude oil and natural gas production has been projected by the Texas Water Development Board (50) for use in the Osborn study. Through the use of an input-output model, the impact of the declining groundwater and petroleum supplies is being estimated.

A lineage of simulation models by Maki, Suttor, and Barnard (41), Mullendore (46), MacMillian (40), Doeksen (17), Byerlee and Halter (10), and Holloway (30) are formulated around the input-output system of analysis. The equations of the models are arranged in a recursive sequence to describe the dynamic behavior of the regional economies. In this recursive system, the influence of both exogenous and endogenous variables have a unidirectional influence on resultant endogenous variables. This framework allows an explicit causal interpretation of any one variable on the system. While the dynamic properties and the general framework of these simulation models are found in the recursive process, output determination in each year involves the use of the Leontief inverse matrix, an interdependent system.

All of these models differ only slightly in their basic structure for the solution in a given year:

- (1) Final demand is estimated with some portions (generally, consumption and investment) determined by previous years'

outputs, incomes, and population and other portions (generally, exports and government) estimated exogenously.

- (2) Sector output is determined by the estimated final demand subject to constraints on input supplies (e.g.; capital, labor, water capacity constraints). Prices are constant; that is, supply is perfectly elastic up to the capacity limits.
- (3) Employment, income, population, gross regional product, value added, and other variables are determined on the basis of the sectoral output estimates. These variables have policy implications and/or are needed for determination of final demand in subsequent years.

Generally, these models are relatively inexpensive to run on a digital computer and are constructed in a manner conducive to experimentation in changing parameters and measuring the resulting impact on the simulated growth sequence.

### The High Plains Simulation

#### Model - An Overview

The simulation model developed for the High Plains of Oklahoma and Texas is specified in detail in Chapter V. It is the purpose of this section to present the model in broad outline and in relation to the models referred to in the preceding section. In addition, the relevance of the data developed in the next two chapters can only be understood in relation to the general workings of the model.

The strongest ties to previous models for the High Plains model is to the Maki, et al., lineage of models. But, whereas these models are

driven primarily by final demand estimates for each year, the High Plains model is driven primarily by the supply of mined resources. Groundwater, crude oil, and natural gas have an impact on the High Plains economy through the standard backward linkages used in the Maki, et al., lineage of models and through forward linkages such as those used in the Kelso, Martin, and Mack model of the Arizona economy. Since the projections indicate eventual decline in the output of these mined resources, special attention has to be given to mechanisms for both expansion and contraction in the regional economy. This required that variables generally treated exogenously be incorporated endogenously into the model.

The High Plains model is an attempt to trace the impact of mined resources production on the High Plains economy, assuming that the agriculture, the petroleum, and the agricultural and petroleum supply related sectors are the primary driving force in the economy. In contrast, the Susquehanna model investigated the impact of demographic and economic activity on water availability. Resource constraints of time and money prevented use of a more complex process of export determination such as used in the Hamilton model. Rates of change in exports are endogenously determined by the lagged growth rate of the High Plains economy rather than by exogenous rates of growth from national economic projections in previous models of the Maki, et al., lineage.

The High Plains model is heavily indebted to Osborn's (57) work at Texas Tech University for data and for methodology. Osborn's input-output model for 25 counties of Texas is expanded to include the Oklahoma Panhandle and his projections for groundwater, crude oil, and

natural gas are utilized in the High Plains projections. As explained in Chapter IV, Osborn's methodology for translating annual groundwater pumpage into agricultural output by sector is adopted with minor variations for exogenous projections that are used in the simulation model.

Figure 2 shows the major relationships in the High Plains simulation model. The exogenously projected availability of groundwater for a given year determines agricultural crop output and, through forward linkages, feedlot livestock and meat product output. Similarly, exogenously projected crude oil and natural gas output determines natural gas liquid output. Outputs of these sectors, determined from mined resource supply characteristics considered outside of the model, are referred to as "supply output" sectors. Other sectors of the regional economy are referred to as "demand output" sectors. Output of the "demand output" sectors is determined by final demand as found in the traditional input-output framework (household consumption, government expenditures, exports, and sales to capital formation) and in the requirements of the "supply output" sectors from the "demand output" sectors. Interdependence of "demand output" sectors is accounted for through a matrix of direct and indirect requirements.

Output by processing sectors of the regional economy having been determined, employment-output and income-output ratios by sector are utilized to determine regional employment and household income. Regional employment determines regional population through the labor force participation rate. Population and household income for a given year are utilized in the model to determine household consumption and government expenditure components of final demand in subsequent years. Exports are determined by the lagged rate of change in total value



added of processing sectors in the region.

As stated by Richardson (63, p. 183):

A truly dynamic model must allow for the structural relations between stocks (capital) and flows (output) and take explicit account of the fact that substantial increases in output will create additional capacity requirements so that projected changes in final demand will not only require more intermediate goods but also investment goods from all appropriate sectors in the economy.

Capital formation in the High Plains model is handled through a simple accelerator where lagged output changes generate induced investment. Depreciation rates applied to the estimated capital stock of the region provide an estimate of replacement investment. Total investment is transferred into sales of regional sectors to capital formation through a capital coefficients matrix.

Through this process, the components of final demand are estimated for a given year from stock (capital, population) and flow (output, income) estimates for previous years. It is assumed that migration rates will adjust perfectly to provide necessary labor resources or remove excess labor resources and that the accelerator mechanism provides capital resources at a rate sufficient to avoid any capacity constraints.

Projected rates of change in labor-output and capital-output ratios, not shown in Figure 2, are included in the model to attempt to account for productivity changes which may have substantial effects on the growth of important variables in the model. These projections of productivity change are extensions of time series for sectors of the input-output model. In addition, yield per acre increases are estimated in some of the alternate crop output projections.

It is obvious from the above outline of the High Plains model that

the data requirements for the model are substantial. The interindustry transactions matrix, the capital account, and the human resources account are presented in the next chapter. The projections of sector outputs determined directly by mined resources availability are then presented in Chapter IV.

CHAPTER III

ECONOMIC INFORMATION SYSTEM FOR THE HIGH PLAINS  
OF OKLAHOMA AND TEXAS

Regional information systems, in contrast with regional accounts, are not constrained by accounting rules but organize information in an orderly classification that is considered relevant to the analysis of public and private activities at the regional level (29). Though regional accounts may be an element of the system, the regional information system is a more specific, a more problem-oriented concept. Starting from a policy problem, such as the impact of some exogenous force on the regional economy, the regional information system contains data that is relevant to the specific problem under consideration. The regional information system presented in this chapter was developed to provide data necessary to analyze structural adjustment to the depletion of mined resources in the High Plains with a simulation model. Data in the system represent stocks and flows that are necessary for a dynamic analysis of the regional economy (60).

Interindustry Transactions Matrix

The interindustry transactions or input-output matrix is both an accounting system that measures the interdependence of industries and an analytical tool that evaluates the impact of changes in autonomous variables. The central concept is a fundamental relationship between

the volume of output and the volume of inputs for an industry. Input-output analysis as a general theory of production based on economic interdependence was first formulated and given empirical content by Wassily Leontief (39) in a 1936 publication entitled "Quantitative Input-Output Relations in the Economic System of the United States."

The basic concepts of Leontief's system have been related to the circular flow and general equilibrium concepts of Francois Quesnay's Tableau Economique of 1758 and Leon Walras' general equilibrium model of 1874 (19, 43). Leontief simplified the general equilibrium concept of Walras to one that could be empirically implemented. This involved two simplifying assumptions that lie at the heart of input-output analysis:

1. A sector of an input-output model consists of plants producing only one homogeneous product. But, as stated by Baumol (4, p. 480), this can be interpreted rather broadly such that the good is "... a composite commodity which is made up of several items produced in fixed proportions."
2. Resources are combined in fixed proportions in the production process and the use of inputs expands in proportion to the level of output. Baumol (4, p. 481) notes that this assumption is the special case of constant returns to scale where substitution of one factor for another is not allowed.

### Input-Output Methodology<sup>1</sup>

The input-output model is generally presented in three parts: a transactions matrix, a direct coefficient matrix, and a total requirement

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<sup>1</sup>For a more complete presentation of the input-output model, see (43), (63), or (15).

or direct and indirect coefficients matrix. Given the division of an economic system into sectors, the transactions matrix is an empirical description of the flow of inputs and outputs in the system during a particular period of time. This is the basic matrix of the input-output model from which the other matrices are derived. Flows of goods and services in the transactions matrix are expressed in dollar values to the producer (producers' prices).<sup>2</sup> Sectors of the input-output model are divided into two groups, the processing or intermediate sectors and the final sectors. This division reflects the distinction made in economic analysis between the production of goods and services and the final disposition of goods and services. The transactions matrix can be divided into four quadrants as shown in Figure 3. Quadrant I is the processing or interindustry section of the table and shows the flow of goods and services which are currently produced and sold but do not reach the ultimate users. The input-output model concentrates on this quadrant of the transactions table which shows the relation of intermediate (processing) sectors. In an income and product accounting system, these intermediate flows are netted out because they represent "double-counting".

In Figure 3 a total of "n" processing sectors are listed at the top and at the left-hand side of Quadrant I. For a given sector "i", reading across a row gives the sales of that sector to all other sectors in the economy during the time period (usually a year). The value in the cell where row "i" intersects with column "j",  $x_{ij}$ , represents the dollar value in producers' prices of the intermediate flow between

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<sup>2</sup>For a statement of producers' prices methodology, see (43).



sectors "i" and "j". Thus,  $x_{ij}$  may be read as the sales of sector "i" to sector "j" or as the purchase of industry "j" from industry "i". That is, reading down a column relates the purchases of a sector from other sectors. The final demand sectors of Quadrant II represent final users in the economy (e.g., households) and households and industries outside the economy (exports). Dollar values of sales to final demand sectors are designated as  $Y_i$ . Final payments by sector, represented in Quadrant III, represent all factor payments, depreciation, taxes, and imports. Quadrant IV, where final demand and final payments sectors intersect includes inputs to final demand sectors not purchased from the processing sectors of Quadrant I and transfer payments.

The row total for a given sector,  $X_i$ , represents the gross output for the sector, the sum of sales to processing sectors plus the sum of sales to final demand sectors. The column total for a given sector,  $X_j$ , represents the gross outlay for a sector, the sum of purchases from processing sectors plus the sum of payments to final payments sectors. Gross output must equal gross outlay for each processing sector as the receipts from sales are paid out for goods and services from processing or final payments sectors.

Thus, the disposition of output in the transactions matrix can be described by the following set of equations:

$$X_1 = \sum_{j=1}^n x_{1j} + Y_1$$

$$X_2 = \sum_{j=1}^n x_{2j} + Y_2$$

-  
-  
-

$$X_n = \sum_{j=1}^n x_{nj} + Y_n$$

As stated previously, a basic assumption of input-output analysis is that the flow from sector "i" to sector "j" is always proportional to the output of sector "j". This assumption can be stated precisely as follows:

$$x_{ij} = a_{ij}x_j \quad (i = 1, - - -, n) \\ (j = 1, - - -, n)$$

where  $a_{ij}$  is a constant that represents the direct purchase by the jth purchasing sector from the ith producing sector per dollar of outlay (output) in the jth purchasing sector. A matrix of direct coefficients is computed from the processing portion (Quadrant I) of the transactions matrix by calculating:

$$a_{ij} = \frac{x_{ij}}{x_j} \quad (i = 1, - - -, n) \\ (j = 1, - - -, n)$$

The set of equations given above to show the disposition of output in the transactions matrix can be written as:

$$x_i = \sum_{j=1}^n a_{ij}x_j + Y_i \quad (i = 1, - - -, n)$$

or representing the matrix of direct coefficients,  $a_{ij}$ 's, by A, the disposition of output can now be represented as:

$$X = AX + Y$$

where X is a column vector of gross outputs (outlays) and Y is a column vector of sales to final demand. This can be rewritten as:

$$X - AX = Y$$

or

$$(I-A) X = Y$$

Under the condition that (I-A) is non-singular, both sides of the equation can be multiplied by the inverse of (I-A) yielding

$$X = (I-A)^{-1}Y$$

which is the standard "solution" to the input-output system where total outputs are a function of final demands. Any size and composition of final demand can be represented in the vector  $Y$  and the level of gross output for each sector is determined. This provides a powerful tool for the analysis of the impact of exogenous forces on the economy.

$(I-A)^{-1}$  is the total requirements or direct and indirect coefficients matrix. The coefficients in a given column  $j$  of this matrix reflect the total dollar production directly and indirectly required from each sector  $i$  to support a dollar of delivery to final demand by sector  $j$ .

### National and Regional Input-Output Studies

Leontief constructed transactions tables for the United States for 1919, 1929, and 1939. National tables for the United States have been constructed by the federal government for 1949, 1953, 1958, 1963, and 1967. The first transaction matrix for a regional economy was published in 1952 for the Eighth Federal Reserve District (24). This study and numerous studies for multi-state, state and sub-state regions have input coefficients from the national transactions tables. The first study to adjust for differences of regional production and trade from the national coefficients was made by Moore and Peterson (45) in 1955. In 1959 Hirsch (28) published the first survey-based regional transactions matrix in his study of the St. Louis Metropolitan Area. Since Hirsch's study, many survey-based regional studies have been completed (9).

Today, one finds a mixture of survey-based and national coefficient based regional transactions tables being completed. Due to the high

cost of the survey-based table, several techniques for adjusting the national coefficients have been developed. These techniques attempt to correct for problems of differences in production functions, in product mix, and in the degree of openness of regional and national economies.

Systematic efforts to investigate differences in production functions between regions has been hampered by the unavailability of data. Jarvis Emerson (21) cites two studies which show that advanced national economies have considerable similarity in their production structures. Then he compares the Kansas survey-based input-output model with the Norway model. Though the two economies are similar in size, national income, exports, etc., their internal structures were found to be quite different.

Part of the problem may be due to the level of aggregation found in the input-output model but there are problems of regional differences in production techniques. For example, consider the case of electricity production which will be highly interrelated with other sectors of the regional economy. In the Northwest U.S., a large part of electricity production is from hydroelectric sources; in the Southwest, electric plants are built primarily for the use of natural gas as a fuel; and in the Northeast, coal is the principal fuel. The national coefficients will be a composite production function with a mix of the three types of fuel. If these coefficients are used at the regional level, they may have little correspondence to the actual production technology in use.

Gerald Karaska (36) investigated some of these problems in relation to an input-output model of the Philadelphia area. Comparing national and regional technical coefficients in several industries, Karaska

found significant variations. In looking at agglomeration economies in the Philadelphia area, Karaska found that local industries buy a large number and variety of products from local sources but that these local purchases do not constitute a large part of total inputs. That is, a large, metropolitan area provides a diversified industrial base to provide quick and efficient sources of supply of a highly differentiated flow of commodities and services but the major raw materials and markets of many large firms are not local. For example, looking at the Paper and Paper Products industrial complex, Karaska found that paper converters purchase most of their paper from mills outside the region, even though there is considerable production of local paper: ". . . while Philadelphia paper mills produce \$136 million worth of paper, Philadelphia paper converting firms purchase \$68 million worth of paper, only \$5 million of which are local purchases" (36, p. 356). A similar relationship existed between the paperboard containers and boxes sector and the paper and paperboard sector.

These problems of a high degree of specialization and product differentiation are heavily involved in what is often stated as a second limitation to the use of national coefficients at the regional level - product mix. Differences in product mix for a sector between nation and region can result in errors in the estimation of regional coefficients. This is basically a problem of aggregation but to completely adjust for it would require something close to the separation of each product for each firm. The author saw many possibilities for error in the use of national coefficients at the regional level due to specialization and product differentiation in a primary data study in which he was involved in North Central Texas (48). For example, there is heavy

use of aluminum products by the aerospace industry in North Central Texas and there is a large aluminum plant in the region. However, the aluminum plant produces aluminum ingots, all of which are exported from the region for fabrication into sheets, tubes, etc., and all of the finished products used by the aerospace industry are imported back into the region. Techniques of adjustment of national coefficients to the regional level, described below, would show the regional aerospace industry purchasing large quantities of aluminum products within the region unless a level of disaggregation was used which differentiated between aluminum at different stages of production.

The "openness" of regional economies results in the need for identification of the regional source of inputs. Regions tend to be highly specialized in production relative to the nation so that national production coefficients must be adjusted to reflect trade relationships among regions. Several studies have investigated the relationship of secondary and primary data regional models, trying to derive a suitable technology for adjustment of national coefficients. Czamanski and Malizia (16) constructed a Washington State input-output table from national coefficients and compared this with a survey table. As is the usual procedure the survey model was treated as representing the "true" coefficients. Contending that production functions tend to be uniform, they argued that the most difficult problems came from differences in industrial mix and in the importance and structure of regional trade. This study concluded very weakly that acceptable results can be achieved using secondary data. But, to obtain these "acceptable" results, they say that it is important to (1) exclude tertiary sectors through aggregation and (2) use field surveys in order to obtain input-output

coefficients for (a) primary industries and (b) industries in which the regional economy is specialized. As W. H. Miernyk (42) states in a review of the article, these "conditions" and the errors they report show you cannot develop a good regional model from national coefficients.

In another comparison of the Washington State primary data model with secondary data models, Schaffer and Chu (67, p. 96) concluded that "there is still no acceptable substitute for a good survey-based study." Schaffer and Chu used three techniques of adapting national coefficients to the region: (1) location-quotient procedures, (2) supply-demand pool technique, and (3) an iterative simulation procedure. Again, survey-based coefficients were considered as "true" coefficients. The location-quotient procedures provided the best estimates of production coefficients.

The simple location-quotient method uses a ratio defined as follows:

$$LQ_i = \frac{x_i/x}{X_i/X}$$

where  $x_i$  represents regional output of industry  $i$ ,  $x$  the total regional output,  $X_i$  the national output of industry  $i$ , and  $X$  the total national output. If  $LQ_i \geq 1$ , the national input coefficient is used as the regional coefficient and when applied to known gross outputs and final demand except exports, exports are determined as a residual. If  $LQ_i < 1$ , the regional production coefficients,  $a_{ij}$ , in row  $i$ , are computed as:

$$a_{ij} = LQ_i \cdot A_{ij}$$

where  $A_{ij}$  are the national input coefficients. Imports of product  $i$ ,  $m_{ij}$ , are then computed as the amounts necessary to satisfy production requirements:

$$m_{ij} = A_{ij} \cdot x_j - x_{ij}$$

where  $x_j$  is gross output of industry  $j$ .

Boster and Martin (8) have compared a 6 year, \$600,000, primary data study of Arizona with a one and one-half year, \$8,000, secondary data study of Arizona. Comparisons were made between entire trade and interdependency matrices, between four submatrices, between columns, and between weighted and unweighted output multipliers. The null hypothesis of "no difference" could not be rejected for either the complete trade or interdependence matrices. Only one of the trade submatrices showed a significant statistical difference between the two models whereas only one of the interdependency sub-matrices showed correspondence. Six of nineteen of the columns in the trade matrix and seven of seventeen of the columns in the interdependency matrix had statistically significant differences. Unweighted output multipliers showed no relation for the two models whereas multipliers weighted by the relative size of their associated final demand were highly significant as to likeness. In general, differences in the two models became larger as they moved to less aggregative components. Boster and Martin argue that, considering the cost differences and the applications, secondary data models are quite adequate as the answers of policy questions will not be significantly different from the results of primary data models.

Boster and Martin use the primary data model as the "true" model in their tests but make a significant observation for the comparative analysis of primary versus secondary models (8, p. 35):

- - a priori assumptions of primary data supremacy are unwarranted. Poorly drawn samples, sampling errors, inadequate or poorly conceived schedules are among sources of error to balance against the possibilities of secondary data (especially national model coefficients) being inapplicable to a region.

Very little work has been done on the reliability of primary data models. Analysis of the statistical significance of primary data input coefficients would be valuable in making a comparison of the two approaches. Due to specialization and product differentiation in an open regional economy, it was suggested above that national coefficients adjusted by location-quotients would tend to overstate interdependency within regions. Schaffer and Chu (67, p. 96) reported income multipliers that were significantly higher on the average, 21 percent for the simple location-quotient and 38 percent for the cross-industry location-quotient, than survey results. At the present, no definitive conclusions are possible. But, where decisions are made on the basis of small differences, the user of secondary-data models should be aware of the model's limitations and consider the possibility that the regional interdependencies shown are significantly overstated.

### Changes in Coefficients<sup>3</sup>

Over time changes in regional input coefficients are expected due to change in technology and in trade patterns. Studies of changes in technology at the national level have been completed by Anne Carter (11) and Beatrice Vaccara (105). These studies show that changes in input coefficients due to technical advance occur slowly for most industries. Carter found that the most significant changes were not in intermediate inputs but in labor inputs. An across-the-board decrease in labor inputs was the striking feature of technological change.

The potential for even greater instability comes from changing

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<sup>3</sup>For a more complete discussion of this problem see (63).

trade patterns. The few empirical studies available have not supported the hypothesis of trade stability that is implied in fixed regional input coefficients (63, p. 178). As is true with most hypotheses generated for regional economies, further empirical tests are needed to settle the question but the paucity of data at the regional level hampers progress. It would be expected that during periods of regional growth the "threshold" level would be met for many firms whose products were previously imported, increasing the intraregional coefficients; and, that during periods of decline, a decrease in regional self-sufficiency would occur. Whether these processes occur, their magnitude, and the occurrence of symmetry during growth and decline need empirical investigation but, at present, there is no methodology that can be applied without the high costs of primary data collection.

#### The High Plains Transactions Matrix

A primary data input-output matrix for 56 counties of Northwest Texas in 1967 is the major data source for the High Plains Transactions Matrix. This model was completed by Osborn and McCray (59) for 94 processing sectors, 6 final payments sectors, and 7 final demand sectors. This 56 county model was used by Osborn (57) to estimate an input-output model for the 25 Texas counties in the High Plains. The location-quotient technique described in the preceding subsection for developing a regional table from a national table was used where the location-quotient measured activity in the 25 county subregion relative to the 56 county region. The 25 county model has 43 processing sectors, 6 final payments sectors, and 7 final demand sectors. It is expected that this transactions table for the 25 county area is much less

susceptible to problems of differences in production functions, in product mix, and in import requirements than a table developed from national coefficients since the subregion accounts for a large part of the total region for which the primary data model was developed.

The transactions table for the High Plains of Oklahoma and Texas (Table I) estimates flows during 1967 in 1967 prices. To develop the table, gross outputs by sector for the three Oklahoma counties were estimated (Appendix A) and assuming direct input coefficients to be the same in the three Oklahoma counties as in the adjacent 25 county Texas region, the totals were distributed to individual sectors. Due to minor differences in industrial composition, it was necessary to make some small balancing adjustments. If expanded requirements due to the addition of the three Oklahoma counties could not be supplied from the additional output of the counties, exports, if available, were decreased; but, if exports were not available, imports were increased. The High Plains input-output transactions account has 42 processing sectors (swine and cattle feedlot sectors of the 25 county model were aggregated), 6 final payments sectors, and 7 final demand sectors. Sector definitions in terms of Standard Industrial Classification (SIC) codes (22) are presented in Appendix B.

By reading down a column of the transactions table, the dollar value of inputs that a given sector purchased from the sectors identified on the left side of the table can be determined. For example, in 1967, the Range Livestock sector (column 9) purchased \$2,483,500 of output from the Milling and Feeds sector (row 19), made payments to Households (row 43) of \$22,480,690, and paid \$9,792,670 for Imports (row 47). An examination of the sales distribution of a given processing

TABLE I

INPUT-OUTPUT TRANSACTIONS MATRIX--HIGH PLAINS OF OKLAHOMA AND TEXAS, 1967  
(Thousands of Dollars)

	1	2	3	4	5	6	7	8
1 IRR COTTON	37.95	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 IRR FOOD GRAIN	0.0	854.28	0.0	0.0	0.0	0.0	0.0	0.0
3 IRR FEED GRAIN	0.0	0.0	1620.60	0.0	0.0	0.0	276.16	0.0
4 OTHER IRR CRUP	0.0	0.0	0.0	1993.31	0.0	0.0	0.0	0.0
5 DRY COTTON	0.0	0.0	0.0	0.0	10.09	0.0	0.0	0.0
6 DRY FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	1105.07	0.0	0.0
7 DRY FEED GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 OTHER DRY CRUP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 RANGE LVSTK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 FEEDLOT LVSTK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 AG SERVICES	2192.11	1031.59	4700.67	320.35	676.54	1206.90	704.82	0.0
12 CRUDE OIL & GAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13 NATL GAS LIQ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14 OIL & GAS SERV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 CONSTRUCTION	130.93	541.46	1032.49	351.24	27.22	170.54	94.15	12.72
16 MEAT PRODUCTS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17 FOOD PROCESS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18 TEXTILE PRDCT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19 MILLING & FEEDS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 BEVERAGES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21 WOOD & PAPER & PRI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22 CHEMICALS	1192.75	5280.40	10772.19	1893.01	117.80	715.50	0.0	0.0
23 PETRO PRODUCT	746.57	2979.62	7502.37	1012.27	192.34	1733.47	1026.60	62.38
24 SOIL & ROCK PRDCT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 METAL PRODUCT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 MACHINERY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 OTHER MFG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28 TRANSPORTATION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29 COMMUNICATION	37.48	161.44	297.88	100.62	9.07	48.72	26.89	3.47
30 GAS SERV	250.56	2089.97	2689.02	1963.55	0.0	0.0	0.0	0.0
31 ELECTRIC SERV	132.82	959.44	1434.59	728.71	7.76	48.72	26.89	3.47
32 WATER & SAN SERV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33 WHL AGR PRDCT	0.0	204.79	452.18	77.51	0.0	62.20	49.60	0.0
34 WHL PETRO PRDCT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35 OTHER WHOLESALE	141.24	0.0	0.0	0.0	44.47	0.0	0.0	0.0
36 AGR SUPPLIES	143.25	655.88	1331.22	401.88	15.36	186.26	26.99	0.0
37 GAS SERV STAT	229.33	915.32	2304.48	311.00	59.09	532.49	315.36	19.14
38 OTHER RETAIL	449.64	1862.24	4018.74	829.33	102.54	754.82	448.31	119.49
39 FINANCE	314.62	1747.99	2820.89	2576.40	55.73	467.30	205.14	61.66
40 INSUR & R. E.	216.62	4362.38	1638.41	578.84	46.56	223.63	95.84	21.25
41 EDUCATION SERV	185.40	786.39	1459.14	497.23	40.12	249.49	132.95	18.09
42 OTHER SERV	139.43	1082.98	1566.29	1921.48	5.10	24.35	13.46	24.28
43 HOUSEHOLDS	13447.68	25646.79	61813.75	16278.05	5250.38	7693.29	11759.11	4771.41
44 LOCAL GOVT	385.97	1639.26	3042.51	1035.49	62.97	514.95	276.83	38.05
45 STATE GOVT	4.89	19.65	35.77	12.99	1.33	6.32	3.49	0.29
46 FEDERAL GOVT	111.16	550.97	1226.79	709.20	24.62	266.01	168.15	41.62
47 IMPORTS	2343.46	8224.86	16677.26	2702.80	537.40	2929.41	1686.96	260.84
48 DEPRECIATION	1102.14	8321.90	14159.41	6878.54	222.91	2424.36	1429.40	91.34
GRSS OUTLAY	23936.20	69919.56	162596.69	45173.60	7524.60	23390.60	10767.10	5549.70

TABLE I (Continued)

	9	10	11	12	13	14	15	16
1 IRR COTTON	0.0	0.0	596.44	0.0	0.0	0.0	0.0	0.0
2 IRR FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 IRR FEED GRAIN	284.22	25868.85	0.0	0.0	0.0	0.0	0.0	0.0
4 OTHER IRR CROP	800.11	2598.49	0.0	0.0	0.0	0.0	0.07	0.0
5 DRY COTTON	0.0	0.0	193.36	0.0	0.0	0.0	0.0	0.0
6 DRY FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7 DRY FEED GRAIN	68.58	4076.85	0.0	0.0	0.0	0.0	0.0	0.0
8 OTHER DRY CROP	405.14	539.66	0.0	0.0	0.0	0.0	0.0	0.0
9 RANGE LVSTK	5042.47	3555.71	0.0	0.0	0.0	0.0	14.97	3294.42
10 FEEDLOT LVSTK	0.0	26.30	0.0	0.0	0.0	0.0	0.0	15779.48
11 AG SERVICES	1412.46	1542.18	263.43	0.0	0.0	0.0	0.0	0.0
12 CRUDE OIL & GAS	0.0	0.0	0.0	20.67	9446.62	0.0	0.04	0.0
13 NATL GAS LIQ	0.0	0.0	0.0	0.0	0.0	65.57	0.52	0.0
14 OIL & GAS SERV	0.0	0.0	0.0	13363.29	742.82	2084.74	165.02	0.0
15 CONSTRUCTION	589.62	78.94	144.29	28.22	6918.20	0.0	269.82	136.65
16 MEAT PRODUCTS	0.0	0.0	0.0	0.0	0.0	0.0	1.05	2892.99
17 FOOD PROCESS	3618.33	3888.86	0.0	0.0	0.0	0.0	0.42	0.0
18 TEXTILE PROD	0.0	0.0	0.0	0.0	0.0	0.0	19.46	0.0
19 MILLING & FEEDS	2483.50	9256.31	0.0	0.0	0.0	0.0	0.0	1381.88
20 BEVERAGES	0.0	0.0	0.0	0.0	0.0	0.0	7.98	0.0
21 WOOD & PAPER & PRI	0.0	29.07	32.31	0.0	0.0	26.28	3277.65	2.27
22 CHEMICALS	29.20	0.0	0.0	1119.47	264.58	0.0	883.00	0.0
23 PETRO PRODUCT	1322.67	200.05	316.18	830.95	1907.18	1406.82	3276.81	0.74
24 SOIL & ROCK PROD	0.0	0.0	0.0	72.73	0.0	0.0	7140.52	0.0
25 METAL PRODUCT	0.0	0.0	0.0	0.0	0.0	0.0	9031.28	0.0
26 MACHINERY	0.0	0.0	142.77	3943.39	0.0	0.0	1329.82	0.0
27 OTHER MFG	0.0	0.0	0.0	0.0	492.98	1.26	3581.24	0.0
28 TRANSPORTATION	436.30	29.24	51.01	0.0	0.0	4.53	509.70	328.10
29 COMMUNICATION	155.82	128.53	98.31	315.94	364.31	49.82	547.47	42.79
30 GAS SERV	6.86	204.64	42.91	32.18	61.39	1.39	48.41	2.91
31 ELECTRIC SERV	154.57	356.96	155.40	261.10	134.03	17.44	165.69	63.52
32 WATER & SAN SER	0.0	0.0	16.97	0.0	624.98	0.46	44.58	88.34
33 WHL AGR PROD	948.20	5247.10	219.06	0.0	0.0	0.0	0.0	20.83
34 WHL PETRO PROD	0.0	0.0	140.06	0.0	0.0	31.68	97.15	0.0
35 OTHER WHOLESALE	0.0	0.0	93.34	247.57	188.32	1555.81	2021.02	2014.80
36 AGR SUPPLIES	5.34	0.0	0.0	0.0	0.0	0.0	0.0	0.03
37 GAS SERV STAT	406.32	51.74	8.41	255.53	0.0	273.68	438.67	0.23
38 OTHER RETAIL	2374.39	129.20	106.30	194.33	0.0	321.28	473.77	0.0
39 FINANCE	2128.50	6533.35	97.98	0.0	0.0	77.85	854.05	2.27
40 INSUR & R. E.	1930.25	324.14	146.25	25.78	129.97	1131.68	2453.05	29.08
41 EDUCATION SERV	1211.16	70.34	9.62	5757.11	383.20	124.43	350.17	33.04
42 OTHER SERV	117.80	171.67	994.95	547.22	26.54	602.02	2465.01	209.87
43 HOUSEHOLDS	22480.69	14610.35	4567.83	83530.69	19123.12	12454.34	59679.99	2311.68
44 LOCAL GOVT	2545.06	109.11	2.25	1342.02	11.60	10.89	311.08	4.09
45 STATE GOVT	20.01	21.14	9.20	5525.82	406.93	128.57	220.25	33.53
46 FEDERAL GOVT	422.59	333.15	609.60	83963.00	21171.97	791.13	9999.34	187.76
47 IMPORTS	9792.67	134786.50	9406.04	97343.00	57217.94	10360.72	58072.27	18758.81
48 DEPRECIATION	7654.77	3645.44	733.23	98677.88	14217.72	1579.21	2601.26	1622.29
GROSS OUTLAY	88847.56	218413.88	19197.50	397398.00	134034.56	33101.60	166352.56	49242.40

TABLE I (Continued)

	17	18	19	20	21	22	23	24
1 IRR COTTON	5044.24	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 IRR FOOD GRAIN	0.0	0.0	62.94	0.0	0.0	0.0	0.0	0.0
3 IRR FEED GRAIN	0.0	0.0	5050.18	0.0	0.0	0.0	0.0	0.0
4 OTHER IRR CROP	5949.94	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5 DRY COTTON	1421.42	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6 DRY FOOD GRAIN	0.0	0.0	16.75	0.0	0.0	0.0	0.0	0.0
7 DRY FEED GRAIN	0.0	0.0	1270.19	0.0	0.0	0.0	0.0	0.0
8 OTHER DRY CROP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 RANGE LVSTK	2672.76	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 FEEDLOT LVSTK	0.0	0.0	0.80	0.0	0.0	0.0	0.0	0.0
11 AG SERVICES	0.0	995.60	0.0	0.0	0.0	0.0	0.0	0.0
12 CRUDE OIL & GAS	0.0	0.0	0.0	0.0	0.0	0.0	16410.27	0.0
13 NATL GAS LIQ	0.0	0.0	0.0	0.0	0.0	11216.56	888.93	0.0
14 OIL & GAS SERV	0.0	0.0	0.0	0.0	0.0	1433.74	1812.01	103.54
15 CONSTRUCTION	53.22	0.0	56.10	1.46	7.83	5927.67	0.35	17.45
16 MEAT PRODUCTS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17 FOOD PROCESS	152.60	0.0	32.78	23.44	0.0	0.0	0.0	0.0
18 TEXTILE PROD	65.09	966.94	6.71	0.0	11.06	0.0	0.0	0.0
19 MILLING & FEEDS	0.0	0.0	696.73	0.0	0.0	0.0	0.0	0.0
20 BEVERAGES	0.0	0.0	0.0	95.22	0.0	0.0	0.0	0.0
21 WOOD & PAPER & PRI	29.73	7.29	15.11	0.10	99.75	31.41	242.21	0.09
22 CHEMICALS	151.74	1.15	0.0	1.17	3.69	9152.94	1711.99	0.0
23 PETRO PRODUCT	164.60	113.58	106.07	82.54	34.80	3145.86	20262.37	1490.43
24 SOIL & ROCK PROD	0.0	0.0	0.0	0.0	0.0	1.98	10.65	142.65
25 METAL PRODUCT	0.0	0.0	0.0	0.0	2.18	60.35	25.18	0.24
26 MACHINERY	0.0	0.0	0.0	5.56	2.99	591.36	0.0	0.0
27 OTHER MFG	0.0	0.0	0.0	0.0	0.81	25.07	0.20	0.0
28 TRANSPORTATION	256.35	17.60	534.09	9.34	203.96	1501.22	3244.38	361.09
29 COMMUNICATION	160.07	52.78	56.14	83.35	122.08	144.73	233.52	40.45
30 GAS SERV	200.03	20.49	13.64	22.12	19.95	1922.44	4362.58	7.71
31 ELECTRIC SERV	511.24	22.05	152.21	44.55	111.69	2214.04	1519.34	9.48
32 WATER & SAN SERV	20.47	14.04	15.69	14.80	15.14	548.00	212.81	5.67
33 WHL AGR PROD	204.79	0.0	602.61	0.0	0.0	0.0	0.0	0.0
34 WHL PETRO PROD	42.58	1.45	47.87	31.47	0.0	0.0	0.0	9.44
35 OTHER WHOLESALE	264.53	7.62	10.37	32.43	280.10	1418.86	232.54	208.70
36 AGR SUPPLIES	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0
37 GAS SERV STAT	11.87	13.45	4.31	0.35	10.62	2.16	4.44	7.00
38 OTHER RETAIL	33.59	124.04	63.19	0.70	8.01	20.70	12.42	24.41
39 FINANCE	936.04	188.75	44.09	29.86	18.43	18.32	0.0	38.10
40 INSUR & R. E.	332.70	62.57	21.79	32.15	92.23	341.01	229.34	52.16
41 EDUCATION SERV	112.51	16.28	42.24	49.96	56.59	333.81	977.51	63.17
42 OTHER SERV	353.31	121.09	428.02	112.80	221.72	1292.62	848.10	209.54
43 HOUSEHOLDS	6423.82	1105.73	2161.27	4076.05	6897.07	18517.43	40762.50	4365.72
44 LOCAL GOVT	141.76	0.28	13.43	49.42	45.00	290.46	96.05	23.79
45 STATE GOVT	49.61	17.43	38.75	28.89	38.22	212.09	1004.82	56.04
46 FEDERAL GOVT	375.11	48.15	773.43	625.12	1633.48	5239.21	4094.67	717.48
47 IMPORTS	22343.41	1233.14	2163.97	4731.19	5056.86	20633.66	70346.06	4673.09
48 DEPRECIATION	1675.87	197.60	273.11	440.56	580.79	13951.10	7637.10	693.56
GROSS OUTLAY	50155.40	5349.10	14774.60	10624.60	15575.70	100906.75	177182.38	15321.00

TABLE I (Continued)

	25	26	27	28	29	30	31	32
1 IRR COTTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 IRR FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 IRR FEED GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 OTHER IRR CROP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5 DRY COTTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6 DRY FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7 DRY FEED GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 OTHER DRY CROP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 RANGE LVSTK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 FEEDLOT LVSTK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 AG SERVICES	0.0	0.06	0.0	0.0	0.0	0.0	0.0	0.0
12 CRUDE OIL & GAS	0.0	0.0	0.0	0.0	0.0	27335.40	0.0	0.0
13 NATL GAS LIQ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14 OIL & GAS SERV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 CONSTRUCTION	5.66	3.02	0.13	1181.87	47.95	60.08	97.60	552.66
16 MEAT PRODUCTS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17 FOOD PROCESS	0.0	0.0	0.0	18.42	0.0	0.0	0.0	0.0
18 TEXTILE PROD	0.0	0.0	0.0	0.0	0.0	2.94	4.93	4.87
19 MILLING & FEEDS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 BEVERAGES	0.0	1.05	0.0	0.0	0.0	0.0	0.0	0.0
21 WOOD & PAPER & PRI	9.13	14.63	142.12	15.36	74.13	18.65	79.68	19.86
22 CHEMICALS	0.0	46.75	0.0	0.0	0.0	0.03	0.59	146.36
23 PETRO PRODUCT	9.28	127.50	142.61	2063.83	34.10	34.53	66.20	68.64
24 SOIL & ROCK PROD	0.0	0.0	0.0	2.48	0.0	0.0	2.77	111.08
25 METAL PRODUCT	0.42	138.92	248.25	251.34	0.0	0.0	0.39	29.42
26 MACHINERY	0.0	25.25	0.0	20.21	0.0	0.0	0.0	2.83
27 OTHER MFG	0.37	41.08	451.41	78.29	0.0	0.70	3.84	17.05
28 TRANSPORTATION	921.53	99.99	34.25	641.95	84.24	40.23	230.82	0.0
29 COMMUNICATION	47.12	66.79	70.75	1572.12	116.72	114.75	287.60	27.92
30 GAS SERV	521.74	59.76	14.20	335.76	30.14	2056.35	9178.90	0.0
31 ELECTRIC SERV	103.29	197.40	42.50	464.32	293.16	30.82	0.0	704.14
32 WATER & SAN SER	4.42	6.12	9.17	62.40	31.04	9.31	140.53	930.39
33 WHL AGR PROD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34 WHL PETRO PROD	0.09	32.34	58.81	1017.84	0.0	7.12	27.34	23.48
35 OTHER WHOLESALE	40.40	171.41	39.06	1665.68	41.22	45.02	223.11	350.83
36 AGR SUPPLIES	0.0	0.08	0.0	0.0	0.0	0.0	0.0	0.0
37 GAS SERV STAT	2.89	15.43	3.88	0.0	10.46	28.02	35.11	0.0
38 OTHER RETAIL	5.33	34.58	48.62	0.0	3.34	89.03	617.90	0.0
39 FINANCE	37.02	17.06	29.36	46.96	7.94	140.02	227.09	0.0
40 INSUR & R. E.	52.58	21.12	57.75	1407.54	450.41	371.53	399.43	56.81
41 EDUCATION SERV	29.90	94.74	44.61	640.26	604.05	607.79	1359.72	0.0
42 OTHER SERV	41.64	348.41	211.91	1317.95	368.35	483.31	330.25	0.0
43 HOUSEHOLDS	4462.77	8439.57	1978.73	22083.99	10673.75	10223.09	28361.49	3369.65
44 LOCAL GOVT	31.72	28.41	13.74	243.01	747.25	675.20	1623.79	0.0
45 STATE GOVT	16.19	87.73	41.13	586.89	339.02	299.22	645.24	0.0
46 FEDERAL GOVT	588.10	1954.19	160.50	1882.09	5124.83	2070.03	3084.81	83.07
47 IMPORTS	7882.51	8100.28	7307.48	6413.40	7600.47	33807.13	1648.73	1630.08
48 DEPRECIATION	192.60	305.63	163.08	2342.38	5506.25	3273.15	7931.12	3083.06
GROSS OUTLAY	15007.10	20745.30	11324.10	40839.50	32471.90	142201.00	61609.70	11212.26

TABLE I (Continued)

	33	34	35	36	37	38	39	40
1 IRR COTTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 IRR FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 IRR FEED GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 OTHER IRR CROP	0.0	0.0	0.63	0.0	0.0	0.0	0.0	0.0
5 DRY COTTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6 DRY FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7 DRY FEED GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 OTHER DRY CROP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 RANGE LVSTK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 FEEDLST LVSTK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 AG SERVICES	109.21	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12 CRUDE OIL & GAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13 NATL GAS LIQ	0.0	0.0	18.18	0.0	28.83	0.0	0.0	0.0
14 OIL & GAS SERV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 CONSTRUCTION	222.71	947.96	849.54	64.05	151.25	552.79	416.45	487.40
16 MEAT PRODUCTS	0.0	0.0	34.45	0.0	0.0	0.0	0.0	2.40
17 FOOD PROCESS	0.68	0.0	8.88	0.0	0.0	0.0	0.0	0.63
18 TEXTILE PROD	0.0	0.0	0.0	0.0	0.0	0.44	0.0	0.0
19 MILLING & FEEDS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 BEVERAGES	0.0	0.0	8.33	0.0	0.0	0.0	5.93	89.06
21 WOOD & PAPER & PRI	35.30	413.57	2668.33	11.92	0.0	2643.86	7.36	305.00
22 CHEMICALS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 PETRO PRODUCT	124.21	0.0	3927.91	24.58	60.55	1133.75	0.0	9.29
24 SOIL & ROCK PROD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 METAL PRODUCT	0.0	0.0	0.0	0.0	0.0	24.52	0.0	0.0
26 MACHINERY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 OTHER MFG	35.68	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28 TRANSPORTATION	589.15	68.71	4223.93	44.80	0.0	4107.19	24.69	46.47
29 COMMUNICATION	122.10	883.76	2608.62	19.74	42.70	2845.71	503.95	298.08
30 GAS SERV	35.60	91.16	295.67	5.01	0.0	756.57	44.05	118.20
31 ELECTRIC SERV	70.30	455.86	1304.06	27.47	210.27	2704.63	289.10	539.39
32 WATER & SAN SER	2.36	60.93	554.19	3.86	0.0	361.39	34.98	96.65
33 WHL AGR PROD	10.37	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34 WHL PETRO PROD	2.10	0.0	458.73	0.0	6775.79	141.45	0.0	0.0
35 OTHER WHOLESALE	76.39	2341.42	3566.66	64.70	1035.75	26893.17	611.33	124.50
36 AGR SUPPLIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37 GAS SERV STAT	12.47	0.0	870.78	7.55	18.57	261.35	40.64	128.01
38 OTHER RETAIL	16.40	364.91	2638.37	51.48	0.0	868.55	101.41	276.25
39 FINANCE	487.55	1858.35	1625.17	99.74	46.61	1478.86	1340.85	2012.21
40 INSUR & R. E.	74.58	1158.17	2142.65	72.45	237.48	1930.99	2388.16	715.52
41 EDUCATION SERV	41.04	272.66	726.04	15.28	43.49	666.46	299.64	726.07
42 OTHER SERV	391.55	498.86	6005.63	97.62	98.88	1368.35	2170.08	1816.70
43 HOUSEHOLDS	113.15	22152.73	93751.88	1528.23	5261.25	20453.63	46853.91	20553.39
44 LOCAL GOVT	48.48	398.14	1049.45	21.08	64.14	740.90	520.92	512.40
45 STATE GOVT	19.71	92.78	252.48	5.83	14.30	344.09	59.84	523.72
46 FEDERAL GOVT	1025.27	462.82	7686.89	87.81	400.35	6593.65	4117.91	714.62
47 IMPORTS	4108.42	2368.70	14632.99	256.99	195.05	12328.96	7231.97	916.76
48 DEPRECIATION	485.62	2361.71	9006.93	256.11	203.88	1422.14	1132.23	1600.28
GRUSS OUTLAY	11560.90	37253.20	157917.38	2766.30	14897.60	160823.30	66202.00	32613.00

TABLE I (Continued)

	41	42	49 HOUSEHOLDS	50 LOCAL GOVT	51 STATE GOVT	52 FEDERAL GOVT	53 EXPORTS	54 NET INV CHNG
1 IRR COTTON	0.0	0.0	0.0	0.0	0.0	14574.81	13950.55	-10267.79
2 IRR FLOOD GRAIN	0.0	0.0	0.0	0.0	0.0	20061.68	20193.66	-1272.96
3 IRR FEED GRAIN	0.0	0.0	0.0	0.0	0.0	25691.53	103805.13	0.0
4 OTHER IRR CROP	0.0	0.0	4718.87	0.0	0.0	5176.74	21935.64	0.0
5 DRY COTTON	0.0	0.0	0.0	0.0	0.0	4626.41	4489.32	-3212.80
6 DRY FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	5710.25	15985.15	-426.40
7 DRY FEED GRAIN	0.0	0.0	0.0	0.0	0.0	5572.01	7979.47	0.0
8 OTHER DRY CROP	0.0	0.0	83.23	0.0	0.0	3208.53	1313.14	0.0
9 RANGE LVSTK	0.0	0.0	1533.51	0.0	1.16	2219.79	47846.07	2666.72
10 FEEDLOT LVSTK	0.0	0.0	0.0	0.0	0.0	8.55	187662.38	14936.39
11 AG SERVICES	0.0	0.0	504.66	0.0	0.0	0.0	3536.82	0.0
12 CRUDE OIL & GAS	0.0	0.0	0.0	0.0	0.0	0.0	344165.00	0.0
13 NATL GAS LIQ	0.0	5.70	0.0	0.0	0.0	0.0	121810.25	0.0
14 OIL & GAS SERV	0.0	0.0	0.0	0.0	0.0	0.0	13396.44	0.0
15 CONSTRUCTION	435.59	853.86	21003.57	417.71	100.30	27.02	12751.70	0.0
16 MEAT PRODUCTS	1289.49	105.36	944.29	0.0	0.0	2605.00	42136.19	-768.82
17 FOOD PROCESS	3105.26	115.73	7043.20	0.0	475.21	5806.88	34339.68	-8475.60
18 TEXTILE PROD	7.68	0.0	47.70	236.75	32.78	0.0	3952.98	-10.63
19 MILLING & FEEDS	493.48	0.0	0.0	0.0	2.23	0.0	0.0	460.47
20 BEVERAGES	0.0	0.0	5868.71	0.0	0.0	0.0	4507.40	40.92
21 WOOD & PAPER & PRI	501.51	1556.27	1135.50	0.0	135.34	119.84	1952.01	-76.94
22 CHEMICALS	44.71	14.24	0.0	210.67	347.58	59.87	67051.81	7775.00
23 PETRO PRODUCT	19.82	3134.23	20.82	2716.14	1380.82	383.80	108443.50	3322.82
24 SOIL & ROCK PROD	0.89	0.0	0.0	0.0	40.45	0.68	5497.31	296.81
25 METAL PRODUCT	20.70	2036.97	2.38	0.0	31.04	50.67	2295.13	121.15
26 MACHINERY	33.04	0.0	133.28	16.81	90.03	4.38	7206.30	1229.51
27 OTHER MFG	230.62	158.20	0.0	805.16	24.05	26.66	3514.82	110.21
28 TRANSPORTATION	442.27	865.21	19294.04	1.40	224.26	3523.99	3663.11	0.0
29 COMMUNICATION	604.09	2434.03	14039.55	0.0	276.96	603.69	555.37	0.0
30 GAS SERV	431.40	299.28	9093.09	24.51	25.26	449.34	104374.19	0.0
31 ELECTRIC SERV	1216.68	1338.63	25804.44	86.27	144.17	360.64	12952.23	0.0
32 WATER & SAN SER	233.26	199.65	3904.65	30.46	37.37	1078.08	1598.24	0.0
33 WHL AGR PROD	0.0	0.0	0.0	0.0	0.0	0.0	3429.16	0.0
34 WHL PETRO PROD	0.0	1326.67	23426.65	0.0	23.10	566.54	2963.05	0.0
35 OTHER WHOLESALE	1026.74	2144.95	49372.74	411.44	125.28	183.24	56305.44	0.0
36 AGR SUPPLIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37 GAS SERV STAT	2.32	109.83	4284.66	1723.60	0.0	0.0	856.24	0.0
38 OTHER RETAIL	8.81	867.43	146077.31	66.81	3.55	0.0	1861.08	0.0
39 FINANCE	16.48	1292.15	21192.76	5812.54	639.22	6309.95	2044.99	0.0
40 INSUR & R. E.	2257.56	1821.31	2184.85	121.79	125.25	16.97	0.0	0.0
41 EDUCATION SERV	7.49	384.43	54191.95	0.0	0.0	7407.06	2984.33	0.0
42 OTHER SERV	597.59	4861.56	61137.37	1020.03	148.23	12466.23	37738.79	0.0
43 HOUSEHOLDS	52627.61	87869.69	11576.12	7024.65	11539.41	126734.94	163443.00	0.0
44 LOCAL GOVT	11.44	409.57	8491.21	0.0	1678.05	1273.32	0.0	0.0
45 STATE GOVT	2.27	193.92	29187.42	0.0	0.0	14301.62	0.0	0.0
46 FEDERAL GOVT	564.95	5860.64	208109.75	313.01	93.43	0.0	0.0	0.0
47 IMPORTS	6671.26	23144.52	565068.94	9955.71	31676.23	105309.31	0.0	19.10
48 DEPRECIATION	11402.57	6343.35	0.0	0.0	0.0	0.0	0.0	0.0
49 GROSS OUTLAY	54307.75	150047.56	1300577.00	51000.46	49820.60	379022.69	1026487.00	6467.16

TABLE I (Continued)

55		
CAP FORM GROSS OUTPUT		
1	IRR COTTON	0.0 23936.20
2	IRR FOOD GRAIN	0.0 69919.56
3	IRR FEED GRAIN	0.0 162596.69
4	OTHER IRR CROP	0.0 43173.80
5	DRY COTTON	0.0 7529.80
6	DRY FOOD GRAIN	0.0 23390.80
7	DRY FEED GRAIN	0.0 18767.10
8	OTHER DRY CROP	0.0 5549.70
9	RANGE LVSTK	0.0 68847.56
10	FEEDLOT LVSTK	0.0 218413.88
11	AG SERVICES	0.0 19197.50
12	CRUDE OIL & GAS	0.0 397398.00
13	NATL GAS LIQ	0.0 134034.56
14	OIL & GAS SERV	0.0 33101.60
15	CONSTRUCTION	108524.13 166352.56
16	MEAT PRODUCTS	0.0 49242.40
17	FOOD PROCESS	0.0 50155.40
18	TEXTILE PROD	0.0 5349.10
19	MILLING & FEEDS	0.0 14774.60
20	BEVERAGES	0.0 10624.60
21	WOOD & PAPER & PKI	0.0 15575.70
22	CHEMICALS	0.0 108988.75
23	PETRO PRODUCT	16.20 177182.38
24	SOIL & ROCK PROD	0.0 13321.00
25	METAL PRODUCT	636.57 15007.10
26	MACHINERY	5967.77 20745.30
27	OTHER MFG	1734.38 11334.10
28	TRANSPORTATION	174.30 46839.50
29	COMMUNICATION	45.90 32471.90
30	GAS SERV	0.0 142201.00
31	ELECTRIC SERV	0.0 61609.70
32	WATER & SAN SERV	0.0 11212.20
33	WHL AGR PROD	32.50 11560.90
34	WHL PETRO PROD	0.0 37253.20
35	OTHER WHOLESALE	444.40 157917.38
36	AGR SUPPLIES	0.0 2766.30
37	GAS SERV STAT	0.0 14897.80
38	OTHER RETAIL	350.50 166823.38
39	FINANCE	0.0 68202.00
40	INSUR & R. E.	0.0 32813.00
41	EDUCATION SERV	0.0 84307.75
42	OTHER SERV	0.0 150047.56
43	HOUSEHOLDS	0.0 1300577.00
44	LOCAL GOVT	0.0 31000.46
45	STATE GOVT	0.0 34889.65
46	FEDERAL GOVT	0.0 388264.69
47	IMPORTS	0.0 1488824.00
48	DEPRECIATION	0.0 248346.00
	GROSS OUTLAY	11726.63 6417136.00

sector involves a movement across the industry's row in the transaction table. It was noted that the Range Livestock sector (column 9) purchased \$2,483,500 of output from the Milling and Feed sector (row 19). This is the same as reading across row 19 and finding that the Milling and Feeds sector sells \$2,483,500 of output to the Range Livestock sector. That is, transactions are interpreted as sales or purchases, depending on whether one reads across a row or down a column.

The High Plains is a relatively "open" economy, meaning that a large proportion of the regional transactions is made with parties located outside of the region. Firms within a given sector generally import many inputs for their production processes. Inspection of the transactions table indicates that the dollar values of imports (row 43) represent a large proportion of gross outlay in most sectors. Also, firms in the High Plains export large amounts of output as can be seen by inspection of the dollar values of exports (column 53) relative to the gross output for each sector. Agriculture and petroleum sectors are seen to be the leading exporters in the region.

The direct requirements or input coefficients matrix (Table II) is derived by dividing each column entry in Table I by the sector's gross outlay. For each dollar of output by an industry listed at the top of a column, each column entry in the table is an estimate of the direct requirement from the industry listed on the left. For example, the Meat Products sector (16) purchases \$0.320445 of livestock from the Feedlot Livestock sector (10) in the region for each \$1.00 of gross output.

The direct requirements matrix is an estimate of the initial, direct effect on sectors of the regional economy when a given sector

TABLE II  
DIRECT REQUIREMENTS MATRIX--HIGH PLAINS OF OKLAHOMA AND TEXAS, 1967

	1	2	3	4	5	6	7	8
1 IRR COTTON	0.001565	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 IRR FOOD GRAIN	0.0	0.012218	0.0	0.0	0.0	0.0	0.0	0.0
3 IRR FEED GRAIN	0.0	0.0	0.009967	0.0	0.0	0.0	0.014715	0.0
4 OTHER IRR CROP	0.0	0.0	0.0	0.046169	0.0	0.0	0.0	0.0
5 DRY COTTON	0.0	0.0	0.0	0.0	0.001340	0.0	0.0	0.0
6 DRY FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	0.047244	0.0	0.0
7 DRY FEED GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 OTHER DRY CROP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 RANGE LVSTK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 FEEDLOT LVSTK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 AG SERVICES	0.091581	0.014754	0.028910	0.007420	0.089646	0.051597	0.037556	0.0
12 CRUDE OIL & GAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13 NATL GAS LIQ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14 OIL & GAS SERV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 CONSTRUCTION	0.005470	0.007744	0.006350	0.008135	0.003615	0.007291	0.005017	0.002292
16 MEAT PRODUCTS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17 FOOD PROCESS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18 TEXTILE PROD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19 MILLING & FEEDS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 BEVERAGES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21 WOOD & PAPER & PRI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22 CHEMICALS	0.049830	0.075521	0.066251	0.043846	0.015645	0.030589	0.0	0.0
23 PETRO PRODUCT	0.031190	0.042615	0.046141	0.023446	0.025544	0.074109	0.054702	0.011240
24 SOIL & ROCK PROD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 METAL PRODUCT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 MACHINERY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 OTHER MFG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28 TRANSPORTATION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29 COMMUNICATION	0.001574	0.002309	0.001832	0.002331	0.001205	0.002083	0.001433	0.000625
30 GAS SERV	0.010468	0.029891	0.016538	0.045480	0.0	0.0	0.0	0.0
31 ELECTRIC SERV	0.005549	0.013722	0.008823	0.016879	0.001033	0.002083	0.001433	0.000625
32 WATER & SAN SER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33 WHL AGR PROD	0.0	0.002929	0.002781	0.001795	0.0	0.002659	0.002643	0.0
34 WHL PETRO PROD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35 OTHER WHOLESale	0.005901	0.0	0.0	0.0	0.005906	0.0	0.0	0.0
36 AGR SUPPLIES	0.005985	0.009380	0.008187	0.009308	0.002040	0.007963	0.001438	0.0
37 GAS SERV STAT	0.009581	0.013091	0.014173	0.007203	0.007847	0.022765	0.016804	0.003449
38 OTHER RETAIL	0.018785	0.026634	0.024716	0.019209	0.013618	0.032270	0.023888	0.021531
39 FINANCE	0.013144	0.025000	0.017349	0.059675	0.007401	0.020833	0.010931	0.011147
40 INSUR & R. E.	0.009050	0.062391	0.010077	0.013407	0.006183	0.009561	0.005107	0.003829
41 EDUCATION SERV	0.007746	0.011247	0.008974	0.011517	0.005328	0.010666	0.007084	0.003260
42 OTHER SERV	0.005825	0.015489	0.009633	0.044506	0.006668	0.001441	0.000717	0.004375
43 HOUSEHOLDS	0.561813	0.366804	0.503170	0.377035	0.697307	0.414406	0.626581	0.859759
44 LOCAL GOVT	0.016125	0.023445	0.018712	0.023984	0.011019	0.022229	0.014751	0.006856
45 STATE GOVT	0.000204	0.000281	0.000220	0.000301	0.000179	0.000270	0.000186	0.000052
46 FEDERAL GOVT	0.004644	0.007880	0.007545	0.016427	0.003470	0.011458	0.008960	0.007500
47 IMPORTS	0.097904	0.117633	0.102568	0.062603	0.071380	0.123238	0.089889	0.047001
48 DEPRECIATION	0.046045	0.119021	0.087083	0.159322	0.029604	0.103690	0.076165	0.016459
TOTAL	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000

TABLE II (Continued)

	9	10	11	12	13	14	15	16
1 IRR COTTON	0.0	0.0	0.031069	0.0	0.0	0.0	0.0	0.0
2 IRR FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 IRR FEED GRAIN	0.004128	0.118440	0.0	0.0	0.0	0.0	0.0	0.0
4 OTHER IRR CROP	0.011621	0.011897	0.0	0.0	0.0	0.0	0.0	0.0
5 DRY COTTON	0.0	0.0	0.010072	0.0	0.0	0.0	0.0	0.0
6 DRY FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7 DRY FEED GRAIN	0.000956	0.018666	0.0	0.0	0.0	0.0	0.0	0.0
8 OTHER DRY CROP	0.005885	0.002471	0.0	0.0	0.0	0.0	0.0	0.0
9 RANGE LVSTK	0.073241	0.016280	0.0	0.0	0.0	0.0	0.000090	0.066902
10 FEEDLOT LVSTK	0.0	0.000120	0.0	0.0	0.0	0.0	0.0	0.320445
11 AG SERVICES	0.020516	0.007061	0.013722	0.0	0.0	0.0	0.0	0.0
12 CRUDE OIL & GAS	0.0	0.0	0.0	0.000052	0.070479	0.0	0.0	0.0
13 NATL GAS LIQ	0.0	0.0	0.0	0.0	0.0	0.001981	0.000003	0.0
14 OIL & GAS SERV	0.0	0.0	0.0	0.033627	0.005542	0.062980	0.000992	0.0
15 CONSTRUCTION	0.008564	0.000361	0.007516	0.000071	0.051615	0.0	0.001622	0.002775
16 MEAT PRODUCTS	0.0	0.0	0.0	0.0	0.0	0.0	0.000006	0.058750
17 FOOD PROCESS	0.052556	0.017805	0.0	0.0	0.0	0.0	0.000003	0.0
18 TEXTILE PROD	0.0	0.0	0.0	0.0	0.0	0.0	0.000117	0.0
19 MILLING & FEEDS	0.036072	0.042380	0.0	0.0	0.0	0.0	0.0	0.028063
20 BEVERAGES	0.0	0.0	0.0	0.0	0.0	0.0	0.000048	0.0
21 WOOD & PAPER & PRI	0.0	0.000133	0.001683	0.0	0.0	0.000794	0.019703	0.000046
22 CHEMICALS	0.000424	0.0	0.0	0.002817	0.001974	0.0	0.005308	0.0
23 PETRO PRODUCT	0.019212	0.000916	0.016470	0.002091	0.014229	0.042000	0.019698	0.000015
24 SOIL & ROCK PROD	0.0	0.0	0.0	0.000183	0.0	0.0	0.042924	0.0
25 METAL PRODUCT	0.0	0.0	0.0	0.0	0.0	0.0	0.054290	0.0
26 MACHINERY	0.0	0.0	0.007437	0.009923	0.0	0.0	0.007994	0.0
27 OTHER MFG	0.0	0.0	0.0	0.0	0.003678	0.000038	0.021528	0.0
28 TRANSPORTATION	0.006337	0.000134	0.002657	0.0	0.0	0.000137	0.003064	0.006663
29 COMMUNICATION	0.002243	0.000588	0.005121	0.000795	0.002718	0.001505	0.003291	0.000869
30 GAS SERV	0.000100	0.000937	0.002235	0.000081	0.000458	0.000042	0.000291	0.000059
31 ELECTRIC SERV	0.002245	0.001634	0.008095	0.000657	0.001000	0.000527	0.000996	0.001290
32 WATER & SAN SERV	0.0	0.0	0.000884	0.0	0.006155	0.000014	0.000268	0.001794
33 WHL AGR PROD	0.013772	0.024024	0.011411	0.0	0.0	0.0	0.0	0.000423
34 WHL PETRO PROD	0.0	0.0	0.007296	0.0	0.0	0.000957	0.000584	0.0
35 OTHER WHOLESALE	0.0	0.0	0.004862	0.000623	0.001405	0.047001	0.012149	0.040916
36 AGR SUPPLIES	0.000078	0.0	0.0	0.0	0.0	0.0	0.0	0.000001
37 GAS SERV STAT	0.005902	0.000237	0.000438	0.000643	0.0	0.008268	0.002637	0.000005
38 OTHER RETAIL	0.034488	0.000592	0.005537	0.000489	0.0	0.009706	0.042848	0.0
39 FINANCE	0.030916	0.029913	0.005104	0.0	0.0	0.002352	0.005134	0.000046
40 INSUR & R. E.	0.028037	0.001484	0.007618	0.000065	0.000970	0.034188	0.014746	0.000591
41 EDUCATION SERV	0.017592	0.000322	0.000501	0.014487	0.002859	0.003759	0.002105	0.000671
42 OTHER SERV	0.001711	0.000786	0.051827	0.001377	0.000198	0.018187	0.014818	0.004262
43 HOUSEHOLDS	0.326528	0.066893	0.237939	0.210194	0.142673	0.376246	0.358756	0.046945
44 LOCAL GOVT	0.036967	0.000500	0.000117	0.003377	0.000088	0.000329	0.001870	0.000083
45 STATE GOVT	0.000291	0.000097	0.000479	0.013905	0.003036	0.003884	0.001324	0.000681
46 FEDERAL GOVT	0.006138	0.001525	0.031754	0.211282	0.157999	0.023900	0.036064	0.003813
47 IMPORTS	0.142237	0.017115	0.489962	0.244951	0.426069	0.312996	0.349091	0.380948
48 DEPRECIATION	0.111184	0.016691	0.038194	0.248310	0.106075	0.047708	0.015637	0.032945
TOTAL	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000

TABLE II (Continued)

	17	18	19	20	21	22	23	24
1 IRR COTTON	0.100572	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 IRR FOOD GRAIN	0.0	0.0	0.004260	0.0	0.0	0.0	0.0	0.0
3 IRR FEED GRAIN	0.0	0.0	0.341815	0.0	0.0	0.0	0.0	0.0
4 OTHER IRR CROP	0.118630	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5 DRY COTTON	0.028340	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6 DRY FOOD GRAIN	0.0	0.0	0.001134	0.0	0.0	0.0	0.0	0.0
7 DRY FEED GRAIN	0.0	0.0	0.085971	0.0	0.0	0.0	0.0	0.0
8 OTHER DRY CROP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 RANGE LVSTK	0.053290	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 FEEDLOT LVSTK	0.0	0.0	0.000054	0.0	0.0	0.0	0.0	0.0
11 AG SERVICES	0.0	0.186125	0.0	0.0	0.0	0.0	0.0	0.0
12 CRUDE OIL & GAS	0.0	0.0	0.0	0.0	0.0	0.0	0.092618	0.0
13 NATL GAS LIQ	0.0	0.0	0.0	0.0	0.0	0.102915	0.005017	0.0
14 OIL & GAS SERV	0.0	0.0	0.0	0.0	0.0	0.013155	0.010227	0.007773
15 CONSTRUCTION	0.001061	0.0	0.003797	0.000137	0.000503	0.054388	0.000002	0.001310
16 MEAT PRODUCTS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17 FOOD PROCESS	0.003043	0.0	0.002219	0.002206	0.0	0.0	0.0	0.0
18 TEXTILE PROD	0.001298	0.180767	0.000454	0.0	0.000710	0.0	0.0	0.0
19 MILLING & FEEDS	0.0	0.0	0.047157	0.0	0.0	0.0	0.0	0.0
20 BEVERAGES	0.0	0.0	0.0	0.008962	0.0	0.0	0.0	0.0
21 WOOD & PAPER & PRI	0.000593	0.001363	0.001023	0.000009	0.006404	0.000288	0.001367	0.000007
22 CHEMICALS	0.003025	0.000215	0.0	0.000110	0.000237	0.083981	0.009662	0.0
23 PETRO PRODUCT	0.003282	0.021233	0.007179	0.007769	0.002234	0.028864	0.114359	0.111886
24 SOIL & ROCK PROD	0.0	0.0	0.0	0.0	0.0	0.000018	0.000060	0.010709
25 METAL PRODUCT	0.0	0.0	0.0	0.0	0.000140	0.000554	0.000142	0.000018
26 MACHINERY	0.0	0.0	0.0	0.000523	0.000192	0.005426	0.0	0.0
27 OTHER MFG	0.0	0.0	0.0	0.0	0.000052	0.000230	0.000001	0.0
28 TRANSPORTATION	0.005111	0.003290	0.036149	0.000879	0.013056	0.013774	0.018311	0.027107
29 COMMUNICATION	0.003191	0.009867	0.003800	0.007845	0.007838	0.001328	0.001318	0.003037
30 GAS SERV	0.003988	0.003831	0.000923	0.002082	0.001281	0.017639	0.024622	0.000579
31 ELECTRIC SERV	0.010193	0.004122	0.010302	0.004193	0.007171	0.047840	0.008575	0.000712
32 WATER & SAN SER	0.000408	0.002625	0.001062	0.001393	0.000972	0.005028	0.001201	0.000426
33 WHL AGR PROD	0.004083	0.0	0.040787	0.0	0.0	0.0	0.0	0.0
34 WHL PETRO PROD	0.000857	0.000271	0.003240	0.002962	0.0	0.0	0.0	0.000709
35 OTHER WHOLESALE	0.005274	0.001425	0.000702	0.003052	0.017943	0.011183	0.001312	0.015667
36 AGR SUPPLIES	0.0	0.0	0.0	0.0	0.000001	0.0	0.0	0.0
37 GAS SERV STAT	0.000237	0.002514	0.000292	0.000033	0.000682	0.000020	0.000025	0.000525
38 OTHER RETAIL	0.000670	0.023189	0.004277	0.000066	0.000514	0.000190	0.000070	0.001832
39 FINANCE	0.018663	0.035286	0.002984	0.002810	0.001183	0.000168	0.0	0.002860
40 INSUR & R. E.	0.006633	0.011697	0.001475	0.003026	0.005921	0.003129	0.001294	0.003916
41 EDUCATION SERV	0.002243	0.003044	0.002859	0.004702	0.003633	0.003063	0.005517	0.004742
42 OTHER SERV	0.007044	0.022637	0.028970	0.010617	0.014235	0.011860	0.004787	0.015730
43 HOUSEHOLDS	0.128078	0.206713	0.146283	0.383643	0.442848	0.151552	0.230060	0.327732
44 LOCAL GOVT	0.002826	0.000052	0.000909	0.004651	0.002889	0.002665	0.000542	0.001786
45 STATE GOVT	0.000989	0.003258	0.002623	0.002719	0.002424	0.001946	0.005671	0.004207
46 FEDERAL GOVT	0.007479	0.009002	0.052350	0.058837	0.117714	0.048071	0.023110	0.053861
47 IMPORTS	0.445484	0.230532	0.146486	0.445305	0.324665	0.262721	0.397026	0.350806
48 DEPRECIATION	0.033414	0.036941	0.018485	0.041466	0.024448	0.128005	0.043103	0.052065
TOTAL	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000

TABLE II (Continued)

	25	26	27	28	29	30	31	32
1 IRR COTTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 IRR FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 IRR FEED GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 OTHER IRR CROP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5 DRY COTTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6 DRY FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7 DRY FEED GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 OTHER DRY CROP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 RANGE LVSTK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 FEEDLOT LVSTK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 AG SERVICES	0.0	0.000003	0.0	0.0	0.0	0.0	0.0	0.0
12 CRUDE OIL & GAS	0.0	0.0	0.0	0.0	0.0	0.192371	0.0	0.0
13 NATL GAS LIQ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14 OIL & GAS SERV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 CONSTRUCTION	0.000377	0.000146	0.000011	0.025232	0.001477	0.000469	0.001584	0.049291
16 MEAT PRODUCTS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17 FOOD PROCESS	0.0	0.0	0.0	0.000393	0.0	0.0	0.0	0.0
18 TEXTILE PROD	0.0	0.0	0.0	0.0	0.0	0.000021	0.000080	0.000434
19 MILLING & FEEDS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 BEVERAGES	0.0	0.000051	0.0	0.0	0.0	0.0	0.0	0.0
21 WOOD & PAPER & PRI	0.000608	0.000705	0.012539	0.000328	0.002283	0.000131	0.001293	0.001771
22 CHEMICALS	0.0	0.002254	0.0	0.0	0.0	0.000004	0.000010	0.013054
23 PETRO PRODUCT	0.000618	0.0006146	0.012582	0.044062	0.001050	0.000243	0.001075	0.006122
24 SOIL & ROCK PROD	0.0	0.0	0.0	0.000053	0.0	0.0	0.000045	0.009907
25 METAL PRODUCT	0.000028	0.000696	0.021903	0.005366	0.0	0.0	0.000006	0.002624
26 MACHINERY	0.0	0.001217	0.0	0.000431	0.0	0.0	0.0	0.000252
27 OTHER MFG	0.000025	0.001980	0.039828	0.001671	0.0	0.000005	0.000062	0.001521
28 TRANSPORTATION	0.061406	0.004820	0.003022	0.013705	0.002594	0.000325	0.003746	0.0
29 COMMUNICATION	0.003140	0.003220	0.006242	0.033564	0.003594	0.000807	0.004668	0.002490
30 GAS SERV	0.034766	0.002881	0.001253	0.007168	0.000928	0.014461	0.148986	0.0
31 ELECTRIC SERV	0.036883	0.009515	0.003750	0.009913	0.009028	0.000259	0.0	0.062801
32 WATER & SAN SER	0.000295	0.000295	0.000809	0.001332	0.000956	0.000067	0.002281	0.082980
33 WHL AGR PROD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34 WHL PETRO PROD	0.000006	0.001559	0.005189	0.021730	0.0	0.000050	0.000444	0.002094
35 OTHER WHOLESALE	0.002692	0.008263	0.003446	0.035561	0.001209	0.000674	0.003621	0.031290
36 AGR SUPPLIES	0.0	0.000004	0.0	0.0	0.0	0.0	0.0	0.0
37 GAS SERV STAT	0.000193	0.000744	0.000342	0.0	0.000322	0.000197	0.000570	0.0
38 OTHER RETAIL	0.000355	0.001667	0.004290	0.0	0.000109	0.000626	0.010030	0.0
39 FINANCE	0.002467	0.000822	0.002590	0.001003	0.000245	0.000989	0.003696	0.0
40 INSUR & R. E.	0.003530	0.001018	0.005095	0.030050	0.013871	0.002613	0.006483	0.005067
41 EDUCATION SERV	0.001992	0.004567	0.003936	0.013669	0.020476	0.004837	0.022070	0.0
42 OTHER SERV	0.002775	0.016795	0.018697	0.028180	0.011959	0.003441	0.005360	0.0
43 HOUSEHOLD	0.297377	0.406818	0.174586	0.471482	0.328707	0.071896	0.460341	0.300534
44 LOCAL GOVT	0.002114	0.001369	0.001212	0.005201	0.023013	0.006155	0.026356	0.0
45 STATE GOVT	0.001079	0.004229	0.003629	0.012103	0.010440	0.002104	0.010473	0.0
46 FEDERAL GOVT	0.039188	0.094199	0.014161	0.040182	0.157823	0.014557	0.131226	0.007409
47 IMPORTS	0.525252	0.393645	0.644734	0.136935	0.240222	0.659680	0.026761	0.145384
48 DEPRECIATION	0.012834	0.024373	0.016153	0.060683	0.169632	0.023018	0.128732	0.274974
TOTAL	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000

TABLE II (Continued)

	33	34	35	36	37	38	39	40
1 IRR COTTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 IRR FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 IRR FEED GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 OTHER IRR CROP	0.0	0.0	0.000004	0.0	0.0	0.0	0.0	0.0
5 DRY COTTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6 DRY FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7 DRY FEED GRAIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 OTHER DRY CROP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 RANGE LVSTK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 FEEDLOT LVSTK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 AG SERVICES	0.009455	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12 CRUDE OIL & GAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13 NATL GAS LIQ	0.0	0.0	0.000115	0.0	0.001935	0.0	0.0	0.0
14 OIL & GAS SERV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 CONSTRUCTION	0.019264	0.025446	0.005380	0.023154	0.010153	0.003314	0.006106	0.014945
16 MEAT PRODUCTS	0.0	0.0	0.000218	0.0	0.0	0.0	0.0	0.000074
17 FOOD PROCESS	0.000059	0.0	0.000056	0.0	0.0	0.0	0.0	0.000019
18 TEXTILE PROD	0.0	0.0	0.0	0.0	0.0	0.000003	0.0	0.0
19 MILLING & FEEDS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 BEVERAGES	0.0	0.0	0.000053	0.0	0.0	0.0	0.000087	0.002731
21 WOOD & PAPER & PRI	0.003053	0.011102	0.016897	0.004309	0.0	0.015848	0.000108	0.009352
22 CHEMICALS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 PETRO PRODUCT	0.010744	0.0	0.024873	0.008886	0.004064	0.006796	0.0	0.000285
24 SOIL & ROCK PROD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 METAL PRODUCT	0.0	0.0	0.0	0.0	0.0	0.000147	0.0	0.0
26 MACHINERY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 OTHER MFG	0.003086	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28 TRANSPORTATION	0.050961	0.001844	0.026748	0.016195	0.0	0.024620	0.000362	0.001425
29 COMMUNICATION	0.010561	0.023723	0.016519	0.007136	0.002800	0.017058	0.007389	0.009140
30 GAS SERV	0.003079	0.002447	0.001872	0.001811	0.0	0.004535	0.000646	0.003624
31 ELECTRIC SERV	0.006081	0.012237	0.008258	0.009930	0.014651	0.016213	0.004239	0.016539
32 WATER & SAN SER	0.000204	0.001636	0.003509	0.001395	0.0	0.002166	0.000513	0.002964
33 WHL AGR PROD	0.000857	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34 WHL PETRO PROD	0.000182	0.0	0.002905	0.0	0.454818	0.000848	0.0	0.0
35 OTHER WHOLESALE	0.006608	0.062851	0.022586	0.023389	0.069524	0.173196	0.008964	0.003817
36 AGR SUPPLIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37 GAS SERV STAT	0.001079	0.0	0.005514	0.002729	0.001240	0.001567	0.000684	0.003925
38 OTHER RETAIL	0.001419	0.009795	0.016707	0.018610	0.0	0.005206	0.001487	0.008471
39 FINANCE	0.042207	0.049884	0.010291	0.036055	0.003129	0.008805	0.019660	0.061700
40 INSUR & R. E.	0.006451	0.031089	0.013568	0.026190	0.015941	0.011575	0.035016	0.021940
41 EDUCATION SERV	0.003550	0.007319	0.004598	0.005524	0.002919	0.003995	0.004393	0.022263
42 OTHER SERV	0.033868	0.013391	0.038030	0.035289	0.006637	0.026185	0.031827	0.055705
43 HOUSEHOLDS	0.295232	0.594653	0.593677	0.552446	0.353176	0.521232	0.686987	0.630221
44 LOCAL GOVT	0.004193	0.010687	0.006646	0.007620	0.004305	0.004441	0.007638	0.015712
45 STATE GOVT	0.001705	0.002491	0.001599	0.002108	0.000973	0.002063	0.000877	0.016059
46 FEDERAL GOVT	0.088684	0.012424	0.048677	0.031743	0.026885	0.051513	0.060376	0.021912
47 IMPORTS	0.355372	0.063584	0.092662	0.092900	0.013093	0.073904	0.106037	0.028110
48 DEPRECIATION	0.042005	0.063396	0.038038	0.092582	0.013684	0.024710	0.016601	0.049069
TOTAL	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000

TABLE II (Continued)

	41	42
1 IRR COTTON	0.0	0.0
2 IRR FOOD GRAIN	0.0	0.0
3 IRR FEED GRAIN	0.0	0.0
4 OTHER IRR CROP	0.0	0.0
5 DRY COTTON	0.0	0.0
6 DRY FOOD GRAIN	0.0	0.0
7 DRY FEED GRAIN	0.0	0.0
8 OTHER DRY CROP	0.0	0.0
9 RANGE LVSTK	0.0	0.0
10 FEEDLOT LVSTK	0.0	0.0
11 AG SERVICES	0.0	0.0
12 CRUDE OIL & GAS	0.0	0.0
13 NATL GAS LIQ	0.0	0.000036
14 OIL & GAS SERV	0.0	0.0
15 CONSTRUCTION	0.005171	0.005691
16 MEAT PRODUCTS	0.015255	0.000702
17 FOOD PROCESS	0.036832	0.000771
18 TEXTILE PROD	0.000084	0.0
19 MILLING & FEEDS	0.005853	0.0
20 BEVERAGES	0.0	0.0
21 WOOD & PAPER & PRI	0.005949	0.010372
22 CHEMICALS	0.000530	0.003095
23 PETRO PRODUCT	0.000235	0.020888
24 SOIL & ROCK PROD	0.000011	0.0
25 METAL PRODUCT	0.000246	0.013575
26 MACHINERY	0.000352	0.0
27 OTHER MFG	0.002735	0.001054
28 TRANSPORTATION	0.005246	0.005766
29 COMMUNICATION	0.007165	0.016222
30 GAS SERV	0.005117	0.001995
31 ELECTRIC SERV	0.014431	0.008523
32 WATER & SAN SERV	0.002767	0.001331
33 WHL AGR PROD	0.0	0.0
34 WHL PETRO PROD	0.0	0.008842
35 OTHER WHOLESALE	0.012178	0.014295
36 AGR SUPPLIES	0.0	0.0
37 GAS SERV STAT	0.000028	0.000732
38 OTHER RETAIL	0.000104	0.005781
39 FINANCE	0.000195	0.008612
40 INSUR & R. E.	0.026778	0.012138
41 EDUCATION SERV	0.000089	0.002562
42 OTHER SERV	0.007088	0.032400
43 HOUSEHOLDS	0.624232	0.585612
44 LOCAL GOVT	0.000136	0.002730
45 STATE GOVT	0.000027	0.001292
46 FEDERAL GOVT	0.006701	0.039059
47 IMPORTS	0.079130	0.154248
48 DEPRECIATION	0.135254	0.044275
TOTAL	1.000000	1.000000

sector expands output by one dollar. There is also an indirect effect associated with the expansion of a sector's output. Any sector providing inputs to an expanding sector will have to expand its own output to meet this new demand for its inputs. Expanding its output requires the purchase of more inputs from its supplying sectors, initiating more purchases by these sectors from their suppliers, and the process continues through the regional economy until stopped by leakages from the income generation stream. The total direct and indirect effect on processing sectors which results from a dollar increase in final demand for the output of each processing sector is computed by inverting the  $(I-A)$  matrix as explained in a preceding subsection. This total requirements or direct and indirect coefficients matrix is presented in Table III.

The total requirements matrix presented in Table III is for 29 of the 42 processing sectors in the High Plains economy. These 29 processing sectors are the "demand output" sectors whose outputs are determined by final demand and by requirements of the thirteen "supply output" sectors.<sup>4</sup> Each column entry in the total requirements matrix is the total direct plus indirect output requirement from the industry named at the left to support a dollar of sales to final demand by the industry named at the top of the column. For example, the Electric Services sector (31) increases its output by \$0.053943 as a result of a one dollar increase in final demand for the output of the chemicals manufacturing sector (22). The direct requirements table (Table II) shows that \$0.047840 of this amount goes directly from sector 31 to

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<sup>4</sup>These concepts were presented in the last section of Chapter II.

TABLE III  
TOTAL REQUIREMENTS MATRIX--HIGH PLAINS  
OF OKLAHOMA AND TEXAS, 1967

	11	14	15	17	18	19	20	21
11 AG SERVICES	1.014023	0.000001	0.000031	0.000340	0.230381	0.000522	0.000001	0.000105
14 OIL & GAS SERV	0.000249	1.067806	0.001837	0.000102	0.000407	0.000147	0.000107	0.000054
15 CONSTRUCTION	0.008904	0.001546	1.002953	0.001932	0.003444	0.006499	0.000575	0.001368
17 FOOD PROCESS	0.000111	0.000243	0.000161	1.003175	0.000252	0.002551	0.002439	0.000190
18 TEXTILE PROD	0.000006	0.000004	0.000163	0.001592	1.220656	0.000591	0.000006	0.000876
19 MILLING & FEEDS	0.000011	0.000036	0.000023	0.000019	0.000035	1.049518	0.000033	0.000028
20 BEVERAGES	0.000030	0.000113	0.000098	0.000025	0.000061	0.000014	1.009051	0.000022
21 WOOD & PAPER & PRI	0.003042	0.002851	0.021030	0.001029	0.003683	0.002075	0.000368	1.007154
22 CHEMICALS	0.000320	0.000592	0.006168	0.003387	0.000757	0.000205	0.000261	0.000338
23 PETRO PRODUCT	0.021236	0.053809	0.030022	0.004725	0.035815	0.012389	0.009392	0.004335
24 SOIL & ROCK PROD	0.000401	0.000076	0.043526	0.000091	0.000194	0.000300	0.000042	0.000074
25 METAL PRODUCT	0.001348	0.000468	0.055335	0.000272	0.000887	0.001075	0.000213	0.000531
26 MACHINERY	0.007627	0.000020	0.008071	0.000041	0.001754	0.000078	0.000538	0.000216
27 OTHER MFG	0.000331	0.000129	0.022558	0.000089	0.000176	0.000411	0.000048	0.000145
28 TRANSPORTATION	0.004752	0.003310	0.009512	0.005945	0.007127	0.041629	0.001383	0.014264
29 COMMUNICATION	0.007200	0.004006	0.005304	0.004120	0.015844	0.006985	0.008491	0.009237
30 GAS SERV	0.004705	0.002317	0.003966	0.006088	0.008131	0.003847	0.003234	0.002925
31 ELECTRIC SERV	0.009799	0.003041	0.003276	0.011055	0.009504	0.012496	0.004895	0.008153
32 WATER & SAN SER	0.001245	0.000548	0.000652	0.000611	0.004122	0.001472	0.001641	0.001274
33 WHL AGR PROD	0.011582	0.000002	0.000002	0.004104	0.002634	0.042861	0.000011	0.000004
34 WHL PETRO PROD	0.008356	0.005753	0.002508	0.001265	0.004224	0.004879	0.003188	0.000918
35 OTHER WHOLESALE	0.008362	0.055475	0.015939	0.006526	0.010804	0.004742	0.003898	0.019848
36 AGR SUPPLIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.000001
37 GAS SERV STAT	0.000643	0.009355	0.002912	0.000353	0.003460	0.000469	0.000092	0.000858
38 OTHER RETAIL	0.006460	0.011947	0.003720	0.001123	0.030600	0.005128	0.000332	0.001142
39 FINANCE	0.007595	0.006330	0.007253	0.020152	0.047633	0.006197	0.003532	0.002203
40 INSUR & R. E.	0.010008	0.039585	0.017279	0.008317	0.020242	0.004589	0.003961	0.007527
41 EDUCATION SERV	0.001720	0.005883	0.003735	0.003098	0.005736	0.004563	0.005303	0.004598
42 OTHER SERV	0.056925	0.025768	0.019796	0.009398	0.045928	0.035476	0.011942	0.016860

TABLE III (Continued)

	22	23	24	25	26	27	28	29
11 AG SERVICES	0.000004	0.000001	0.000001	0.000001	0.000004	0.000003	0.000002	0.000002
14 OIL & GAS SERV	0.015862	0.012521	0.009837	0.000050	0.000126	0.000178	0.000635	0.000024
15 CONSTRUCTION	0.060746	0.001488	0.002688	0.002271	0.000793	0.000739	0.027594	0.002104
17 FOOD PROCESS	0.000234	0.000280	0.000270	0.000161	0.000212	0.000203	0.001048	0.000799
18 TEXTILE PROD	0.000021	0.000006	0.000003	0.000004	0.000004	0.000014	0.000013	0.000008
19 MILLING & FEEDS	0.000035	0.000044	0.000040	0.000022	0.000032	0.000031	0.000102	0.000131
20 BEVERAGES	0.000023	0.000009	0.000020	0.000018	0.000058	0.000020	0.000100	0.000043
21 WOOD & PAPER & PRI	0.002304	0.001862	0.000976	0.000981	0.001268	0.013794	0.002868	0.002838
22 CHEMICALS	1.092562	0.011975	0.001416	0.000069	0.002567	0.000197	0.000774	0.000067
23 PETRO PRODUCT	0.040008	1.131557	0.130897	0.004226	0.008160	0.015918	0.053574	0.001850
24 SOIL & ROCK PROD	0.002725	0.000152	1.010953	0.000108	0.000041	0.000045	0.001276	0.000105
25 METAL PRODUCT	0.004335	0.000472	0.000627	1.000566	0.007085	0.023189	0.007513	0.000331
26 MACHINERY	0.006433	0.000090	0.000046	0.000047	1.001241	0.000014	0.000672	0.000028
27 OTHER MFG	0.001717	0.000108	0.000157	0.000204	0.002131	1.041541	0.002482	0.000131
28 TRANSPORTATION	0.017447	0.021498	0.031075	0.062692	0.006066	0.005626	1.017220	0.003085
29 COMMUNICATION	0.003358	0.002647	0.005228	0.005701	0.004183	0.007761	0.036876	1.004382
30 GAS SERV	0.029168	0.030392	0.004750	0.037143	0.005153	0.003531	0.011466	0.002745
31 ELECTRIC SERV	0.053943	0.010928	0.002976	0.007954	0.010358	0.005116	0.012977	0.009959
32 WATER & SAN SER	0.006367	0.001673	0.000864	0.000516	0.000489	0.001109	0.002058	0.001229
33 WHL AGR PROD	0.000002	0.000003	0.000003	0.000002	0.000002	0.000002	0.000008	0.000009
34 WHL PETRO PROD	0.000914	0.000653	0.001996	0.001572	0.002287	0.005960	0.022807	0.000400
35 OTHER WHOLESALE	0.016032	0.003572	0.019170	0.005598	0.009797	0.006037	0.040456	0.002268
36 AGR SUPPLIES	0.0	0.0	0.0	0.0	0.000004	0.0	0.0	0.0
37 GAS SERV STAT	0.000493	0.000190	0.000782	0.000277	0.000841	0.000468	0.000500	0.000424
38 OTHER RETAIL	0.001569	0.000479	0.002530	0.000672	0.002119	0.004919	0.001667	0.000480
39 FINANCE	0.001645	0.000491	0.003965	0.003259	0.001465	0.003903	0.005422	0.001468
40 INSUR & R. E.	0.006837	0.003257	0.006624	0.006250	0.002128	0.006852	0.034889	0.015343
41 EDUCATION SERV	0.005753	0.007194	0.006521	0.003566	0.005252	0.004972	0.016661	0.021272
42 OTHER SERV	0.017189	0.007289	0.019767	0.005777	0.018542	0.021811	0.035323	0.013867

TABLE III (Continued)

	30	31	32	33	34	35	36	37
11 AG SERVICES	0.000005	0.000021	0.000113	0.009598	0.000004	0.000004	0.000002	0.000003
14 OIL & GAS SERV	0.000006	0.000028	0.000530	0.000221	0.000083	0.000367	0.000191	0.000136
15 CONSTRUCTION	0.000615	0.002350	0.055405	0.021666	0.027315	0.007522	0.025142	0.023560
17 FOOD PROCESS	0.000190	0.000872	0.000098	0.000319	0.000390	0.000356	0.000327	0.000351
18 TEXTILE PROD	0.000027	0.000109	0.000597	0.000009	0.000020	0.000022	0.000013	0.000015
19 MILLING & FEEDS	0.000031	0.000143	0.000015	0.000034	0.000061	0.000042	0.000047	0.000054
20 BEVERAGES	0.000009	0.000024	0.000027	0.000037	0.000111	0.000105	0.000092	0.000106
21 WOOD & PAPER & PRI	0.000283	0.001987	0.004039	0.004480	0.013822	0.018823	0.006566	0.008145
22 CHEMICALS	0.000019	0.000103	0.016006	0.000323	0.000245	0.000457	0.000332	0.000265
23 PETRO PRODUCT	0.000457	0.002067	0.012480	0.016987	0.003690	0.031995	0.013803	0.009081
24 SOIL & ROCK PROD	0.000028	0.000175	0.013334	0.000950	0.001210	0.000374	0.001113	0.001039
25 METAL PRODUCT	0.000093	0.000284	0.006026	0.002106	0.001839	0.001201	0.002076	0.001622
26 MACHINERY	0.000007	0.000032	0.000810	0.000273	0.000229	0.000083	0.000216	0.000198
27 OTHER MFG	0.000039	0.000206	0.002997	0.003859	0.000680	0.000297	0.000670	0.000590
28 TRANSPORTATION	0.000464	0.004601	0.002827	0.053097	0.004905	0.029775	0.018767	0.004694
29 COMMUNICATION	0.001020	0.005731	0.004388	0.014081	0.026807	0.019882	0.010276	0.016987
30 GAS SERV	1.014813	0.151693	0.011626	0.005519	0.005430	0.005032	0.004724	0.005400
31 ELECTRIC SERV	0.000484	1.001167	0.070209	0.008108	0.014827	0.011004	0.012393	0.022752
32 WATER & SAN SER	0.000116	0.002685	1.090999	0.000575	0.002390	0.004304	0.002003	0.001527
33 WHL AGR PROD	0.000002	0.000010	0.000002	1.001009	0.000004	0.000003	0.000003	0.000004
34 WHL PETRO PROD	0.000204	0.000980	0.002791	0.002444	1.000857	0.006740	0.002376	0.456402
35 OTHER WHOLESALE	0.001040	0.006603	0.037192	0.011018	0.068571	1.029866	0.030372	0.103531
36 AGR SUPPLIES	0.0	0.0	0.0	0.0	0.0	0.0	1.000000	0.0
37 GAS SERV STAT	0.000226	0.000708	0.000454	0.001331	0.000697	0.005876	0.003198	1.002091
38 OTHER RETAIL	0.000718	0.010452	0.001690	0.002267	0.011779	0.017948	0.020028	0.007016
39 FINANCE	0.001290	0.004796	0.001766	0.044734	0.054508	0.012993	0.039971	0.030214
40 INSUR & R. E.	0.003024	0.008506	0.008159	0.011537	0.036592	0.017611	0.031027	0.034947
41 EDUCATION SERV	0.005046	0.023353	0.002478	0.005601	0.009915	0.006789	0.007679	0.008820
42 OTHER SERV	0.003977	0.007770	0.004165	0.040646	0.022111	0.044365	0.042781	0.021585

TABLE III (Continued)

	38	39	40	41	42
11 AG SERVICES	0.000005	0.000001	0.000004	0.000037	0.000003
14 OIL & GAS SERV	0.000183	0.000028	0.000059	0.000040	0.000298
15 CONSTRUCTION	0.006093	0.007262	0.016786	0.006284	0.006991
17 FOOD PROCESS	0.000311	0.000248	0.000975	0.037033	0.000963
18 TEXTILE PROD	0.000027	0.000004	0.000020	0.000175	0.000015
19 MILLING & FEEDS	0.000043	0.000036	0.000149	0.006153	0.000026
20 BEVERAGES	0.000059	0.000195	0.002838	0.000081	0.000043
21 WOOD & PAPER & PRI	0.020072	0.001298	0.011220	0.006883	0.011780
22 CHEMICALS	0.000263	0.000079	0.000208	0.000809	0.000454
23 PETRO PRODUCT	0.015642	0.001510	0.002927	0.001781	0.025784
24 SOIL & ROCK PROD	0.000302	0.000324	0.000767	0.000318	0.000324
25 METAL PRODUCT	0.001182	0.000909	0.001815	0.000850	0.014543
26 MACHINERY	0.000071	0.000062	0.000151	0.000453	0.000066
27 OTHER MFG	0.000260	0.000224	0.000528	0.003027	0.001327
28 TRANSPORTATION	0.031217	0.001216	0.003005	0.006587	0.008467
29 COMMUNICATION	0.022673	0.008933	0.011891	0.008489	0.018337
30 GAS SERV	0.008887	0.001907	0.007228	0.008116	0.005175
31 ELECTRIC SERV	0.019766	0.005718	0.019050	0.016108	0.010814
32 WATER & SAN SERV	0.003391	0.000847	0.003676	0.003291	0.001791
33 WHL AGR PROD	0.000003	0.000002	0.000010	0.000403	0.000005
34 WHL PETRO PROD	0.003667	0.000836	0.002635	0.000493	0.000878
35 OTHER WHOLESALE	0.181884	0.010912	0.008800	0.013864	0.018120
36 AGR SUPPLIES	0.0	0.0	0.0	0.0	0.0
37 GAS SERV STAT	0.002745	0.000967	0.004263	0.000277	0.000983
38 OTHER RETAIL	1.008952	0.002341	0.009648	0.000918	0.006729
39 FINANCE	0.012850	1.023012	0.065771	0.003166	0.010977
40 INSUR & R. E.	0.017450	0.037803	1.027404	0.028793	0.014942
41 EDUCATION SERV	0.006994	0.005869	0.024296	1.001673	0.004219
42 OTHER SERV	0.037824	0.036722	0.063042	0.010859	1.036827

sector 22. An increase of \$0.006103 in the output of sector 31 is the indirect effect of the additional dollar of sales to final demand by sector 22; that is, \$0.006103 is due to the generation of additional business activity through a number of sectors of the economy that purchase inputs from sector 31.

These accounts depicting interindustry flows in the High Plains economy, are an integral part of the simulation model specified in Chapter V. It is through these accounts that the total impact of structural changes in the economy are measured.

### Capital Account

Estimates of the size of the capital stock and of the interaction of capital stocks and output flows are necessary for the development of a truly dynamic model of a regional economy. In this section the concepts and definitions, the methodology, and the data for the High Plains capital account are presented and discussed.<sup>5</sup>

#### Concepts and Definitions

The input-output transactions matrix of the preceding section shows only the interindustry flows of current outputs and inputs while capital expenditures are aggregated into the capital formation column of the final demand quadrant. In a capital flow matrix this column is disaggregated with rows representing sales of capital-producing sectors and columns representing the purchases of capital-consuming sectors. An individual element,  $b_{ij}$ , in the capital flow matrix represents the

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<sup>5</sup>Much of the basic methodology of this section is based on the work of Doeksen and Schreiner (18).

dollar value of capital purchases of the  $j$ th sector from the  $i$ th sector.

To formulate input-output analysis in a dynamic model requires the estimation of a capital coefficient matrix. The capital coefficient matrix is computed from a capital flow matrix by finding the percentage distribution of each column. Thus a capital coefficient,  $g_{ij}$ , is defined as

$$g_{ij} = \frac{b_{ij}}{b_j}$$

where  $b_{ij}$  is an element of the capital flow matrix as defined above and  $b_j$  is the dollar value of total capital purchases of the  $j$ th sector from all sectors ( $b_j = \sum_i b_{ij}$ ). The capital coefficient,  $g_{ij}$ , is interpreted as the amount of capital goods purchased from the  $i$ th sector per dollar's worth of capital expenditures by the  $j$ th sector per unit of time.

For purposes of this study the capital-output ratio is defined as the normal operating ratio of the net value of plant and equipment to output where "normal operating" refers to the long-run trend value of the time series of the ratio in the designated year. Given sectoral outputs, the capital stock of each sector necessary to produce these outputs at a "normal operating" ratio of capital to output can be estimated as follows:

$$K_j = X_j (K/X)_j$$

where  $K_j$  is the dollar value of the capital stock of sector  $j$ ,  $X_j$  is the gross output of sector  $j$ , and  $(K/X)_j$  is the capital output ratio for sector  $j$ .

Depreciation coefficients for each sector complete the capital account needs of this study. The coefficients,  $d_j$ , are defined as the depreciation per dollar of depreciable assets:

$$d_j = \frac{D_j}{K_j}$$

where  $D_j$  is the total annual depreciation of capital stock in sector  $j$ .

### Capital Coefficient Matrix

The capital coefficient matrix for the High Plains was developed from the capital flow matrix for the United States in 1963 that was prepared by the Office of Business Economics (OBE) of the Department of Commerce (109). This represents the latest and most detailed data available for developing a capital coefficient matrix. The OBE capital flow matrix has 76 columns representing users of capital and 37 rows representing industries which produce capital. A supplementary table has been developed by the OBE which has detailed information on 106 producing industries (99). Flows are recorded in producers' prices as is the convention for the national input-output transactions matrices.

It was necessary to aggregate the capital flow matrix to the 42 processing sectors of the High Plains input-output matrix for the capital-using sectors and to 16 capital-producing sectors. High Plains employment data as reported in County Business Patterns--1967 (98) were used as weights for aggregation purposes.<sup>6</sup> In instances where employment data for the total region were not disaggregated to the degree necessary, employment data (1) for the Amarillo SMSA or (2) the states of Texas and Oklahoma were the basis for aggregation.

Capital coefficients for the 42 processing sectors of the High

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<sup>6</sup>This methodology assumes that the capital flows of a given sector are the same in the region and the U.S. and that employment weights for aggregation adjust for differences in the industrial composition of sectors in the region and the U.S.

Plains economy are presented in Table IV. They were derived from the collapsed capital flow matrix by finding the percentage distribution of each of the 42 columns. By reading down a column, purchases of capital goods from the producing sectors (row sectors) per dollar of capital outlay by the column sector are estimated. For example, with each dollar of capital outlay by the Chemical Products Industry (Sector 22) there are capital purchases of 0.24022 dollars from Construction (sector 15), of 0.00062 dollars from the Textile Products Industry (sector 18), of 0.00504 dollars from the Wood, Paper and Printing Industry (sector 21), etc. In several instances the capital coefficients are the same for several sectors (e.g., agriculture sectors) due to a less detailed aggregation in the national sectors than in the High Plains sectors.

#### Capital - Output Ratios

The capital-output ratios for each of the 42 processing sectors are very important to the capital accounts of the High Plains information system. There are many difficulties in the measurement of the capital stock and its relationship to output flows. This area of economic accounting has not been given the attention that has been awarded the treatment of input and output flows. Since sales to capital formation are a minor part of the final demand for goods and services in the High Plains economy, only rough estimates of the ratios were developed. The cost of additional information about the values of the ratios relative to the additional accuracy that would be achieved in the simulation models' projections is believed to be very high.

Capital is defined as the net capital stock which is the value of depreciable assets less accumulated depreciation. Output, consistent

TABLE IV  
CAPITAL COEFFICIENT MATRIX<sup>a</sup> FOR HIGH PLAINS OF OKLAHOMA AND TEXAS

Sector	1-8	9-10	11	12, 13	14	15	16,17,19,20	18	21	22	23	24
15	.19413	.53159	.23903	.81334	.22710	.07969	.26782	.20824	.21828	.24022	.61258	.27012
18	.00005	0	0	.00010	0	.00046	.00120	.00366	.00258	.00062	.00081	.00059
21	.00029	.00024	0	.00057	.00166	.00322	.01111	.02471	.01804	.00504	.00570	.00452
23	0	0	0	.00003	0	.00014	.00030	.00092	.00079	.00012	.00020	.00020
25	.00106	.00445	0	.00111	.00041	.00185	.02229	.00092	.00377	.14508	.02321	.00079
26	.38818	.03910	.47649	.10962	.49358	.46037	.44687	.53089	.53569	.38389	.20033	.39065
27	.20061	.32295	.13479	.04666	.17820	.31117	.16066	.12265	.08902	.14699	.10851	.23910
28	.01883	.01035	.01254	.00253	.01740	.02115	.00938	.01602	.00872	.01113	.00550	.01472
29	0	0	0	0	0	0	0	0	0	0	0	0
33	.00265	.00139	.00272	.00078	.00345	.00400	.00327	.00279	.00350	.00310	.00158	.00289
34	.00855	.00449	.00876	.00252	.01113	.01289	.01053	.00899	.01129	.01000	.00510	.00930
35	.03626	.01903	.03712	.01068	.04717	.05465	.04466	.03811	.04786	.04237	.02162	.03944
36	.00195	.00067	.00129	.00016	.00024	.00070	.00026	.00035	.00048	.00012	.00011	.00036
37	.01050	.00362	.00696	.00084	.00130	.00377	.00140	.00188	.00104	.00062	.00059	.00192
38	.00410	.04058	.07796	.00940	.01461	.04217	.01567	.02111	.02922	.00695	.00663	.02148
40	.00453	.01275	.00235	.00125	.00249	.00073	.00323	.00229	.00258	.00289	.00733	.00334

TABLE IV (Continued)

Sector	25	26	27	28	29	30-32	33-38	39	40	41	42
15	.23745	.22811	.27742	.21076	.32555	.63593	.33224	.62960	.94502	.55566	.67411
18	.00147	.00202	.00213	.00100	.00091	.00027	.00195	.00541	.00003	.00121	.00107
21	.00907	.01338	.01404	.00665	.00977	.00178	.10360	.02817	.00021	.03085	.02050
23	.00045	.00056	.00056	.00029	.00027	.00008	.00056	.00155	.00001	.00037	.00031
25	.01621	.00135	.00194	.00200	.00597	.02344	.01776	.02455	0	.00015	.00008
26	.50368	.53142	.41486	.07885	.02195	.09229	.17660	.16220	.00869	.07528	.03362
27	.15029	.13952	.20373	.62986	.46319	.21731	.24021	.06883	.00246	.23192	.18985
28	.00941	.00764	.00845	.01187	.00386	.00604	.01494	.00523	.00032	.00769	.00450
29	0	0	0	0	.12987	0	0	0	0	0	0
33	.00294	.00286	.00279	.00189	.00146	.00112	.00380	.00214	.00006	.00219	.00186
34	.00948	.00922	.00898	.00609	.00470	.00361	.01225	.00690	.00019	.00706	.00600
35	.04017	.03907	.03808	.02581	.01992	.01529	.05191	.02925	.00080	.02994	.02541
36	.00024	.00032	.00034	.00034	.00018	.00004	.00055	.00041	.00004	.00075	.00053
37	.00128	.00172	.00184	.00183	.00098	.00022	.00298	.00220	.00020	.00405	.00288
38	.01435	.01922	.02064	.02059	.01094	.00251	.03342	.02464	.00227	.04533	.03222
40	.00283	.00281	.00328	.00034	.00029	0	.00406	.00765	.03967	.00559	.00574

<sup>a</sup>Dollar amount of capital goods required from the row sector per dollar's worth of capital expenditures by the column sector. Row sectors not included have no sales of capital and are rows of zeros in the matrix.

with the input-output matrix, is defined as the dollar value of receipts except for trade sectors where it is defined as the value of receipts less cost of goods sold. The capital-output ratios used are average rather than marginal ratios. The marginal relationship is potentially much more unstable than the average since the average ratio compares a stock of capital accumulated over many years with the current output while the marginal ratio relates an addition to the capital stock over a short period to the change in output over the period (106). The average ratios estimated are defined for a time period of one year, 1967. Different sources and techniques were used for the agricultural and non-agricultural sectors. The ratios are presented in Table V. Estimates of average annual rates of change in capital-output ratios by sector were from the work of Kendrick (38) on the movements in the post-World War II years and are also presented in Table V.

Capital-output ratios for the agricultural sectors (sectors 1-10) were estimated by Dr. Vernon Eidman (20) of the Department of Agricultural Economics at Oklahoma State University. The data sources for these estimates were the budget studies of farm enterprises kept on file in the Department of Agricultural Economics.

For the non-agricultural sectors (11-42) Internal Revenue Service (102) data for the years 1954-1969 were utilized. The IRS data by SIC has been used for studies of the movement of capital-output ratios over time by Creamer, Dobrovolsky, and Borenstein (13) and by Kendrick (38). The ratio of the net capital stock to output for each year from 1957 through 1969 was developed from the IRS data and was aggregated by sector of the High Plains input-output model using the same weighting techniques as used for the capital flow matrix aggregation. A trend

TABLE V

CAPITAL-OUTPUT RATIOS, AVERAGE ANNUAL RATES OF CHANGE IN CAPITAL-OUTPUT RATIOS, 1967 CAPITAL STOCK, AND DEPRECIATION COEFFICIENTS FOR PROCESSING SECTORS OF THE HIGH PLAINS OF OKLAHOMA AND TEXAS

Sector	1967 Capital- Output-Ratio	Annual Change In Capital-Output Ratio	1967 Capital Stock	Depreciation Coefficient
	Dollars of Capital per Dollar of Output	One Plus Annual Rate of Change	Thousands of 1967 Dollars	Annual Dollars of Depreciation per Dollar of Capital Stock
1	.6231	0.9980	14,914.6	.10000
2	.6504	0.9980	45,475.7	.10000
3	.5479	0.9980	89,086.7	.10000
4	.9619	0.9980	41,528.9	.10000
5	.4266	0.9980	3,212.2	.10000
6	.3925	0.9980	9,180.9	.10000
7	.4192	0.9980	7,867.2	.10000
8	.4895	0.9980	2,716.6	.10000
9	3.6275	0.9980	294,744.7	.01670
10	.0252	0.9980	5,504.0	.10000
11	.3167	1.0070	6,079.8	.11088
12	.4347	0.9488	172,748.9	.06169
13	.4347	0.9488	58,264.8	.06169
14	.3167	1.0070	10,483.3	.11088
15	.0793	1.0395	13,191.8	.10545
16	.1384	0.9823	6,815.1	.07034
17	.1384	0.9823	6,941.5	.07034
18	.0474	0.9737	235.5	.08040
19	.1384	0.9823	2,044.8	.07034
20	.1384	0.9901	1,470.4	.07034
21	.1966	0.9823	3,062.2	.07105
22	.3219	0.9728	35,083.5	.06741
23	.4512	0.9901	79,945.7	.04704
24	.3954	1.0020	5,267.1	.06299
25	.1814	1.0030	2,722.3	.07170
26	.1988	0.9814	4,124.2	.08694
27	.1450	0.9940	1,643.4	.08520
28	.9786	0.9940	45,837.1	.05909
29	1.7575	0.9930	47,072.6	.04621
30	2.7026	0.9765	384,312.4	.03486
31	2.7026	0.9765	166,506.4	.03486
32	2.7026	0.9921	30,202.1	.03486
33	.1234	1.0030	1,426.6	.08174
34	.1234	1.0030	4,597.0	.08174
35	.1234	1.0030	19,487.0	.08174
36	.2794	1.0000	772.9	.07923
37	.1353	1.0000	2,014.7	.08928
38	.1971	1.0000	32,880.9	.08162
39	.2364	0.9938	16,123.0	.08125
40	1.0134	0.9938	33,050.0	.09137
41	.3167	1.0070	26,700.3	.11088
42	.3167	1.0070	47,520.1	.11088

line of the form  $(K/X)_j = ab^t$  was estimated for the log form of the equation by linear regression and gave a good fit for the time series. As defined earlier, the "normal operating" ratio for a year is the trend value in that year.

### Capital Stock

The value of the capital stock in each processing sector of the High Plains economy was estimated for 1967 by multiplying the capital-output ratio for a sector by the 1967 output from the High Plains input-output transactions matrix. This assumes that each processing sector operated in 1967 at the "normal operating" capital to output relationship. The vector of capital stock values is presented in Table V.

### Depreciation Coefficients

Estimates of depreciation coefficients by sector complete the capital account. Coefficients for the agricultural sectors are from Eidman's (20) interpretation of farm budget data. For each non-agricultural sector the five year average centered on 1967 of the ratio of annual depreciation charges to depreciable assets from IRS (102) data was used as the estimate. The depreciation rates are also presented in Table V.

### Human Resources Account

The human resources account for the High Plains of Oklahoma and Texas consists of measures of the stock of human resources in terms of population and employment, of the stock-flow relationship between employment and output, and of the flow relationship between income and

output. This account has several variables of interest to regional policymakers--the number of people living in the region, the quantity and type of employment available to these people, and the incomes received.

### Population

The population of the High Plains was 357,095 in 1970 as compared to 373,721 in 1960 and 289,595 in 1950 (91, 92, 93, 94, 95, 96). Assuming the decline in population for the total region from 1960 to 1970 occurred at a constant average annual rate, the population for 1967 is estimated to have been 362,361. Population for the region, the Amarillo SMSA, and the non-SMSA area are shown in Table VI.

TABLE VI  
POPULATION FOR THE REGION, AMARILLO SMSA, AND  
NON-SMSA AREA, HIGH PLAINS OF OKLAHOMA  
AND TEXAS, 1950, 1960, AND 1970

Area	Population			Percent Change	
	<u>1950</u>	<u>1960</u>	<u>1970</u>	<u>1950 to 1960</u>	<u>1960 to 1970</u>
Region	289,595	373,721	357,095	29.0	-4.4
Amarillo	87,140	149,493	144,396	71.6	-3.4
Non-SMSA	202,455	224,228	212,699	10.8	-5.1

Source: U. S. Department of Commerce, Bureau of the Census, Census of Population, 1950, 1960 and 1970.

About forty percent of the region's population lived in the Amarillo SMSA in 1960 and 1970 as compared to thirty percent in 1950. The rate of decline in the population of the SMSA between 1960 and 1970, 3.4 percent, was less than for the non-SMSA area of the region, 5.1 percent.

### Employment

As estimated by the Bureau of the Census, employment in the study area was 139,986 in 1970 (Table VII). This represents a two percent increase from 1960 employment of 137,236. The 1960 employment increased 22.1 percent from 1950 employment of 112,362. These employment data refer to the job held by a respondent in the reference week, or in the case of multiple job holders, to the job in which the respondent spent the greatest number of hours in the reference week. These data are not comparable to the data on employment generated by the employment-output ratios discussed in the next section.

Associated with increased urbanization in the region was a decrease in agricultural employment and an increase in manufacturing, trade and services employment. Employment in agriculture decreased from 22,414 in 1950 to 18,792 in 1970. Manufacturing employment increased 43.7 percent from 1950 to 1960 but decreased 2.5 percent from 1960 to 1970. Industries gaining from 1950 to 1970 were trade with an increase of 32.4 percent, finance, insurance and real estate with an increase of 97.6 percent, and services and other employment with an increase of 63.3 percent.

TABLE VII  
EMPLOYMENT BY MAJOR INDUSTRIES, HIGH PLAINS OF  
OKLAHOMA AND TEXAS, 1950, 1960, and 1970

Industry	Employment			Percent Change	
	<u>1950</u>	<u>1960</u>	<u>1970</u>	<u>1950 to 1960</u>	<u>1960 to 1970</u>
Agriculture	22,414	20,044	18,792	-10.6	- 6.2
Mining	5,914	6,323	5,912	6.9	- 6.5
Construction	10,377	11,117	9,354	7.1	-15.9
Manufacturing	10,995	15,803	15,403	43.7	- 2.5
T. C. & U. <sup>a</sup>	10,217	11,406	11,436	11.6	2.6
Trade	24,448	30,246	32,375	23.7	7.0
F. I. R. E. <sup>b</sup>	2,904	4,591	5,737	58.1	25.0
SVCS & Other <sup>c</sup>	25,093	37,706	40,977	50.3	8.7
Total	112,362	137,236	139,986	22.1	2.0

<sup>a</sup>Transportation, Communication and Utilities

<sup>b</sup>Finance, Insurance and Real Estate

<sup>c</sup>Services, Public Administration, Non-Profit Organizations and Industry Not Reported

Source: U. S. Department of Commerce, Bureau of the Census, Census of Population, 1950, 1960 and 1970.

### Employment-Output Ratios

Employment-output ratios are used in this study to estimate the labor requirements consistent with sector outputs in the High Plains economy. The ratios are expressed as the direct quantity of labor employed per \$10,000 of gross output for a sector in the year 1967. The ratios used were estimated by Osborn, et al. (58) for a 56 county area of the Texas High Plains. This was done in conjunction with the estimation of the primary data input-output model used in developing the interindustry flows matrix for the High Plains of Oklahoma and Texas.

Employment-output ratios for each of the 42 sectors of the High Plains economy are reported in Table VIII. Table VIII also shows estimated employment by sector for 1967 as calculated with 1967 gross outputs from the High Plains Input-Output Transactions Matrix (Table I).

For nonagricultural sectors these ratios were estimated from data obtained by interviewing a stratified random sample of establishments within the 56 county region (58, pp. 13-14). The interview data represents the employers' estimates of average employment in the base year, 1967. For the agricultural sectors Osborn, et al. used data from the Census of Agriculture for the number of workers employed on farms during the year, regardless of the number of days worked. This results in employment figures for agriculture that are much larger than the data reported from the Census of Population in Table VII. In constant hour man-years one would expect agricultural employment to be somewhere between the Census of Agriculture and Census of Population estimates.

For use in a simulation model of the type used in this study it would be ideal if the employment-output ratios represented a standardized unit of time (man-hours or man-years) and if the relationship of

TABLE VIII  
EMPLOYMENT-OUTPUT RATIOS AND EMPLOYMENT BY SECTORS,  
HIGH PLAINS OF OKLAHOMA AND TEXAS, 1967

Sector Number	Employment-Output Ratio in Employees Per \$10,000	Employment
1	0.8769	2,099
2	1.7547	12,269
3	0.9367	15,230
4	0.8054	3,477
5	0.4953	373
6	1.1979	2,802
7	1.1198	2,102
8	1.3320	739
9	1.0950	7,539
10	0.0700	1,529
11	0.7031	1,350
12	0.0834	3,314
13	0.0362	485
14	0.5487	1,816
15	0.3968	6,601
16	0.1646	811
17	0.1753	879
18	0.4516	242
19	0.1645	243
20	0.4594	488
21	0.5992	933
22	0.1158	1,262
23	0.1044	1,850
24	0.3880	517
25	0.3930	590
26	0.5012	1,040
27	0.7957	902
28	0.3795	1,778
29	0.6764	2,196
30	0.0822	1,169
31	0.2063	1,271
32	0.6792	762
33	0.2444	283
34	0.5218	1,944
35	0.8421	13,298
36	0.7083	196
37	1.0047	1,497
38	1.0188	16,996
39	0.3690	2,517
40	0.5242	1,710
41	0.7708	6,498
42	0.9727	14,595

the standardized time of employment unit to the number of persons employed were known. This is especially true for the region analyzed in this study. In the High Plains there is a large amount of multiple job holding and seasonal employment that is related to the agricultural sectors. For purposes of estimating changes in labor productivity over time, the standardized employment unit is the best measure. But, for estimating the size of the total population, the preferred data would be the number of employees in the region. A breakdown of the employment estimate into age, sex and proportions of hours worked in different sectors of the economy would increase the potential accuracy of the human resource projections in the High Plains.

The employment-output ratios used in this study are not the ideal type of data described. Improvement of the data would require considerable resources. Data of the type discussed would have to be developed from detailed studies beyond the scope of the present analysis. Sensitivity of the simulation model to changes in employment-output ratios in agricultural crop production is examined in Chapter VI.

#### Labor Productivity Projections

Changes in labor productivity must be accounted for in long range economic projections. In the projections of the High Plains economy to 1985, rates of change in employment-output ratios are used from projections by Almon, et al. for the nonagricultural sectors (2, p. 172-180) and from historical trends of labor productivity reported for Oklahoma and Texas by the U. S. Department of Agriculture for the agricultural sectors (74). From 1985 to 2010 all sectors are projected to have annual changes in labor productivity equal to the overall long

run historical trend in the U. S. or the trend projected for a sector in the period ending in 1985, whichever is the lower rate of change.

The Almon, et al. projections are for annual rates of change in output per employed person to 1985 at the national level for 88 sectors. A number of regression equations and variables were investigated for forecasting labor productivity but in most cases the best performance was found from simple logistic curves where the employment-output ratio is expected to approach an asymptote over time with the rate of change in the employment-output ratio diminishing as the level of the ratio becomes smaller. The Almon, et al. rates of change in labor productivity are aggregated to High Plains sectors 11 through 42 by the same procedures reported for the capital flow matrix.

For the agricultural sectors, indices of farm production per man-hour for 1950 to 1972, by livestock and crop groups in the Southern Plains (Oklahoma and Texas), were used to estimate past trends in labor productivity in agriculture. It is assumed that these trends will continue until 1985. Linear regression was used to estimate the time trends in productivity for all crop output and for all meat output. The index of all crop output per man-hour is estimated as a function of time for 1963 through 1972:

$$\ln y = 4.23940 + 0.02118t \quad R^2 = 0.354 \\ (0.17952) \quad (0.01012) \quad n = 10$$

where  $y$  is the productivity index and  $t$  represents the year which is equal to zero in 1950, one in 1951, etc. Estimated standard errors are reported in parentheses under their respective coefficients. The equation is the logarithmic transformation of the equation  $y = ae^{bt}$ . Thus, the annual rate of change in all crop output per man-hour is

estimated to be 2.118 percent. The index of all meat output per man-hour is estimated as a function of time and annual sales of cattle on feed. Annual sales of cattle on feed are included so as to remove the influence of the transition to feedlot livestock operations on the index. In the High Plains sectoring schemes, feedlot and range operations are in separate sectors with very different employment-output ratios (see Table VIII, sectors 9 and 10). The estimated equation is for 1950 through 1972:

$$\ln w = 0.64197 + 0.01162t + 0.36987z \quad R^2 = .981$$

$$(0.55926) \quad (0.00414) \quad (0.06197) \quad n = 23$$

where  $w$  is the productivity index,  $t$  is the year which is equal to zero in 1950, and  $z$  is the sales of cattle on feed in hundreds of cattle per year. Thus, the annual rate of change in all meat output per man-hour is estimated to be 1.162 percent.

The long run trend in output per employee for the nation that is used as the upper limit of productivity change from 1985 to 2010 is from Series A170 in the U. S. Department of Commerce study of long term economic growth (76, p. 163). This series represents Gross National Product (in 1958 dollars) divided by total employment. The average annual rate of change from 1910 to 1970, 1.6 percent, is used as the upper limit on labor productivity in the High Plains after 1985.

Projections of labor productivity are presented in Table IX for the nonagricultural sectors. The data is presented for each sector as one plus the average annual rate of change in the employment-output ratio since this is the form in which the data is used in the High Plains simulation model.

TABLE IX

ONE PLUS THE AVERAGE ANNUAL RATE OF CHANGE IN EMPLOYMENT-  
OUTPUT RATIO FOR NONAGRICULTURAL SECTORS,  
1967-1975, 1976-1980, 1981-1985

Sector Number	One Plus the Average Annual Rate Of Change in Employment-Output Ratio		
	<u>1967-1975</u>	<u>1976-1980</u>	<u>1981-1985</u>
11	.9879	.9961	.9955
12	.9646	.9796	.9886
13	.9646	.9796	.9886
14	.9879	.9961	.9955
15	.9827	.9859	.9920
16	.9800	.9814	.9839
17	.9745	.9757	.9768
18	.9835	.9950	.9922
19	.9891	.9846	.9879
20	.9748	.9769	.9772
21	.9795	.9836	.9859
22	.9657	.9741	.9754
23	.9574	.9697	.9736
24	.9763	.9792	.9816
25	.9740	.9840	.9875
26	.9719	.9820	.9821
27	.9802	.9835	.9878
28	.9649	.9755	.9797
29	.9649	.9704	.9741
30	.9624	.9639	.9674
31	.9651	.9745	.9796
32	.9624	.9639	.9674
33	.9792	.9865	.9865
34	.9792	.9865	.9865
35	.9792	.9865	.9865
36	.9792	.9865	.9865
37	.9792	.9865	.9865
38	.9792	.9865	.9865
39	.9879	.9961	.9955
40	.9879	.9961	.9955
41	.9879	.9961	.9955
42	.9879	.9961	.9955

### Income-Output Ratios

The households row of the direct coefficients matrix for the High Plains gives dollars of household income per dollar of output by sector. These income-output ratios are assumed fixed over time in the High Plains simulation model. Given a sector's output for a given year, multiplication of the income-output ratio by the dollar output provides an estimate of the household income generated by the sector. These ratios, by sector, are presented in the Households row (row 43) of Table II.

## CHAPTER IV

### PROJECTIONS OF AGRICULTURAL AND PETROLEUM OUTPUTS

Annual projections to 2010 of the supply-determined output of the agricultural crop and range livestock, crude petroleum, natural gas, and natural gas liquids sectors are made independently of the High Plains simulation model. Agricultural feedlot livestock output and other impacts on the regional economy of projected outputs in these sectors is estimated by the simulation model specified in the next chapter.

#### Agricultural Crop Output

Output projections for the eight crop sectors (sectors 1-8) of the input-output model have been made by Osborn for the Texas portion of the High Plains of Texas and Oklahoma (57). These projections were made separately for two regions of the Texas Panhandle. One of the regions, "Lower 2A", is south of Hartley, Moore, Carson, Gray, and Wheeler counties and extends to the southern boundary of the study area while the other region, "Upper 2A", consists of Texas counties north of Lower 2A and extends to the Oklahoma Panhandle. Basic to these output projections are projections of water pumped in acre-feet for each year to 2010 by the Texas Water Development Board (108). Depletion of groundwater in the Lower 2A area has resulted in increased pumping

costs for irrigation to the point where the annual acre-feet of water pumped is expected to decline from 1967 to 2010. Upper 2A, which began extensive development of its water resources for irrigation purposes about 20 years later than in Lower 2A, is projected to have large increases in the annual acre-feet of water pumped until 1990; after which, a decline is expected. Using log data of observed water decline rates, the Texas Water Development Board projections are based on the history of pumping and development in the regions studied. Included in the estimates are factors to account for natural recharge (one-half inch per year), for recirculation (ten percent), and for withdrawal from playa lakes.

#### Alternative Water and Yield Assumption

Four different projections of crop output by sector are made for the High Plains. All of these projections use Osborn's basic methodology for converting projections of water available each year into crop output estimates by sector. These four variations derive from different groundwater and yield projections. The crop output projections are made for three subregions of the High Plains: Lower 2A of Texas, Upper 2A of Texas and the Oklahoma Panhandle. Crop output projections for these areas are aggregated for use in the simulation model but the breakdown is necessary due to different water situations north and south of the Canadian River, to different cropping patterns over the three subregions, and to the need for projections at the county or community level in later studies.

Water Projection I. Water Projection I utilizes the Texas Water Development Board projections for the Upper and Lower 2A subregions and estimates water pumpage in the Oklahoma Panhandle on the basis of the trend in Upper 2A. The Upper 2A area of Texas and the Oklahoma Panhandle are part of the same major section of the Ogallala aquifer and have had a close correspondence in their historical development of the groundwater resource. The Texas Water Development Board projections to 2010 for Upper 2A are composed of ten year linear sections. The percentage change in pumped water over each of these ten year sections has been computed and applied to the 1967 base year estimate of water pumped for irrigation purposes in the Oklahoma Panhandle. This estimate is from a study with survey data made by the Oklahoma Water Resources Board (56). Linear functions were fitted to these estimates by decade to provide the projected annual acre-feet of water pumped in the Oklahoma Panhandle.

Water Projection II. Water Projection II utilizes the Texas Water Development Board projections of water pumpage for the Texas Lower 2A subregion and projections from a study by Bekure (5) for the Texas Upper 2A and Oklahoma Panhandle subregions. Bekure's study includes the Oklahoma Panhandle, a major portion of Texas Upper 2A, and several counties in Southeast Colorado and Southwest Kansas. The Ogallala Formation, an unconsolidated aquifer that underlies most of the Great Plains area, extending from the southern half of South Dakota to a few miles north of the Pecos River in Texas, has three separate, unconnected subdivisions. These subdivisions are a result of the North Platt River, the Arkansas River and Canadian River having cut completely through the

formation. Bekure's study area is the central part of the Ogallala Formation bounded by the Arkansas River on the north and the Canadian River on the south. For Water Projection II the trend in Bekure's study area for his "Model II" assumptions is assumed to apply in the Texas Upper 2A and Oklahoma Panhandle subregions.

Bekure projects the rate of groundwater withdrawal over time using a recursive linear programming (RLP) model. The RLP model is an adaptation of the static linear programming model where the solution to the model in period  $t+1$  is dependent on the solution to the model in period  $t$ . The model maximizes net returns above total costs subject to production restrictions including the soil and water resource base. Each time period represents a span of ten years. Bekure's "Model II" solves the problem of how to allow for the rate of irrigation growth in the production model by allowing the study area to produce more than its historic share of projected U. S. production subject to an upper limit representing the maximum rate of irrigation growth. This maximum rate is determined by an exponential growth model based on the rate at which the maximum physical limit in number of irrigated acres was being approached in the recent past. If a restriction was not imposed, the model would have all irrigable acres in the study area irrigated in the initial time period.

Average annual rates of change in the number of acre-feet of water pumped per year in the Bekure study area were computed for ten year periods using mid-years as representative of the average annual pumpage rates. These rates were then applied to base year data from the Texas Water Development Board for the Texas Upper 2A subregion and from the Oklahoma Water Resources Board for the Oklahoma Panhandle. These

projections resulted in some rather abrupt changes in rates of change between ten year periods that are not representative of the history of the Bekure study area or areas such as Texas Lower 2A where irrigation developed twenty years earlier than in the area of the High Plains north of the Canadian River. To resolve this problem the projections were smoothed by fitting a logistic (Pearl-Reed) curve to the data (14).

Figure 4 shows graphically the annual acre-feet of water pumped for irrigation purposes from 1967 to 2010 for the High Plains Water Projections I and II. Table X reports the projected acre-feet of water pumped in each year from 1967 to 2010 for each subregion and Water Projections I and II. Though the Texas Water Development Board and Bekure both project decreases in water usage beginning from 1990 to 1995 for the Upper High Plains, they reach the turning point with different trends. Whereas the most rapid growth in the Texas Water Development Board's projection is in the 1980-90 decade, Bekure's projection indicates the most rapid growth in the 1970's with growth increasing at a slower rate through the 1980's and 1990's.

Yield Assumptions. Water Projections I and II provide two separate projections of crop output. Constant yield per acre versus projected increases in yield per acre applied to the two different water projections provide two more alternative projections. The crop yield projections used were developed by the U. S. Department of Agriculture for use in the OBERS projections (73). The projections are to 2020 and are made by state, by crop, irrigated and dryland. The general assumption behind these projections is that yields will increase at a decreasing rate in the 1970-2020 period. The general technique used to estimate yield projections was a linear potential, Spillman-type

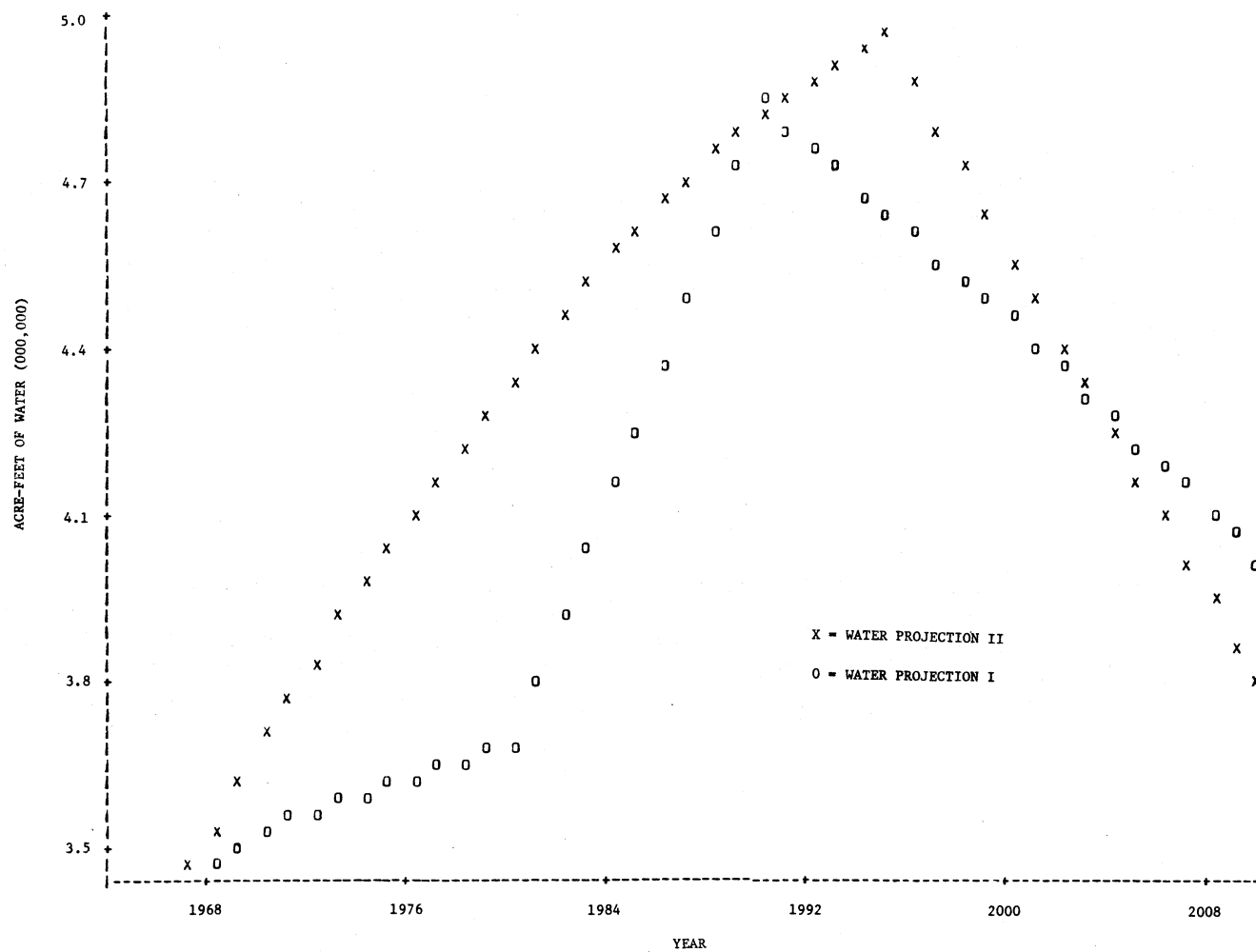


Figure 4. Annual Acre-Feet of Water Pumped for Irrigation, Water Projections I and II, High Plains of Oklahoma and Texas, 1967-2010

TABLE X

ACRE-FEET OF WATER PUMPED FOR IRRIGATION, WATER PROJECTIONS I AND II,  
HIGH PLAINS OF OKLAHOMA AND TEXAS, TOTAL  
AND SUBREGIONS, 1967-2010

Year	Texas Lower 2A	Texas Upper 2A	Oklahoma Panhandle	Total High Plains of Oklahoma and Texas			
	Water Projections I and II	Water Projection I	Water Projection II	Water Projection I	Water Projection II	Water Projection I	Water Projection II
1967	1,454,144	1,597,557	1,597,557	397,231	397,231	3,448,932	3,448,932
1968	1,447,478	1,618,541	1,665,661	403,688	414,702	3,469,707	3,527,841
1969	1,440,812	1,639,524	1,734,719	410,146	432,225	3,490,482	3,607,756
1970	1,427,480	1,681,491	1,804,020	416,603	449,760	3,525,117	3,681,260
1971	1,410,968	1,706,859	1,873,304	423,061	467,224	3,540,888	3,751,496
1972	1,394,455	1,732,227	1,942,325	429,518	484,567	3,555,743	3,821,347
1973	1,377,943	1,757,596	2,010,867	435,975	501,720	3,571,514	3,890,530
1974	1,361,431	1,782,964	2,078,749	442,433	518,659	3,586,828	3,958,839
1975	1,344,919	1,808,332	2,145,974	448,890	535,312	3,602,141	4,026,205
1976	1,328,406	1,833,700	2,212,089	455,348	551,651	3,617,454	4,092,146
1977	1,311,894	1,859,068	2,277,052	461,805	567,593	3,632,767	4,156,539
1978	1,295,382	1,884,437	2,340,592	468,263	583,136	3,648,082	4,219,110
1979	1,278,869	1,909,805	2,402,784	474,720	598,220	3,663,394	4,279,873
1980	1,262,357	1,935,173	2,463,291	481,178	612,880	3,678,708	4,338,528
1981	1,248,057	2,038,084	2,522,130	506,766	626,995	3,792,907	4,397,182
1982	1,233,757	2,140,996	2,579,023	532,355	640,628	3,907,108	4,453,408
1983	1,219,457	2,243,907	2,634,089	557,943	653,674	4,021,307	4,507,220
1984	1,205,157	2,346,818	2,687,327	583,532	666,228	4,135,507	4,558,712
1985	1,190,857	2,449,730	2,738,577	609,120	678,203	4,249,707	4,607,637
1986	1,176,557	2,552,641	2,787,700	634,709	689,619	4,363,907	4,653,876
1987	1,162,257	2,655,553	2,834,583	660,297	700,513	4,478,107	4,697,353
1988	1,147,957	2,758,464	2,879,602	685,886	710,874	4,592,307	4,738,433
1989	1,133,657	2,861,376	2,922,739	711,474	720,640	4,706,507	4,777,036
1990	1,119,357	2,964,287	2,963,513	737,063	729,934	4,820,707	4,812,804
1991	1,103,063	2,946,343	3,002,425	732,600	738,709	4,782,006	4,844,197
1992	1,086,769	2,928,398	3,039,539	728,138	746,983	4,743,305	4,873,291
1993	1,070,475	2,910,454	3,074,420	723,676	754,782	4,704,605	4,899,677
1994	1,054,181	2,892,509	3,107,687	719,214	762,069	4,665,904	4,923,937
1995	1,037,887	2,874,565	3,138,935	714,752	768,949	4,627,204	4,945,771
1996	1,021,592	2,856,620	3,086,975	710,290	756,264	4,588,502	4,864,831
1997	1,005,298	2,838,676	3,035,408	705,828	743,643	4,549,802	4,784,349
1998	989,004	2,820,731	2,984,278	701,366	731,100	4,511,101	4,704,382
1999	972,710	2,802,787	2,933,709	696,904	718,709	4,472,401	4,625,128
2000	956,416	2,784,842	2,883,650	692,442	706,436	4,433,700	4,546,502
2001	938,540	2,764,465	2,834,062	687,375	694,329	4,390,380	4,466,931
2002	920,663	2,744,087	2,785,056	682,307	682,301	4,347,057	4,388,020
2003	902,787	2,723,710	2,736,799	677,240	670,435	4,303,737	4,310,021
2004	884,910	2,703,332	2,688,621	672,173	658,701	4,260,415	4,232,232
2005	867,034	2,682,955	2,641,584	667,106	647,108	4,217,095	4,155,726
2006	849,158	2,662,577	2,594,708	662,038	635,646	4,173,773	4,079,512
2007	831,281	2,642,200	2,548,550	656,971	624,337	4,130,452	4,004,168
2008	813,405	2,621,822	2,502,943	651,904	613,114	4,087,131	3,929,462
2009	795,528	2,601,445	2,457,860	646,836	602,059	4,043,809	3,855,447
2010	777,652	2,581,067	2,413,441	641,769	591,148	4,000,488	3,782,241

curvilinear regression model that projects yields to increase at a decreasing rate over time (73, pp. 6-10). The linear potential for the year 2020 is used as a constraint. From the projections of yield per acre for 1980, 2000, and 2020, the average annual rates of change were computed for each of the three periods and used for crop output projections in the High Plains. These average annual rates of change in yield per acre are given in Table XI, by sector and by state.

#### Crop Output Determination

Given total acre-feet of water used for irrigation in a subregion from the water projections described above, the estimation of crop output by sector proceeds as follows:

1. Total acre-feet of water is allocated to sectors on the basis of base year, 1967, water use by crop in the subregion.
2. Water requirements by sector in the base year in acre-feet per acre are divided into their respective acre-feet of available water to estimate acres of irrigated land in each sector.
3. The total number of acres planted for each sector in 1967 are assumed to be the total acres available for the respective crops in subsequent years and the number of irrigated acres of a crop is subtracted from total acres available for an estimate of acres of dryland production of a crop.
4. Estimates of revenue (including government payments) per planted acre for each sector are multiplied by the number of acres for respective sectors to estimate gross dollar output by sector.
5. For the set of projections of gross dollar output where

TABLE XI  
ANNUAL PERCENTAGE CHANGE IN YIELD  
PER ACRE BY SECTOR FOR  
OKLAHOMA AND TEXAS

State	Sector	Annual Percentage Change in Yield Per Acre		
		<u>1967-80</u>	<u>1981-2000</u>	<u>2001-2010</u>
Oklahoma				
	Irrigated Food Grain	1.88	1.37	0.82
	Irrigated Feed Grain	2.30	1.43	0.73
	Dryland Food Grain	1.23	1.11	0.69
	Dryland Feed Grain	1.55	1.26	0.77
Texas				
	Irrigated Cotton	1.40	0.13	0.10
	Irrigated Food Grain	1.82	1.26	0.63
	Irrigated Feed Grain	1.96	1.21	0.73
	Other Irrigated Crops	1.12	1.12	0.72
	Dryland Cotton	0.86	0.12	0.10
	Dryland Food Grain	0.87	0.87	0.55
	Dryland Feed Grain	1.36	1.36	0.77
	Other Dryland Crops	1.06	1.06	0.68

productivity increases are incorporated, the revenue per acre is increased each year by the average annual rate of change in yield per acre described in the preceding paragraph.

For the Texas subregions the parameters for the estimation procedure are from Osborn's (57) projections. For the Oklahoma Panhandle subregion, base year total water pumped for irrigation, the ratio of water pumped for irrigation by sector to total water pumped for irrigation, and water requirements in acre-feet per acre by crop are from the Oklahoma Water Resources Board (56), total acres planted by crop are from the United States Department of Agriculture (75), and revenue per acre by crop sector is estimated from 1967 acreages and input-output model gross dollar outputs. These parameters are given in Appendix C. Limitations of the crop output determination procedure are discussed in Chapter VIII.

#### Agricultural Livestock Output

For the dairy, poultry and range livestock sector (sector 9), gross dollar output is projected at the rate projected by the OBERS projections of livestock output for Water Resources Region 1109 (104). The OBERS projection is for a 3.2 percent average annual growth rate from 1967 to 1980 and a rate of 1.7 percent from 1980 to 2010.

Projections of feedlot livestock output are made in the simulation model. This projection is based on the interaction of an adjustment factor with the potential feedlot output. The adjustment factor, 33 percent, represents the average annual rate of increase in total marketings of cattle and calves on feed for slaughter from 1968 through 1972 in the Texas portion of the study area as reported by the Texas

Crop and Livestock Reporting Service (71). To adjust to the potential without an abrupt stoppage of feedlot growth, the adjustment rate is arbitrarily set at 15 percent from 1973 through 1975, 5 percent from 1976 to 1980, and 1.7 percent for 1981 through 2010. The potential feedlot output is defined as the number of cattle which can be fed from feed grain output in the region assuming the feed grain requirement per dollar of output in the input-output model remains constant. The availability of locally produced feed grains as a restraining force on growth in feedlot livestock output in the High Plains is analyzed by W. D. Purcell (62). This further assumes that the proportion of feed grains imported by the feedlot sector in 1967 remains constant. Each year feedlot livestock output is increased over the previous year by the adjustment factor unless a slower growth rate is specified on the basis of feed grain availability in the region. The growth rate computation procedure is specified in the following chapter in the specification of the simulation model.

#### Petroleum Output

Projections of annual crude petroleum and natural gas physical output (sector 12) for the twenty-five Texas counties are from the Texas Water Development Board (50). Prices (1967 level) for crude petroleum and natural gas applied to the physical output figures to estimate gross dollar output are from the work of James Vinson for the Texas Input-Output Model (107).

The Texas Water Development Board projections used baseline projections for 1975, 1980, and 1985 made by the Texas Mid-Continent Oil and Gas Association for a 56 county area of Texas. These data were

broken into county estimates by the Texas Water Development Board on the basis of data from the Texas Railroad Commission on actual production by county. "Decline-curve analysis" was then applied to make projections to the year 2020 (50, p. 7). The Texas Water Development Board describes this as involving extrapolation on the basis of past trends and judgement. S. H. Schurr describes decline-curve analysis as follows (69, p. vii):

A particular form of trend extrapolation which has found much favor in the literature of oil and gas projections is the so-called decline-curve analysis, which generalizes from the past production record of exhausted oil fields to obtain a curve which purports to describe the future national behavior of output.

While this type of projection methodology is rejected by Schurr at the national level, it is more appropriate at the regional level where characteristics of exhausted and producing fields can be more carefully matched. However, the exact manner in which this was done is not reported by the Texas Water Development Board so that a definitive critical evaluation of the projections is not possible. For purposes of this study the alternative was to make projections independently without the petroleum industry experience and expertise available from the contributors to the Texas Water Development Board study.

For the three counties of the Oklahoma Panhandle the actual production of crude petroleum and natural gas as reported by the Oklahoma Corporate Commission (51) and 1967 prices referred to above were used through 1973. Projections of output from 1974 to 2010 were made on the basis of projections made at the state level for Oklahoma by the Oklahoma Energy Advisory Council (53). The projections for the state of Oklahoma were to 1990. For the Oklahoma Panhandle these negative growth rates, 2.3 percent per annum for natural gas and 3.6

percent per annum for crude petroleum, were extended until 2010.

Gross output of natural gas liquids (sector 13) are projected on the basis of the assumption that their output will maintain the proportionate relationship to crude petroleum and natural gas production that existed in 1967. This method was used by Osborn in his studies of the Texas Panhandle, based on the opinion of experts in the petroleum industry (57).

These projections of petroleum output do not take into account any effects that could result from changes in prices, taxation policy, future discoveries, or changes in production technology. Annual gross outputs from 1967 to 2010 for sectors 12 and 13 are presented in Table XII. From a gross output of \$397,398,000 in 1967, sector 12 output increases to \$420,701,000 in 1970. Then output declines steadily from 1970 to 2010 when gross output is projected to be \$168,018,000. Sector 13 output is \$134,035,000 in 1967 and remains proportionate to sector 12 output.

TABLE XII  
ANNUAL GROSS OUTPUT PROJECTIONS FOR CRUDE PETROLEUM,  
NATURAL GAS AND NATURAL GAS LIQUIDS, HIGH  
PLAINS OF OKLAHOMA AND TEXAS, 1967-2010

Year	Annual Gross Output in Thousands of 1967 Dollars	
	<u>Crude Petroleum and Natural Gas (12)</u>	<u>Natural Gas Liquids (13)</u>
1967	397,398	134,035
1968	406,757	137,191
1969	419,634	141,534
1970	420,701	141,894
1971	412,693	139,193
1972	400,942	135,230
1973	390,030	131,549
1974	383,242	129,260
1975	376,531	126,997
1976	366,740	123,694
1977	357,022	120,417
1978	347,373	117,162
1979	337,792	113,931
1980	328,277	110,721
1981	321,553	108,454
1982	314,891	106,206
1983	308,288	103,980
1984	301,743	101,772
1985	295,255	99,584
1986	288,998	97,473
1987	282,794	95,381
1988	276,642	93,306
1989	270,539	91,247
1990	264,484	89,205
1991	259,040	87,369
1992	253,558	85,520

TABLE XII (Continued)

Year	Annual Gross Output in Thousands of 1967 Dollars	
	Crude Petroleum and Natural Gas (12)	Natural Gas Liquids (13)
1993	248,288	83,743
1994	242,976	81,951
1995	237,705	80,173
1996	232,475	78,409
1997	227,283	76,658
1998	222,129	74,920
1999	217,011	73,194
2000	211,931	71,480
2001	207,488	69,981
2002	202,901	68,435
2003	198,437	66,929
2004	194,004	65,434
2005	189,601	63,949
2006	185,228	62,474
2007	180,884	61,009
2008	176,569	59,553
2009	172,280	58,107
2010	168,018	56,669

## CHAPTER V

### AN ECONOMIC SIMULATION MODEL FOR THE HIGH PLAINS OF OKLAHOMA AND TEXAS

In this chapter the High Plains simulation model is specified in detail. The term "simulation" as used among economists has been defined by Irma Adelman as follows (1, pp. 268-269):

The term 'simulation' has been generally reserved for processes using a physical or mathematical analogue and requiring a modern high-speed or analogue computer for the execution of experiments.

Quite specific solutions are obtained by simulation techniques.

Adelman further explains the nature of simulation models (1, p. 269):

Given a particular set of initial conditions, a particular set of parameters, and the time period over which the model is to be simulated, a single simulation experiment yields a particular numerically specified set of time paths for the endogenous variables (the variables whose values are explained by the model). A variation in one or more initial conditions or parameters requires a separate simulation experiment which provides a different set of time paths.

Thus, by comparing solutions from various runs of the simulation model some of the properties between the input and output quantities in the economic system investigated can be inferred.

The High Plains simulation model is formulated around the input-output system of analysis. In general, the equations of the model are a series of difference equations arranged in a recursive sequence to describe the dynamic behavior of the regional economy. In a recursive system the influence of both exogenous and endogenous variables has a

unidirectional influence on resultant endogenous variables. This framework allows an explicit causal interpretation of the effects of any one variable on the system. While the dynamic properties and general framework of the High Plains simulation model are found in this recursive process, output determination in each year involves the use of an interdependent system, the Leontief inverse matrix, and a feedback loop. The High Plains simulation model is a deterministic model. A deterministic model is one that, given the assumptions on the nature of the process, the set of parameters, and the initial conditions, will predict an exact outcome of the situation. In contrast, a probabilistic or stochastic model is one that deals with situations where there are random processes involved.

In general terms, the operation of the simulation model for a given year is as follows: (1) estimating final demand, (2) determining sector output subject to predetermined agricultural and petroleum outputs, and (3) determining sector and regional employment and income, and regional population. The data generated on output, employment, income, and population are used in the process of estimating final demand for the following year. The specification of the High Plains simulation model in the remainder of this chapter follows the sequence described, starting with the various components of final demand. A complete listing of variables, matrices, and scalars is presented in Tables XIII, XIV, and XV. Variables are presented by capital letters, matrices by the subscripted capital letter "A", and scalars by the subscripted lower case letter "a".<sup>1</sup>

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<sup>1</sup>The presentation in this chapter follows closely the format used in presentation of earlier models in this lineage, especially Doeksen (17).

TABLE XIII  
VARIABLES IN HIGH PLAINS SIMULATION MODEL

Variable	Description
$(B_1)_t$	Upper limit weight for constraining local consumption expenditures as a percent of household income
$(B_2)_t$	Lower limit weight for constraining consumption expenditures as a percent of household income
$C_t$	Column vector of regional consumption demand in year $t$
$C_t^p$	Column vector of per capita consumption demand in year $t$
$C_t^u$	Column vector of unconstrained regional consumption demand in year $t$
$(CA)_t$	Column vector of regional sales to regional capital formation in year $t$
$(CH)_t$	Total residential construction demand in year $t$
$(CHP)_t$	Residential construction demand per capita in year $t$
$(CHV)_t$	Column vector of zeros except for row 15 which has $(CH)_t$ as its element for year $t$
$(CI)_t$	Column vector of composition of new regional investment in year $t$
$(CL)_t$	Column vector of regional sales to regional capital formation excluding residential construction in year $t$
$E_t$	Column vector of exports for the demand output sectors in year $t$
$E_t^i$	Element of $E_t$ , regional exports of sector $i$ in year $t$
$E_t^*$	Column vector of regional exports for sectors 11, 14, 15, 17-21, 24-29 and 31-42 in year $t$
$(EG)_t$	Column vector of export sales plus federal government payments for sectors three and seven in year $t$
$F_t$	Column vector of federal government purchases from processing sectors in year $t$

TABLE XIII (Continued)

Variable	Description
$(F_T)_t$	Total federal government expenditures in region in year t
$(FPC)_t$	Total federal government expenditures per capita in region in year t
$G_t$	One plus the annual rate of change in feedlot livestock output for the year t
$(GEG)_t$	Total exports by sectors three and seven combined in year t
$H_t$	Ratio of population to total employment in year t
$I_t$	Column vector of total investment in year t
$I_t^i$	Element of $I_t$ , total investment by sector i in year t
$(I_n)_t$	Column vector of induced plant and equipment investment in year t
$(I_n^i)_t$	Element of $(I_n)_t$ , induced plant and equipment investment by sector i in year t
$(I_r)_t$	Column vector of replacement investment in year t
$(I_r^i)_t$	Element of $(I_r)_t$ , replacement investment by sector i in year t
$K_t$	Column vector of capital stocks at beginning of year t
$K_t^i$	Element of $K_t$ , capital stock in sector i at beginning of year t
$L_t$	Column vector of local government purchases in year t
$L_t^e$	Column vector of employment by sector in year t
$L_t^o$	Direct employment of labor by household sector in year t
$(L_T)_t$	Total local government expenditures in year t
$P_t$	Total regional population in year t
$R_t$	Rate of growth of value added in regional processing sectors from t-2 to t-1

TABLE XIII (Continued)

Variable	Description
$S_t$	Column vector of state government purchases in year t
$(S_T)_t$	Total state government expenditures in region in year t
$(SPC)_t$	State government expenditures in region per capita in year t
$SUMC_t^u$	Total of consumption expenditures in vector $C_t^u$
$SUMCY_t$	Ratio of total consumption expenditures in year t to total household income in year t-1
$(TE)_t$	Total regional employment in year t
$(TVA)_t$	Total value added within region by processing sectors in year t
$(VA)_t$	Column vector of value added within region by processing sectors in year t
$W_t$	Column vector of adjusted final demand for sectors 11, 14, 15, 17-42
$\bar{X}_t$	Column vector of estimated gross outputs for sectors 1-10, 12, 13, 16
$\bar{X}_t^i$	Element of $\bar{X}_t$ , gross output of supply output sector i in year t
$x_t^d$	Column vector of gross outputs from sectors 11, 14, 15 and 17-42 to produce adjusted final demand, $W_t$ , in year t
$x_t^D$	Column vector of gross outputs by sector for sectors 1-42 in year t
$(\bar{X}G)_t^{**}$	Column vector of exogenous gross outputs for sectors three and seven in year t
$(\bar{X}GX)^{**}$	Column vector of gross outputs for sectors 1, 2, 4-6, 8-10, 12, 13 and 16
$Y_t$	Household disposable income per capita in year t
$Y_t^*$	Column vector of household income by sector in year t

TABLE XIII (Continued)

Variable	Description
$Y_t^D$	Total household disposable income in year t
$Y_t^T$	Total household income including transfers in year t
$(Y_L)_t$	Lagged percentage change in household disposable income per capita in year t
$Z_t$	Column vector of total final demand for demand output sectors 11, 14, 15, and 17-42.
$(ZG)_t^{**}$	Column vector of sum of capital formation, household purchases, and state and local government components of final demand for sectors three and seven

TABLE XIV  
MATRICES IN HIGH PLAINS SIMULATION MODEL

Matrix	Description
$A_1$	Diagonal matrix of depreciation rates
$A_2$	Diagonal matrix of average capital - output ratios
$A_3$	Diagonal matrix of one plus the annual rate of change in capital - output ratios
$A_4$	Capital coefficient matrix
$A_5$	Diagonal matrix of proportion of regional sales to regional capital formation by sector relative to total sales to regional capital formation by respective sector
$A_6$	Diagonal matrix of estimated income elasticities by sector
$A_8$	Row vector of direct coefficients for payments of each processing sector to local government per dollar of output of the processing sector
$A_9$	Column vector where elements are proportions of local government purchases from each sector per dollar of local government outlay
$A_{10}$	Column vector where elements are proportions of state government purchases from each sector per dollar of state government outlay
$A_{11}$	Column vector whose elements are the proportion of federal government purchases from each sector per dollar of federal government outlay
$A_{12}$	Matrix of direct input-output coefficients where rows are for sectors 11, 14, 15 and 17-42 and columns are for sectors 1-10, 12, 13 and 16
$A_{13}$	Matrix of total requirements coefficients for sectors 11, 14, 15 and 17-42
$A_{14}$	Matrix of direct coefficients where rows and columns are for sectors three and seven
$A_{15}$	Matrix of direct coefficients where rows are for sectors three and seven and columns are for sectors 1, 2, 4-6, 8-10, 12, 13 and 16

TABLE XIV (Continued)

Matrix	Description
$A_{16}$	Matrix of direct coefficients where rows are for sectors three and seven and columns are for sectors 11, 14, 15 and 17-42
$A_{17}$	Diagonal matrix of average employment-output ratios
$A_{18}$	Diagonal matrix of one plus the annual rate of change in employment-output ratios
$A_{19}$	Diagonal matrix of income - output ratios from direct coefficients matrix with households closed
$A_{20}$	Diagonal matrix where each entry represents sum of households and depreciation direct coefficients for the sector

TABLE XV  
SCALARS IN HIGH PLAINS SIMULATION MODEL

Scalar	Description
$a_1, a_2, a_3$	Weights on previous years' percentage changes in household disposable income
$a_4$	Income elasticity of households for residential construction
$a_5, a_6$	Lower and upper limits, respectively, of ratio of total household expenditures in the region to total household income
$a_7, a_8, a_9$	One plus the annual rate of growth in exports for sectors 22, 23 and 30, respectively
$a_{10}$	Ratio of payments to local government to total household income
$a_{11}$	Ratio of payments to local government to total state government expenditures in the region
$a_{12}$	Ratio of payments to local government to total federal expenditures in the region
$a_{13}$	One plus the annual rate of growth in federal government expenditures per capita
$a_{14}$	Ratio of sector 16 gross output to sector 10 gross output
$a_{15}$	Amount of reduction in feedlot livestock growth adjustment factor, $G_t$ , in each loop
$a_{16}$	One plus the annual rate of growth in direct employment by the household sector
$a_{17}$	Labor - total local government purchases ratio
$a_{18}$	Labor - total state government purchases ratio
$a_{19}$	Labor - total federal government purchases ratio
$a_{20}$	One plus the annual rate of change in the ratio of population to total employment, $H_t$
$a_{21}$	Household income per unit of direct employment of labor by household sector

TABLE XV (Continued)

Scalar	Description
$a_{22}$	Household payments - total local government purchases ratio
$a_{23}$	Household payments - total state government purchases ratio
$a_{24}$	Household payments - total federal government purchases ratio
$a_{25}$	Ratio of dollars of household income from outside region to population
$a_{26}$	Transfer payments per capita in base year
$a_{27}$	One minus the ratio of taxes paid by households to total household income

## Estimating Final Demand

### Capital Formation

Private Business Investment. Investment expenditures involve both replacement investment and induced investment. Replacement investment is not influenced directly by changes in output but is that part of total investment which involves the replacement of plant and equipment depreciated during the year. Induced investment is a change in the amount of plant and equipment that is generated by changes in output. This relationship of investment to changes in output is known as the accelerator principle and is the method used for estimating annual investment in the High Plains. Jorgenson's study of the empirical evidence on investment behavior found real output to be the most important single determinant of investment expenditures (34).

Total investment for any sector is never allowed to be negative but the capital stock of a sector may decline if total investment is less than the amount of depreciation during the year. Thus, the capital stock at the beginning of each period is calculated as follows:

$$\begin{aligned} & \text{If } [(I_n^i)_{t-1} \geq 0] \text{ or} \\ & [(I_n^i)_{t-1} < 0 \text{ and } |(I_n^i)_{t-1}| < (I_r^i)_{t-1}] \quad (5.1) \\ & \text{then } K_t^i = K_{t-1}^i + (I_n^i)_{t-1} \end{aligned}$$

for  $i = 1, 2, \dots, 42$ , or

$$\begin{aligned} & \text{If } (I_n^i)_{t-1} \leq 0 \text{ and} \\ & |(I_n^i)_{t-1}| \geq (I_r^i)_{t-1} \quad (5.2) \\ & \text{then } K_t^i = K_{t-1}^i - (I_r^i)_{t-1} \end{aligned}$$

for  $i = 1, 2, \dots, 42$

where:

- $K_t^i$  = capital stock at beginning of year  $t$  in sector  $i$ ,  
 $(I_n^i)_t$  = induced plant and equipment investment by sector  $i$  in  
 year  $t$ , and  
 $(I_r^i)_t$  = replacement investment by sector  $i$  in year  $t$ .

Equation (5.1) calculates the capital stock for a sector in a given year as the sum of the capital stock at the beginning of the preceding year plus the induced investment that occurred during the preceding year for those cases where the induced investment is positive (Case I) and where the induced investment is negative but in absolute value is less than the replacement investment (depreciation) in the preceding year (Case II). In Case I the capital depreciated during the preceding year is replaced and net new investment for the preceding year is zero or positive. In Case II the capital stock of a sector decreases as only a portion of depreciated capital is replaced due to negative induced investment for the preceding year. Equation (5.2) calculates the capital stock for a sector in year  $t$  as the capital stock at the beginning of the preceding year less the amount of depreciation,  $(I_r^i)_t$ , which occurred. This third case occurs when induced investment is negative and greater than the amount of depreciation during the preceding year. The capital stock is allowed to decrease at a maximal rate equal to the depreciation that occurs during the year.

Then  $K_t$ , the capital stock vector in year  $t$  with elements  $K_t^i$ , is constructed:

$$K_t = \begin{bmatrix} K_t^1 \\ K_t^2 \\ . \\ . \\ . \\ K_t^{42} \end{bmatrix} \quad (5.3)$$

Given the estimated capital stock by sector at the beginning of the year, replacement investment is equal to estimated depreciation:

$$(I_r)_t = A_1 K_t \quad (5.4)$$

where:

$(I_r)_t$  = replacement investment vector in year  $t$  with elements

$(I_r^i)_t$ , and

$A_1$  = diagonal matrix of depreciation rates.

The accelerator principle is formulated as follows:

$$(I_n)_t = (A_2)_{t-1} A_3 (x_{t-1}^D - x_{t-2}^D) \quad (5.5)$$

where:

$(I_n)_t$  = induced plant and equipment investment vector in year  $t$  with elements  $(I_n^i)_t$ ,

$(A_2)_{t-1}$  = diagonal matrix of average capital-output ratios in year  $t-1$ ,

$A_3$  = diagonal matrix of one plus the rate of change in capital-output ratios, and

$x_t^D$  = column vector of gross outputs in year  $t$ .

Total investment for each sector,  $I_t^i$ , is the sum of replacement investment and induced investment, with the stipulation that total investment

is always zero or positive:

$$\begin{aligned}
 &\text{If } [(I_n^i)_t \geq 0] \text{ or} \\
 &\quad [(I_n^i)_t < 0 \text{ and} \\
 &\quad | (I_n^i)_t | < (I_r^i)_t] \\
 &\text{then } I_t^i = (I_r^i)_t + (I_n^i)_t
 \end{aligned} \tag{5.6}$$

for  $i = 1, 2, \dots, 42$ , or

$$\begin{aligned}
 &\text{If } [(I_n^i)_t < 0] \text{ and} \\
 &\quad | (I_n^i)_t | \geq (I_r^i)_t \\
 &\text{then } I_t^i = 0
 \end{aligned} \tag{5.7}$$

for  $i = 1, 2, \dots, 42$ .

Then  $I_t$ , the total investment vector in year  $t$  with elements  $I_t^i$ , is constructed:

$$I_t = \begin{bmatrix} I_t^1 \\ I_t^2 \\ \vdots \\ I_t^{42} \end{bmatrix} \tag{5.8}$$

Sources of inputs of capital by producing sectors are found by multiplying the total investment vector by the capital coefficient matrix:

$$(CI)_t = A_4 I_t \tag{5.9}$$

where:

$(CI)_t$  = column vector of composition of new regional investment in year  $t$ , and

$A_4$  = capital coefficient matrix.

Whereas  $(CI)_t$  shows the amount of sales to capital formation by each sector, regardless of geographic origin, the final demand for the region's output sold to capital formation is determined as:

$$(CL)_t = A_5(CI)_t \quad (5.10)$$

where:

$A_5$  = diagonal matrix of proportion of regional sales to regional capital formation by sector relative to total sales to regional capital formation by respective sector, and

$(CL)_t$  = column vector of regional sales to regional capital formation excluding residential construction.

Residential Investment. The form of the function used to estimate household demand for residential construction is discussed in the next subsection. Sales of residential construction by the construction sector (sector 15) are estimated as follows:

$$(CHP)_t = (CHP)_{t-1} + a_4 (Y_L)_t (CHP)_{t-1} \quad (5.12)$$

$$(CH)_t = P_t (CHP)_t \quad (5.13)$$

where:

$(CHP)_t$  = residential construction demand per capita in year  $t$ ,

$a_4$  = income elasticity of households for residential construction,

$(CH)_t$  = total residential construction demand in year  $t$ , and

$P_t$  = total regional population in year  $t$ .

A lagged percentage change in household disposable income per capita is determined for use in estimating residential construction put-in-place,

a component of sales to capital formation by construction, and in estimating household purchases for current consumption, discussed in the next subsection:

$$\begin{aligned}(Y_L)_t = & a_1 [(Y_{t-1} - Y_{t-2})/.5 (Y_{t-1} + Y_{t-2})] \\ & + a_2 [(Y_{t-2} - Y_{t-3})/.5 (Y_{t-2} + Y_{t-3})] \\ & + a_3 [(Y_{t-3} - Y_{t-4})/.5 (Y_{t-3} + Y_{t-4})]\end{aligned}\quad (5.11)$$

where:

$a_1, a_2, a_3$  = weights on previous years' percentage changes in household disposable income, and

$(Y_L)_t$  = lagged percentage change in household disposable income per capita in year  $t$ .

Public Capital Formation. The sales to capital formation of the government sectors (local, state and federal) is treated as a current account transaction and is included in the estimation of final demand purchases by the government sectors.

Summation of Capital Formation. Defining  $(CHV)_t$  as a column vector of zeroes with the exception of the row 15 element which has the value of  $(CH)_t$ , the column vector of regional sales to regional capital formation can be constructed:

$$(CA)_t = (CL)_t + (CHV)_t \quad (5.14)$$

### Household Purchases

As suggested by current theories of consumption expenditures, current consumption is based on household income received over a number of periods rather than only income received in the current period (23).

The consumption function for the High Plains model is formulated on a per capita basis and uses income elasticities by sector developed for long run forecasts of the Texas economy (47). These income elasticities were estimated from projections of consumer expenditures by sector for the nation prepared by the Bureau of Labor Statistics (100) from a study by Houthaker and Taylor (32). These income elasticities are held constant over time and reflect past trends in consumer expenditures. Through use of elasticities the composition of consumer expenditures is changed over time. But, total consumer expenditures of locally produced goods is constrained to stay within certain limits relative to the local expenditure-household income ratio in the base year. While the consumption function used is a rudimentary description of consumer behavior, it is an improvement over previous models of this type (Maki, et al. lineage of models discussed in Chapter II).

The equations for determining the column vector of regional consumption demand for a given year begin with the calculation of per capita consumption expenditures by sector in the preceding year:

$$C_{t-1}^P = C_{t-1} \frac{1}{P_{t-1}} \quad (5.15)$$

where:

$C_t^P$  = column vector of per capita consumption demand in year  $t$ , and

$C_t$  = column vector of regional consumption demand in year  $t$ .

The consumption function is:

$$C_t^P = C_{t-1}^P + (Y_L)_t A_6 C_{t-1}^P \quad (5.16)$$

where:

$A_6$  = diagonal matrix of estimated income elasticities by sector.

Aggregating to total consumption by sector from per capita consumption by sector, the column vector,  $C_t^U$ , of regional consumption demand in year  $t$ , before adjustment for relationship to total household income, is estimated from:

$$C_t^U = P_t C_t^P \quad (5.17)$$

To derive  $C_t$ , the consumption vector constrained by the relation of total regional consumption to total household income, the first step is the summation of the elements of  $C_t^U$ :

$$\text{SUM}C_t^U = iC_t^U \quad (5.18)$$

where:

$\text{SUM}C_t^U$  = total of consumption expenditures in vector  $C_t^U$ , and

$i$  = row unit vector.

Then, the relationship of consumption expenditures to household income in the preceding year is formed:

$$\text{SUM}CY_t = \text{SUM}C_t^U / Y_{t-1}^T \quad (5.19)$$

where:

$\text{SUM}CY_t$  = ratio of total consumption expenditures in year  $t$  to total household income in year  $t-1$ , and

$Y_t^T$  = total household income including transfers in year  $t$ .

The constrained consumption vector,  $C_t$ , is then determined by the following equations:

$$\text{If } a_5 \leq \text{SUM}CY_t \leq a_6 \quad (5.20)$$

$$\text{then } C_t = C_t^U,$$

$$\text{If } \text{SUM}CY_t > a_6, \quad (5.21)$$

$$\text{then } (B_1)_t = a_6 / \text{SUM}CY_t$$

and  $C_t = (B_1)_t C_t^u$ , or

If  $SUMCY_t < a_5$ , (5.22)

then  $(B_2)_t = a_5 / SUMCY_t$

and  $C_t = (B_2)_t C_t^u$

where:

$a_5, a_6$  = lower and upper limits, respectively, of ratio of total household expenditures in the region to total household income, and

$(B_1)_t, (B_2)_t$  = upper and lower limit weights, respectively, for constraining consumption expenditures as a percent of household income.

In summary, household purchases of locally produced goods and services for a given year are estimated with a consumption function which relates per capita consumption in a sector to lagged percentage change in household disposable income. Total regional household purchases from a sector are estimated as the product of per capita consumption and estimated population for the year. Then, household purchases for locally purchased goods and services are weighted, if necessary, to maintain the local expenditure--household income ratio of the base year.

### Exports

Exports for the supply output sectors (agricultural sectors 1-10, petroleum sectors 12 and 13, and meat products manufacturing sector 16) are the residuals after regional requirements are subtracted from projected output. These sectors' outputs are determined by supply

considerations; that is, the demand for their exports is not a determinant of their output in the simulation model. Subject to demand considerations that are included in the projections for the supply output sectors presented in Chapter IV, this methodology assumes that the export demand for the output of these sectors is perfectly elastic.

In contrast, the supply of output is perfectly elastic in the traditional input-output model projections framework and that methodology is used for the demand determined sectors of the High Plains simulation model. In the basic formulation of the simulation model, the demand for the exports of the demand determined sectors (with the exception of sectors 22, 23 and 30) is endogenously determined on the basis of the lagged growth rate in the total value added of processing sectors 1 to 42 in the region. This assumes that the supply determined sectors provide the propulsive force for the High Plains economy. In Chapter VII alternative assumptions about the exports of the demand determined sectors are used in the simulation model. Exports of three sectors, Chemicals (22), Petroleum Products (23), and Gas Services (30) are dependent on the output of crude petroleum and natural gas. Accordingly, the exports of these sectors are related to the trend in petroleum supplies.

The lagged growth rate in total value added is determined as follows:

$$R_t = [(TVA)_{t-1} - (TVA)_{t-2}] / .5 [(TVA)_{t-1} + (TVA)_{t-2}] \quad (5.23)$$

where:

$R_t$  = rate of growth of value added in regional processing sectors  
from  $t-2$  to  $t-1$ , and

$(TVA)_t$  = total value added within region by processing sectors in year  $t$ .

The column vector,  $E_t^*$ , of regional exports in year  $t$  for sectors 11, 14, 15, 17-21, 24-29, and 31-42 is computed as:

$$E_t^* = (1 + R_t) E_{t-1}^* \quad (5.24)$$

Exports of the three sectors where the growth of petroleum supplies is the determining factor are estimated as one plus the estimated annual rate of growth in exports times the value of exports in the preceding year, by respective sector:

$$E_t^{22} = a_7 E_{t-1}^{22} \quad (5.25)$$

$$E_t^{23} = a_8 E_{t-1}^{23} \quad (5.26)$$

$$E_t^{30} = a_9 E_{t-1}^{30} \quad (5.27)$$

where:

$E_t^i$  = regional exports of sector  $i$  in year  $t$ , and

$a_7, a_8, a_9$  = one plus the rate of growth in exports for sectors 22, 23 and 30, respectively.

The column vector,  $E_t$ , of regional exports in year  $t$  for the demand determined sectors 11, 14, 15 and 17-42 is constructed from the  $E_t^i$ 's and  $E_t^*$ :

$$E_t = \begin{bmatrix} E_t^* \\ - - - \\ E_t^i \end{bmatrix} \quad (5.28)$$

### Government Purchases

Sales to three final demand sectors, representing three levels of government, local, state and federal, must be determined for each year simulated. For local government expenditures a balanced budget concept is utilized where total purchases by local government units is equal to total revenues of the local government units in the preceding year:

$$(L_T)_t = A_8 X_t^D + a_{10} Y_{t-1}^T + a_{11} (S_T)_{t-1} + a_{12} (F_T)_{t-1} \quad (5.29)$$

where:

$(L_T)_t$  = total local government expenditures in year t,

$A_8$  = row vector of direct coefficients for payments of each processing sector to local government per dollar of output.

$X_t^D$  = column vector of gross output by sector in year t for the 42 processing sectors,

$a_{10}$  = ratio of payments to local government to total household income

$a_{11}$  = ratio of payments to local government to total state government expenditures in the region,

$(S_T)_t$  = total state government expenditures in region in year t,

$a_{12}$  = ratio of payments to local government to total federal government expenditures in the region, and

$(F_T)_t$  = total federal government expenditures in region in year t.

The column vector,  $L_t$ , of local government purchases by processing sector in year t is estimated on the basis of the base year proportions of purchases from each processing sector:

$$L_t = A_9 (L_T)_t \quad (5.30)$$

where:

$A_9$  = column vector where elements are proportions of local government purchases from each sector per dollar of local government outlay.

Studies of state government expenditures for the state of Washington (72) and for the state of Texas (47) found spending to be

highly correlated with personal income. Both studies covered periods of increasing population where population and total personal income were highly correlated. Since the expectation is for a period of population decline in the High Plains, state government expenditures in the region are estimated on a per capita basis. Per capita state government expenditures in the region are assumed to grow at the same rate as per capita disposable income. Population estimated endogenously is then used to estimate total state government expenditures in the region. The equations for estimating the column vector,  $S_t$ , of state government purchases from each of the 42 processing sectors in year  $t$  are as follows:

$$(SPC)_t = [1 + (Y_L)_t] (SPC)_{t-1} \quad (5.31)$$

$$(S_T)_t = P_t (SPC)_t \quad (5.32)$$

$$S_t = A_{10} (S_T)_t \quad (5.33)$$

where:

$(SPC)_t$  = state government expenditures per capita in the region in year  $t$ , and

$A_{10}$  = column vector where elements are ratios of purchases to outlay for state government.

Federal government expenditures fluctuate widely for a particular region due to defense expenditures and the vagaries of the political process. This makes the projection of federal expenditures in the High Plains a most difficult task. Per capita expenditures in the High Plains are projected on the basis of past trends at the national level and multiplied by regional population for the estimated total federal expenditures. Base year expenditures by sector are used to determine

the column vector,  $F_t$ , of federal government purchases from each of the 42 processing sectors in year  $t$ . The projection procedure is as follows:

$$(FPC)_t = a_{13} (FPC)_{t-1} \quad (5.34)$$

$$(F_T)_t = P_t (FPC)_t \quad (5.35)$$

$$F_t = A_{11} (F_T)_t \quad (5.36)$$

where:

$(FPC)_t$  = total federal government expenditures per capita in region in year  $t$ ,

$a_{13}$  = one plus the rate of growth in federal government expenditures per capita, and

$A_{11}$  = column vector whose elements are the proportion of federal government purchases from each sector per dollar of federal government outlay.

### Total Final Demand

Total final demand is the sum of demands from capital formation, household purchases, exports, and government purchases. The total final demand for the demand determined sectors is specified through the following definitional equation:

$$Z_t = (CA)_t + C_t + E_t + L_t + S_t + F_t \quad (5.37)$$

where:

$Z_t$  = column vector of total final demand specified for sectors 11, 14, 15 and 17-42.

The elements of the column vectors of the final demand components on the right side of Equation 5.37 are for only the row indices of those

vectors corresponding with  $Z_t$ ; that is, they are redefined in this equation to include only rows 11, 14, 15 and 17-42.

The sum of the capital formation, household purchases, and state and local government components of final demand for the feed grain production sectors, three and seven, is used in the next section for determining the level of feedlot livestock production. The column vector  $(ZG)_t^{**}$  is defined as:

$$(ZG)_t^{**} = (CA)_t + C_t + L_t + S_t \quad (5.38)$$

where the column vectors on the right side of the equation refer to only the row indices three and seven.

#### Estimating Sector Output Subject to Agricultural and Petroleum Output Projections

##### Supply Output

The projections of output for sectors 1-10, 12 and 13 were discussed in Chapter IV. The projections of sectors 1-9, 12 and 13 are fed into the simulation model as exogenous data. As specified in Chapter IV, output of sector 10, feedlot livestock, is dependent on the interaction of an adjustment factor with the potential feedlot output. Computation of changes in the adjustment factor specified in this subsection are through a feedback loop from the next subsection where demand output is determined. The variable  $\bar{X}_t^i$  is defined as output of the  $i$ th supply output sector in year  $t$ . Accordingly,  $\bar{X}_t^i$ 's for  $i = 1-9$ , 12 and 13 are exogenous data. Feedlot livestock (sector 10) output is calculated from

$$\bar{X}_t^{10} = G_t \bar{X}_{t-1}^{10} \quad (5.39)$$

where:

$G_t$  = one plus the annual rate of change in feedlot livestock output for the year  $t$ .

At this point in the simulation for a year,  $G_t$  is assigned an exogenous value, an adjustment factor as defined in Chapter IV. As described below, a loop back to Equation 5.39 occurs when the feed grain availability constraint is operative, decreasing the value of  $G_t$ . Thus, the exogenous  $G_t$  is the maximum allowable growth rate for sector ten.

A supply output sector not previously discussed is meat products manufacturing, sector 16. This sector has been a major growth sector in the High Plains as meat slaughtering and packing plants have moved towards a decentralized marketing system, relocating to the most rapidly growing feeding areas (62). The purchase of 32 cents of feedlot livestock output per dollar of meat products output (direct coefficient from Table II) illustrates the large interdependence of the two sectors. The forward linkage from feedlot livestock to meat products manufacturing is accounted for in the High Plains simulation model by maintaining a constant relationship between meat products manufacturing output and feedlot livestock output. Thus, output in sector 16 is determined by:

$$\bar{X}_t^{16} = a_{14} \bar{X}_{t-1}^{10} \quad (5.40)$$

where:

$a_{14}$  = ratio of sector 16 gross output to sector 10 gross output.

To determine the demand outputs, the gross outputs of the supply output sectors are listed in the column vector  $\bar{X}_t$ , constructed as follows:

$$\bar{X}_t = \begin{bmatrix} \bar{X}_t^1 \\ \bar{X}_t^2 \\ \vdots \\ \bar{X}_t^{10} \\ \bar{X}_t^{12} \\ \bar{X}_t^{13} \\ \bar{X}_t^{16} \end{bmatrix} \quad (5.41)$$

### Demand Output

In Chapter III, the basic equation of the disposition of output in the input-output framework was shown to be  $X = AX + Y$  and the standard solution to be  $X = (I - A)^{-1}Y$ . In this analysis of the High Plains economy the processing sectors have been separated into two groups, the supply output and demand output sectors. To identify the structure of this system, the disposition of output equation is partitioned into submatrices representing supply output and demand output sectors. This is similar to Romanoff's (65) partitioning for basic and non-basic industries. Using the symbols repeated above from Chapter III, but using the subscript "1" for supply output sectors and the subscript "2" for demand output sectors, the equation for the disposition of output can be written:

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} Q_{11} & Q_{12} \\ Q_{21} & Q_{22} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix}$$

where the  $Q_{ij}$ 's are partitions of the direct coefficients matrix

referred to as "A" above with the  $i$  and  $j$  row and column indices indicating supply output or demand output sectors. This can be rewritten as two equations, the first representing the disposition of output for the supply output sectors, the second the disposition of output for the demand output sectors:

$$X_1 = Q_{11}X_1 + Q_{12}X_2 + Y_1$$

$$X_2 = Q_{21}X_1 + Q_{22}X_2 + Y_2$$

The output of the supply output sectors,  $X_1$ , is exogenous. It has been predetermined and is not affected by the level of output of the demand output sectors,  $X_2$ . In the High Plains simulation model local uses of supply output ( $Q_{11}X_1$ ,  $Q_{12}X_2$  and non-export components of  $Y_1$ ) are assumed to take precedence over sales outside the region. The exports component of  $Y_1$  is a residual, given gross output and the disposition of output to other processing and final demand sectors. Thus, the two equations are not solved interdependently on the basis of final demands  $Y_1$  and  $Y_2$ . Given  $X_1$  as exogenous data,  $Q_{21}$  and  $Q_{22}$  as parameters of the model from the direct coefficients matrix, and  $Y_2$  as the final demand for the demand output sectors, the solution for  $X_2$  can be derived from the equation for the disposition of  $X_2$ . Rewriting the equation:

$$X_2 - Q_{22}X_2 = Q_{21}X_1 + Y_2$$

which can be rewritten as:

$$(I - Q_{22}) X_2 = Q_{21}X_1 + Y_2$$

or:

$$X_2 = (I - Q_{22})^{-1} [Q_{21}X_1 + Y_2]$$

This differs from the "standard solution". Final demand for the demand output sectors is "adjusted" to include the requirements of the supply output sectors from the demand output sectors and the output of the supply output sectors is not induced by the level of demand output sectors.

For the simulation model, the column vector  $W_t$  of adjusted final demand for the demand output sectors 11, 14, 15 and 17-42 in year  $t$  is calculated as follows:

$$W_t = A_{12}\bar{X}_t + Z_t \quad (5.42)$$

where:

$A_{12}$  = matrix of direct input-output coefficients where rows are for sectors 11, 14, 15 and 17-42 and columns are for sectors 1-10, 12, 13 and 16.

Then, demand output to produce adjusted final demand is:

$$X_t^d = A_{13}W_t \quad (5.43)$$

where:

$X_t^d$  = column vector of gross outputs required from sectors 11, 14, 15 and 17-42 to produce adjusted final demand,  $W_t$ , in year  $t$ , and

$A_{13}$  = matrix of total requirements coefficients for sectors, 11, 14, 15 and 17-42.

As discussed in the preceding subsection, the growth rate of the feedlot livestock sector is constrained by the output of feed grains. If exports of feed grains become negative, the growth rate for feedlot livestock,  $G_t$ , is decreased and the simulation model returns to Equation 5.39. This loop is repeated until exports of feed grains

become greater than or equal to zero. This procedure begins with the calculation for exports for the feed grain sectors:

$$\begin{aligned}
 (EG)_t = & (\overline{XG})_t^{**} - A_{14}(\overline{XG})_t^{**} \\
 & - A_{15}(\overline{XGX})_t^{**} - A_{16}x_t^d \\
 & - (ZG)_t^{**}
 \end{aligned} \tag{5.44}$$

where:

$(EG)_t$  = column vector of export sales plus federal government payments for sectors three and seven,

$(\overline{XG})_t^{**}$  = column vector of exogenous gross outputs for sectors three and seven in year  $t$ ,

$A_{14}$  = matrix of direct coefficients where rows and columns are for sectors three and seven,

$A_{15}$  = matrix of direct coefficients where rows are for sectors three and seven and columns are for sectors 1, 2, 4-6, 8-10, 12, 13 and 16,

$(\overline{XGX})_t^{**}$  = column vector of gross outputs for sectors 1, 2, 4-6, 8-10, 12, 13 and 16, and

$A_{16}$  = matrix of direct coefficients where rows are for sectors three and seven and columns are for sectors 11, 14, 15 and 17-42.

Then feed grain exports are aggregated:

$$(GEG)_t = i (EG)_t \tag{5.45}$$

where:

$(GEG)_t$  = total exports by sectors three and seven combined in year  $t$ ,

$i$  = row unit vector

The logical statements for review of the feed grain exports situation and the decision to lower  $G_t$  are:

$$\begin{aligned} &\text{If } (GEG)_t \geq 0, \\ &\text{go to Equation (5.48), or} \end{aligned} \quad (5.46)$$

$$\begin{aligned} &\text{If } (GEG)_t < 0, \\ &\text{then } G_t = G_t - a_{15} \end{aligned} \quad (5.47)$$

and return to Equation 5.39

where:

$a_{15}$  = amount of reduction of  $G_t$  in each loop.

Outputs of the supply output and demand output sectors are combined in the column vector  $X_t^D$ :

$$X_t^D = \begin{bmatrix} \bar{X}_t \\ \text{---} \\ X_t^d \end{bmatrix} \quad (5.48)$$

### Estimating Employment, Population, Income and Value Added

The projection of output by processing sector is the basis for estimates of employment, population and income.

#### Employment

Employment in the 42 processing sectors is estimated with employment output ratios which are updated each year for estimated technological change:

$$L_t^e = (A_{17})_{t-1} A_{18} X_t^D \cdot 10^{-1} \quad (5.49)$$

where:

- $L_t^e$  = column vector of employment by sector in year  $t$ ,
- $(A_{17})_t$  = diagonal matrix of average employment output ratios in year  $t$ , and
- $A_{18}$  = diagonal matrix of one plus the rate of change in the labor-output ratio.

Regional employment in year  $t$ ,  $(TE)_t$ , is estimated by:

$$\begin{aligned} (TE)_t = iL_t^e + a_{16} L_{t-1}^0 + a_{17} (L_T)_t \\ + a_{18} (S_T)_t + a_{19} (F_T)_t \end{aligned} \quad (5.50)$$

where:

- $i$  = row unit vector,
- $a_{16}$  = one plus rate of growth in direct employment by the household sector,
- $L_t^0$  = direct employment of labor by household sector in year  $t$ ,
- $a_{17}$  = labor-total local government purchases ratio,
- $a_{18}$  = labor-total state government purchases ratio, and
- $a_{19}$  = labor-total federal government purchases ratio.

### Population

Population in the High Plains is estimated as a simple linear function of the previous year's total employment. A factor to account for the trend in the labor force participation rate is included. This is a simple demographic model which assumes perfect mobility in and out of the region to maintain full employment and a fixed composition of the population, including the institutional population. The equation for estimation of population is:

$$P_{t+1} = a_{20} H_{t-1} (TE)_t \quad (5.51)$$

where:

$a_{20}$  = one plus the rate of change in  $H_t$ , and

$H_t$  = the ratio of population to total employment in year  $t$ .

### Income

Household income by processing sector is estimated as follows:

$$Y_t^* = A_{19} X_t^D \quad (5.52)$$

where:

$Y_t^*$  = column vector of household income by sector in year  $t$ , and

$A_{19}$  = diagonal matrix of income-output ratios from direct coefficient matrix with households closed.

Total household income including transfers in year  $t$ ,  $Y_t^T$ , is estimated as:

$$\begin{aligned} Y_t^T = & iY_t^* + a_{21} L_t^0 + a_{22} (L_T)_t \\ & + a_{23} (S_T)_t + a_{24} (F_T)_t \\ & + a_{25} P_t + a_{26} P_t \end{aligned} \quad (5.53)$$

where:

$i$  = row unit vector,

$a_{21}$  = household income per unit of direct employment of labor by household sector,

$a_{22}$  = household payments - total local government purchases ratio,

$a_{23}$  = household payments - total state government purchases ratio,

$a_{24}$  = household payments - total federal government purchases ratio,

$a_{25}$  = ratio of dollars of household income from outside region to population, and

$a_{26}$  = transfer payments per capita in 1967.

Disposable income and disposable income per capita are calculated as follows:

$$Y_t^D = a_{27} Y_t^T \quad (5.54)$$

$$Y_t = Y_t^D / P_t$$

where:

$Y_t^D$  = total household disposable income in year  $t$ ,

$a_{27}$  = one minus the ratio of taxes paid by households to total household income, and

$Y_t$  = household disposable income per capita.

### Value Added

Value added by processing sector and totaled for all processing sectors is calculated as follows:

$$(VA)_t = A_{20} X_t^D \quad (5.56)$$

$$(TVA)_t = i (VA)_t$$

where:

$(VA)_t$  = column vector of value added within the region by processing sectors in year  $t$ , and

$A_{20}$  = diagonal matrix where each entry represents sum of households and depreciation direct coefficients for the respective sector.

This concludes the specification of the High Plains simulation model. In the next chapter results of the model are presented. An evaluation of the model is made in Chapter VIII.

## CHAPTER VI

### RESULTS OF HIGH PLAINS SIMULATION MODEL

Several scenarios of the High Plains economy from 1967 to 2010 are summarized in this chapter. The projection of variables in the High Plains simulation model are on an annual basis so that time paths from the base year to the terminal year can be traced and analyzed. Input data for these alternate simulations are presented in Chapters III and IV and Appendix D. The terminal year, 2010, was selected in order to observe the effects of declines in the annual water pumped for irrigation.

Empirical estimates of variables of primary interest to planners in business and government are presented: population, output, employment and household income. To facilitate orderly presentation, a "base" projection is identified and discussed in detail in the first section of the chapter. Then, as exogenous supply output data and selected parameters are changed, the alternate scenarios of the High Plains economy can be related to the base projection. After the base projection, the results from an alternate annual groundwater pumpage schedule and the corresponding crop outputs are reported. The importance of the mining sectors in the High Plains economy is analyzed by describing the effects of an alternate assumption on crude petroleum and natural gas output. In the final section of this chapter the effects of variations in selected parameters of the model are studied. These experiments

demonstrate the capability of the High Plains simulation model to incorporate changes in exogenous supply outputs and selected parameters.<sup>1</sup>

### Base Projection

Water Projection II, which utilizes the Texas Water Development Board (108) projection of annual water pumpage for the Lower High Plains and the Bekure (5) study for the Upper High Plains, is assumed for the crop output projections for the base projection of the High Plains economy. As presented in Table X of Chapter IV, the Water Projection II assumptions result in projections of the annual acre-feet of water pumped for irrigation that decrease steadily from 1967 to 2010 for the Lower High Plains. But, in the Upper High Plains there is a steady increase in the annual acre-feet of water pumped for irrigation from 1967 to 1995 and a steady decline from 1995 to 2010. And, when the total acre-feet of water pumped annually in the High Plains is considered, it has the same 1995 turning point as indicated for the Upper High Plains. Also incorporated as an assumption for the base projection are the increases in yield per acre from the U. S. Department of Agriculture (73) for the OBERS projections. Crop output projections under these assumptions are discussed in the Agricultural Crop Output section of Chapter IV. Other data and the specification of the model are as discussed previously.

### Population

The base projection of total population in the High Plains from

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<sup>1</sup>The model was programmed in the Fortran IV language and computer runs for the 44 years from 1967 to 2010 cost approximately \$15 each.

1967 to 2010 is illustrated in Figure 5 and recorded in Table XVI. Population increases at an average annual rate of 1.7 percent from 1967 to 1979. After 1979, there are small increases until the peak population of 443,958 is reached in 1981. This peak year population is 22.5 percent greater than the base year, 1967, population of 362,361. From 1979 to 1996, a 17 year span, population is relatively stable in the High Plains with a small, overall downward trend. The population of 432,263 in 1996 represents a decrease of 10,074 or 2.3 percent from the 1979 population of 442,337. From 1996, the simulated population of the High Plains begins a steady decline at an average annual rate of 1.5 percent to the terminal year, 2010. Population in the terminal year is 348,629. This is 3.4 percent less than the base year population and 21.5 percent less than the peak year population.

Thus, if the assumptions of the High Plains base projection are accurate, the decline in annual pumpage of groundwater for irrigation purposes after 1995 will be accompanied by a decline in the total population of the region. However, expectations that population will follow the same trend as the annual acre-feet of groundwater pumped for irrigation purposes, increasing to 1995 and then declining, are not supported by the base projection. In contrast to the trend for irrigated crop production, population is projected to be relatively stable for 17 years before it starts to have a strong downward movement. This trend for population growth has important implications for the provision of public services which is discussed in the next chapter.

There are a number of interacting factors which account for the trend in population growth reported for the base projection. The following discussion summarizes these factors and the following

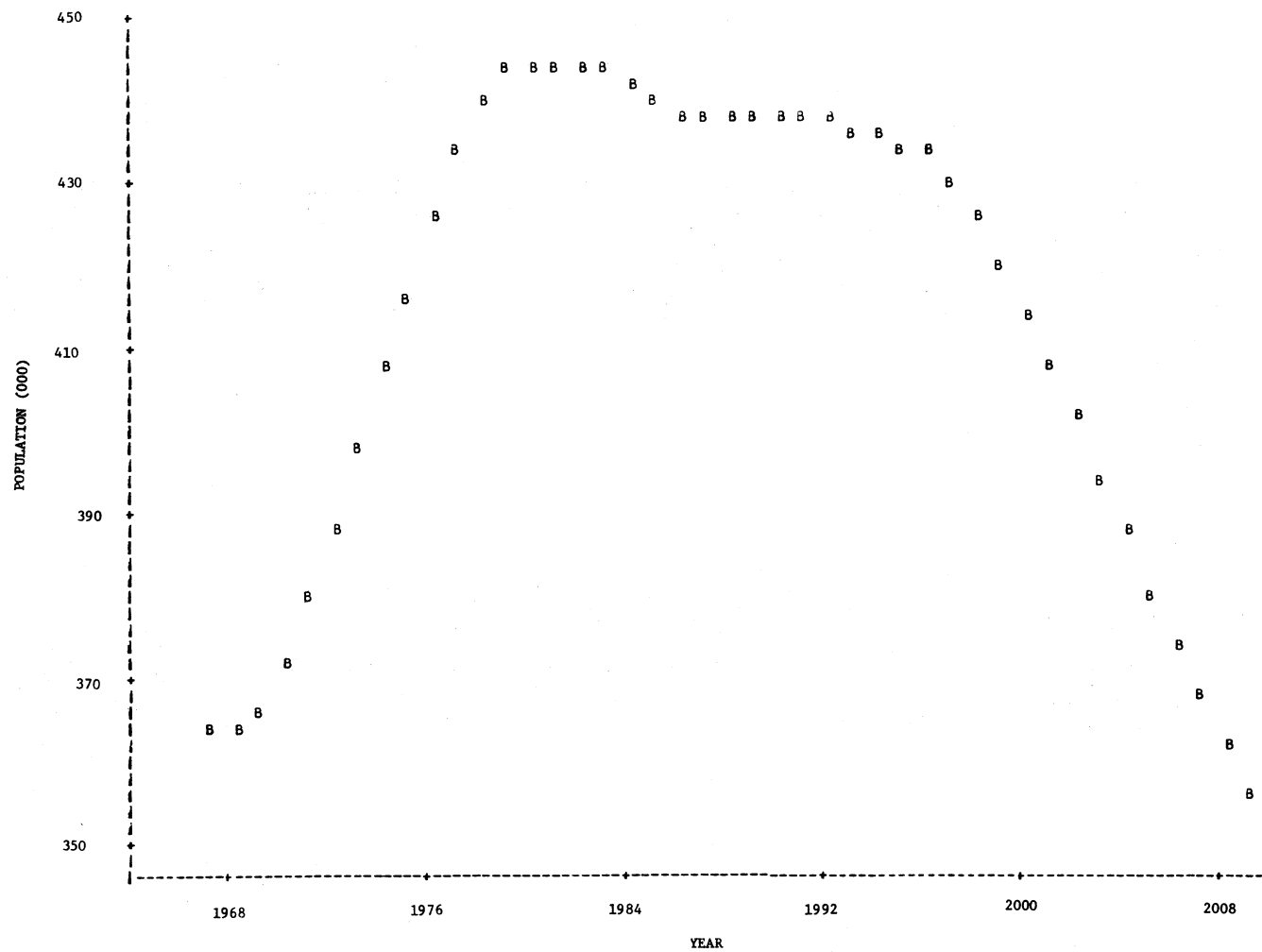


Figure 5. Population, Base Projection, High Plains of Oklahoma and Texas, 1967-2010

TABLE XVI  
POPULATION, TOTAL EMPLOYMENT, AND DISPOSABLE INCOME  
PER CAPITA, BASE PROJECTION, HIGH PLAINS OF  
OKLAHOMA AND TEXAS, 1967-2010

Year	Population	Total Employment	Disposable Income per Capita
	<u>Number</u>	<u>Number</u>	<u>1967 Dollars</u>
1967	362,361	153,295	3,010
1968	363,084	155,074	3,081
1969	365,099	157,677	3,157
1970	370,857	161,068	3,219
1971	378,455	164,756	3,270
1972	386,732	169,347	3,333
1973	397,111	173,795	3,372
1974	407,135	177,748	3,411
1975	415,977	181,826	3,462
1976	425,097	185,623	3,486
1977	433,541	188,255	3,497
1978	439,177	189,769	3,510
1979	442,337	190,489	3,528
1980	443,570	190,846	3,553
1981	443,958	190,904	3,579
1982	443,649	190,437	3,602
1983	442,120	189,824	3,633
1984	440,256	189,236	3,666
1985	438,455	188,773	3,702
1986	436,943	188,740	3,739
1987	436,430	188,912	3,772
1988	436,393	189,182	3,804
1989	436,577	189,448	3,835
1990	436,755	189,660	3,865
1991	436,806	189,646	3,893
1992	436,388	189,471	3,922

TABLE XVI (Continued)

Year	Population	Total Employment	Disposable Income per Capita
	<u>Number</u>	<u>Number</u>	<u>1967 Dollars</u>
1993	435,498	189,204	3,953
1994	434,449	188,909	3,985
1995	433,340	188,628	4,019
1996	432,263	187,697	4,043
1997	429,699	185,983	4,061
1998	425,348	183,624	4,082
1999	419,532	180,967	4,110
2000	413,050	178,304	4,144
2001	406,563	175,740	4,181
2002	400,317	173,031	4,213
2003	393,751	170,172	4,244
2004	386,859	167,271	4,279
2005	379,884	164,431	4,315
2006	373,060	161,702	4,354
2007	366,502	159,124	4,394
2008	360,297	156,655	4,433
2009	354,352	154,279	4,473
2010	348,629	151,954	4,511

subsections on output, employment and income provide more detail. Of primary importance in the period of population increase are the forward linkages from feed grains to feedlot livestock to meat products and backward linkages of these sectors to other sectors in the High Plains economy. After the growth of feedlot livestock production becomes restricted by local feed grain output in 1978, the population becomes relatively stable. Although there is continued growth in the output of most sectors of the regional economy until 1995, it is not of such proportions as to overcome decreases in employment-output ratios. The result is relatively stable total employment and population. After 1995, decreases in water pumpage are reflected in crop output and in the operation of backward and forward linkages of the High Plains economy. These decreases in economic activity are accentuated by continued decreases in employment-output ratios. All of this occurs while output and employment are decreasing in petroleum and petroleum-related sectors from 1970 to 2010.

### Sectoral Output

Table XVII presents base projections of gross output in 1967 prices for each of the 42 processing sectors in the High Plains economy. The 44 years of output data estimated for each of the 42 sectors by the simulation model are difficult to comprehend in total. To avoid this problem Table XVII contains only the gross outputs for the base year, 1967, for the last year of increasing groundwater pumpage for irrigation, 1995, and for the terminal year, 2010.

The most dramatic increases in gross output in the High Plains are those projected for feedlot livestock (sector 10). The basis for this

TABLE XVII  
GROSS OUTPUT BY SECTOR, BASE PROJECTION,  
HIGH PLAINS OF OKLAHOMA AND TEXAS,  
1967, 1995 AND 2010

Sector		Gross Output in Thousands of 1967 Dollars		
<u>Number</u>	<u>Name</u>	<u>1967</u>	<u>1995</u>	<u>2010</u>
1	Irri. Cotton	24,656	21,772	16,589
2	Irri. Food Grain	71,096	148,653	129,866
3	Irri. Feed Grain	165,867	333,867	292,980
4	Other Irri. Crop	44,419	46,221	39,597
5	Dry Cotton	7,098	12,991	16,287
6	Dry Food Grain	23,237	24,367	33,174
7	Dry Feed Grain	21,935	17,594	35,249
8	Other Dry Crop	5,259	9,961	14,498
9	Range Livestock	68,848	133,518	161,931
10	Feedlot Livestock	218,414	2,127,854	2,013,090
11	Ag. Services	19,460	44,600	43,377
12	Crude Oil & Gas	397,398	237,705	168,018
13	Natl. Gas Liq.	134,035	80,173	56,669
14	Oil & Gas Ser.	32,943	36,096	31,352
15	Construction	165,773	215,576	191,018
16	Meat Products	49,242	471,717	457,064
17	Food Process	50,149	166,632	109,435
18	Textile Prod.	5,349	8,933	8,330
19	Milling & Feeds	14,774	115,274	111,065
20	Beverages	10,624	16,187	14,515
21	Wood & Paper & Pri.	15,545	24,867	22,563
22	Chemicals	100,873	93,318	77,753
23	Petro. Product	173,220	159,419	137,275
24	Soil & Rock Prod.	13,294	19,362	17,629
25	Metal Product	14,927	21,292	19,121
26	Machinery	20,695	28,007	24,358

TABLE XVII (Continued)

Sector		Gross Output in Thousands of 1967 Dollars		
<u>Number</u>	<u>Name</u>	<u>1967</u>	<u>1995</u>	<u>2010</u>
27	Other Mfg.	11,306	16,224	14,690
28	Transportation	39,541	71,042	64,404
29	Communication	32,213	61,760	58,506
30	Gas Service	141,989	125,332	104,861
31	Electric Service	61,178	102,010	93,063
32	Water & San. Ser.	11,149	18,365	16,445
33	Whl. Agr. Prod.	11,586	66,178	63,224
34	Whl. Petro. Prod.	37,146	59,551	53,746
35	Other Wholesale	157,569	266,833	243,827
36	Agr. Supplies	2,822	4,945	4,447
37	Gas. Serv. Stat.	15,015	24,704	23,118
38	Other Retail	167,016	261,900	235,986
39	Finance	68,373	176,700	164,742
40	Insur. & R.E.	32,479	60,430	56,481
41	Education Serv.	84,219	143,623	131,874
42	Other Serv.	149,814	262,707	239,147

growth is the availability and expansion of feed grain output in the region. Output in feedlot livestock, in constant 1967 dollars, increases by 33 percent per year to 1972, by 15 percent per year from 1972 to 1975, and by 5 percent per year from 1975 to 1977. After 1977, the growth rate for feedlot livestock output is restricted by the availability of locally produced feed grains (as described in Chapters IV and V). Thus the annual growth rate is 2.8 percent for 1978 and 1979, 2.6 percent for 1980, and 1.7 percent for 1981 through 1995. In 1996, the growth rate is 1.5 percent. After 1996, the annual growth rate is negative but never more than 0.9 percent in a single year. Through backward and forward linkages, this growth trend in feedlot livestock has repercussions in other sectors of the High Plains economy. The major forward linkage effect is seen in the rapid growth of meat products manufacturing (sector 16) which increases its output from \$49,242,000 in 1967 to \$471,717,000 in 1995. The major backward linkage is to milling and feeds (sector 19) which increases its output from \$14,774,000 in 1967 to \$115,274,000 in 1995.

Cotton production in the High Plains is in the area south of the Canadian River, the Lower High Plains, where the acre-feet of water pumped per year decreases from the base to the terminal year. Correspondingly, irrigated cotton output decreases from \$24,656,000 in 1967 to \$16,589,000 in 2010. Land taken out of irrigated cotton production is used for dryland cotton production so that output of dryland cotton increases from \$7,098,000 in 1967 to \$16,287,000 in 2010. Yield per acre increases result in the total dollar value of irrigated and dryland cotton combined being larger in 2010 as compared to 1967.

From 1967 through 1995, increasing water pumpage in the Upper

High Plains is greater than the decreases in the Lower High Plains. This results in substantial increases in irrigated food and feed grain production (sectors 2 and 3) and a small increase in other irrigated crop production (sector 4) from 1967 to 1995. In the dryland production of the good grains, feed grains, and other crops sectors there are mixed results in the trends from 1967 to 1995. This is a result of the interplay of the transfer of acreage from irrigated to dryland production in the Lower High Plains, of the transfer from dryland to irrigated production in the Upper High Plains, and of the increases in yield per acre. As a result, dryland food grain output increases by a small amount, dryland feed grain output decreases moderately, and dryland other crop production increases substantially from 1967 to 1995. There are significant increases in the outputs of these three sectors from 1995 to 2010 as land is transferred from irrigated to dryland farming throughout the High Plains and production per acre continues to increase.

In the base projection, petroleum and petroleum-related sectors have decreases in output throughout the time span simulated. From 1967 to 2010, crude oil and natural gas output (sector 12) decreases from \$397,398,000 to \$168,018,000 and natural gas liquid output (sector 13) decreases from \$134,035,000 to \$56,669,000. Chemicals (sector 22), Petroleum Products (sector 23) and Gas Services (sector 30) have decreases in gross output of 22.9, 20.8, and 26.1 percent, respectively, from the base year to the terminal year.

Most other sectors of the High Plains economy follow closely the trend in the agricultural supply output sectors. The most rapid growth is led by the feedlot livestock sector in the 1960's and the 1970's.

In the 1980's and the first half of the 1990's growth continues but at a much slower pace. Then, post-1995, the declines in water pumpage for irrigation result in reductions in crop output which, compounded by decreases in petroleum output, triggers decreases in output of other sectors of the economy through the system of sectoral interrelationships.

### Employment

Trends in employment by sectors are directly affected by trends in the employment-output ratios and by trends in sectoral output. For example, a decrease in employment in a given sector can occur while the sector's output is increasing if the output increases are not commensurate with decreases in the employment-output ratio. Thus, both of these direct factors must be incorporated in an interpretation of labor projections for the High Plains.

In the base projection total employment (Table XVI) increases from 153,295 in 1967 to a peak of 190,904 in 1981. Total employment is relatively stable from 1978 to 1995 and decreases steadily from 1995 to 2010. This is the same trend as discussed previously for population which is to be expected since population has a simple proportionate relation to total employment (Equation 5.51).

Table XVIII presents employment by industry in the High Plains for 1967, 1995 and 2010 base projections. The agricultural production sectors (1-10) maintain a relatively constant percentage of total employment throughout the 44 years simulated, 32.0, 33.0 and 33.1 percent in 1967, 1995 and 2010, respectively. Mining employment (sectors 12 and 13) drops from 2.5 percent to 0.7 percent of total employment from 1967 to 1995 and to 0.5 percent in 2010, a result of both labor productivity

TABLE XVIII  
EMPLOYMENT BY INDUSTRY AND PERCENT OF TOTAL EMPLOYMENT,  
BASE PROJECTION, HIGH PLAINS OF OKLAHOMA AND TEXAS,  
1967, 1995 AND 2010

Industry	Employment			Percent of Total Employment		
	<u>1967</u>	<u>1995</u>	<u>2010</u>	<u>1967</u>	<u>1995</u>	<u>2010</u>
Agriculture <sup>a</sup>	49,112	62,266	50,296	32.0	33.0	33.1
Mining <sup>b</sup>	3,799	1,294	770	2.5	0.7	0.5
Construction <sup>c</sup>	6,578	6,143	4,843	4.3	3.2	3.2
Manufacturing <sup>d</sup>	9,610	12,725	9,494	6.3	6.7	6.2
Transportation & Utilities <sup>e</sup>	6,866	5,481	3,959	4.5	2.9	2.6
Trade <sup>f</sup>	34,215	36,523	27,083	22.3	19.4	17.8
Finance, Insurance & Real Estate <sup>g</sup>	4,226	8,055	7,025	2.7	4.3	4.6
Services <sup>h</sup>	24,240	34,705	29,682	15.8	18.4	19.6
Other <sup>i</sup>	14,649	21,436	18,802	9.6	11.4	12.4
Total	153,295	188,628	151,954	100.0	100.0	100.0

<sup>a</sup>Sectors 1-10

<sup>b</sup>Sectors 12, 13

<sup>c</sup>Sector 15

<sup>d</sup>Sectors 16-27

<sup>e</sup>Sectors 28-32

<sup>f</sup>Sectors 33-38

<sup>g</sup>Sectors 39-40

<sup>h</sup>Sectors 11, 14, 41-42

<sup>i</sup>Households, Government

increases and output decreases. Manufacturing employment increases from 9,610 in 1967 to 12,725 in 1995 but decreases to 9,494 in 2010. From 1967 to 1995, decreases in employment for the chemicals and petroleum products manufacturing sectors are offsetting increases in other manufacturing sectors. After 1995, employment declines in all manufacturing sectors. Decreases in employment throughout the time span simulated occur for the total transportation and utilities industry. This is a result of decreases in output for the gas services sector which includes the operations of natural gas pipelines in the region. Finance, insurance and real estate, services, and government increase their share of total employment throughout the simulated period. This is in large part due to changes in consumption patterns reflected in the consumption function and to relatively smaller decreases in employment-output ratios for these industries.

#### Household Income

Total household income including transfers, in 1967 dollars, increases steadily from \$1,298,467,000 in 1967 to \$2,080,403,000 in 1996, a 60.2 percent increase. Then, total household income including transfers decreases steadily to \$1,872,294,000 in 2010, a decrease of 10.0 percent from 1996. Disposable income per capita increases throughout the time span simulated, as illustrated in Figure 6 and Table XVI. There is an average annual increase in disposable income per capita of 0.9 percent from the 1967 value of \$3,010 to the terminal year value of \$4,511.

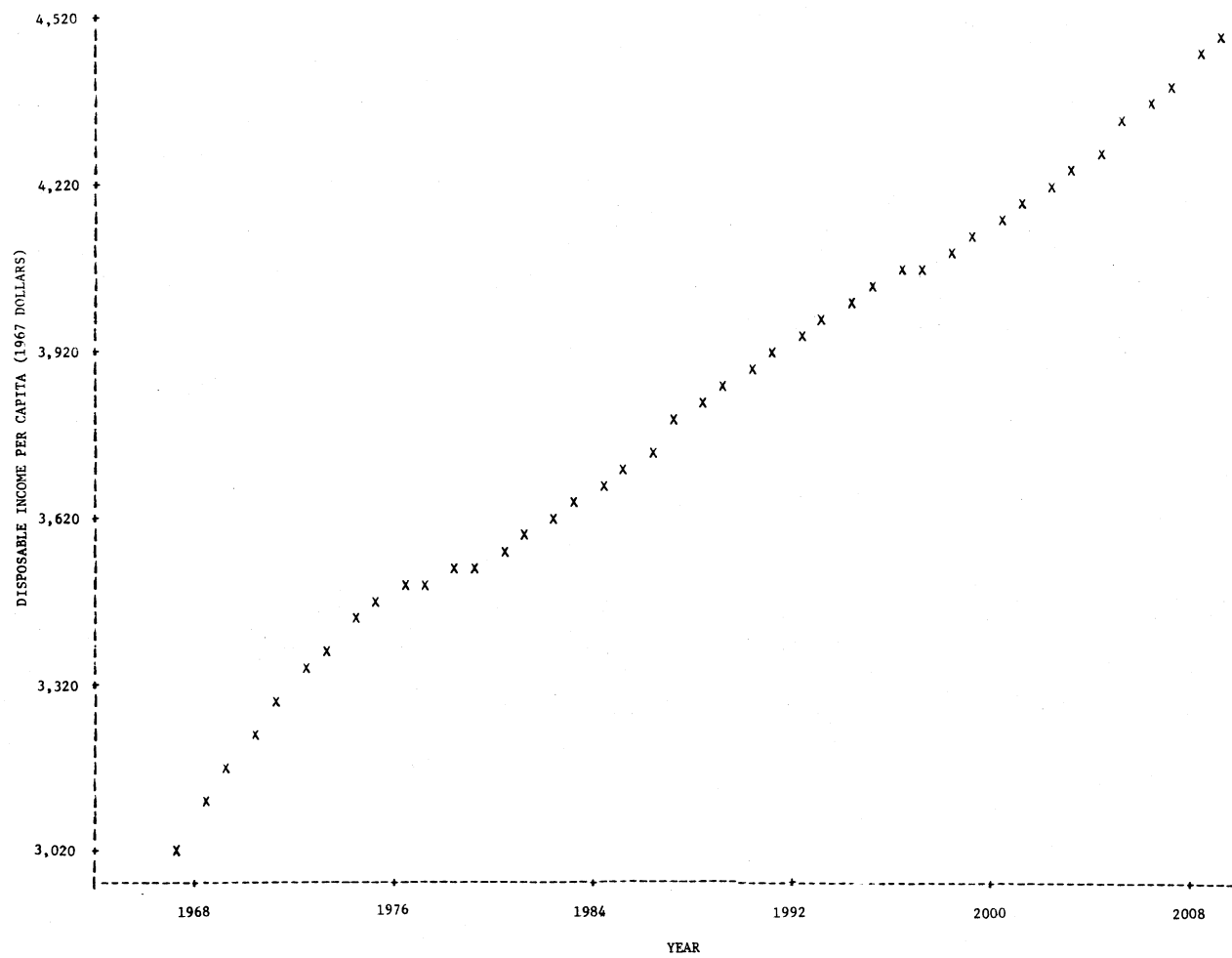


Figure 6. Disposable Income Per Capita, Base Projection, High Plains of Oklahoma and Texas, 1967-2010

### Alternate Groundwater Projection

The next run of the High Plains simulation model differs from the base projection by using crop output projections (sectors 1-8) that are derived from Water Projection I (as discussed in Chapter IV). All other assumptions and input data are the same. Water Projection I has the same Texas Water Development Board projections of annual acre-feet of groundwater pumped for irrigation in the Lower High Plains as Water Projection II. But, in Water Projection I the groundwater pumpage projections for the Upper High Plains are also from the Texas Water Development Board. As illustrated in Figure 4 of Chapter IV the turning point for groundwater pumping in the High Plains is 1990 in Water Projection I whereas it is 1995 in Water Projection II. Also, while the annual pumpage increased at a decreasing rate from 1967 to 1995 in Water Projection II, the most rapid increase in annual pumpage in Water Projection I is from 1980 to 1990 following relatively moderate increases from 1967 to 1980.

### Population

As illustrated in Figure 7, the simulated High Plains population from 1967 to 2010 for the alternate groundwater projection follows the base projection trend closely. Population increases in the first decade of simulation and is relatively stable for the following 15 years. After 1991 there is a steady decrease in population to 2010. Whereas the peak population in the base projection is 443,958 in 1981, the alternate groundwater projection has a peak population of 426,104 occurring in 1991. In 1981, the population from the alternate groundwater

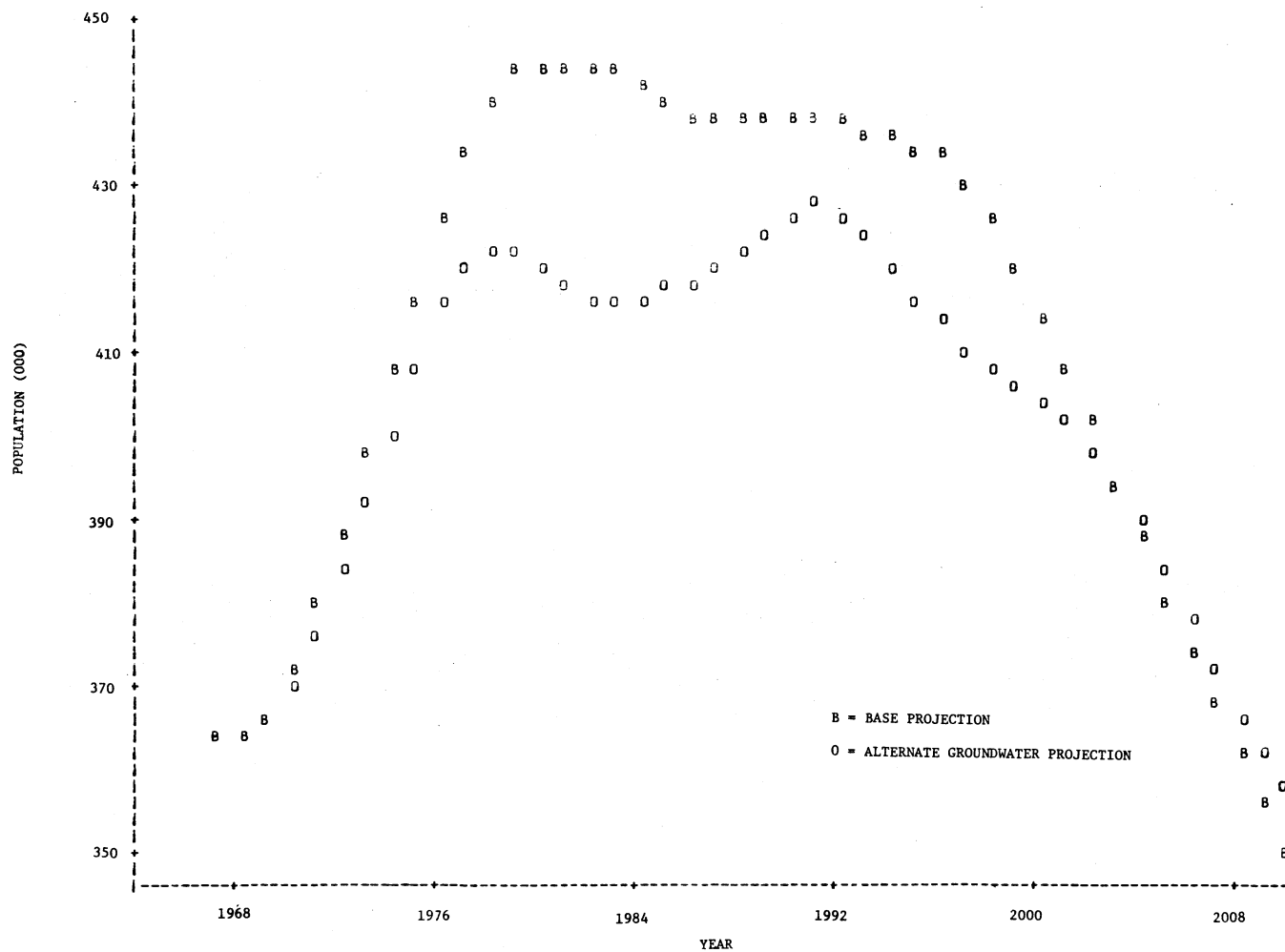


Figure 7. Population, Alternate Groundwater and Base Projections, High Plains of Oklahoma and Texas, 1967-2010

projection is 416,196 which is 27,762 or 6.3 percent less than in the base projection.

The alternate groundwater projection has two points of change from increasing to decreasing population, 1978 and 1991. The 1978 population is at the end of the period of very rapid growth in feedlot livestock production. From 1978 to 1983 population declines from 421,405 to 415,526 before the relatively rapid increase in irrigation from 1980 to 1990, as projected by Water Projection I, causes renewed growth until the peak population occurs in 1991. In the terminal year, 2010, population is 356,500 which is 2.3 percent more than in the base projection.

### Sectoral Output

As discussed above, the major differences in Water Projections I and II are the peak in 1990 for I as compared to the peak in 1995 for II and the rapid increase from 1980 to 1990 for I as compared to increases at decreasing rate from 1967 to 1995 for II. This difference in trends in groundwater pumpage is reflected not only in the outputs of the eight crop producing sectors but also in other sectors through backward and forward linkages. This is most prominent in the forward linkages from feed grains to feedlot livestock to meat products manufacturing. The rate of growth in feedlot livestock output is dampened by feed grain availability much faster in the alternate groundwater projection than in the base projection. Through 1974 the annual rate of growth in feedlot livestock output is the same in both projections but for the alternate groundwater projection decreases to 13.0 percent in 1975 and averages 2.0 percent per year for 1976 through 1980. In the

alternate groundwater projection the growth rate of feedlot livestock output does not become negative until 2002 as compared to 1996 in the base projection. This trend is reflected in the meat products manufacturing and milling and feeds manufacturing sectors.

Other sectors, except for those directly related to crude petroleum and natural gas production, tend to grow rapidly during the early feedlot "boom" and then grow at moderate rates during the 1980's. Though Water Projection I has a decrease in annual groundwater pumpage for irrigation purposes earlier than in Water Projection II, the decreases are more moderate. As a result, the demand output sectors sustain their output at a relatively stable level or with nominal gains in the 1990's and into the first few years of the 21st century. The rate of growth of value added by all processing sectors becomes negative in 1997 in the base projection but remains positive until 2002 in the alternate groundwater projection.

### Employment

Total employment in the alternate groundwater projection follows the same trend as population. From 153,299 in 1967, employment increases to a peak employment of 185,013 in 1990. Employment then decreases to 155,963 in 2010 as a result of output decreases in the crop and petroleum sectors, of nominal growth in the 1990's and early 2000's followed by declines for the output of the demand output sectors, and of decreases in the employment-output ratios.

In Table XIX the employment of selected representative sectors in 1967 and at the end of each decade are presented for the base projection, the alternate groundwater projection, and the alternate petroleum

TABLE XIX

EMPLOYMENT IN SELECTED REPRESENTATIVE SECTORS, BASE PROJECTION,  
ALTERNATE GROUNDWATER PROJECTION, AND ALTERNATE PETROLEUM  
PROJECTION, HIGH PLAINS OF OKLAHOMA AND TEXAS, 1967-2010

Year	Base Projection	Alternate Groundwater Projection	Alternate Petroleum Projection
<u>Sector 3: Irrigated Feed Grains</u>			
1967	15,537	15,537	15,537
1970	16,247	15,695	16,247
1980	18,008	15,693	18,008
1990	18,365	18,397	18,365
2000	16,560	16,205	16,560
2010	12,680	13,337	12,680
<u>Sector 7: Dryland Feed Grains</u>			
1967	2,456	2,456	2,456
1970	2,150	2,329	2,150
1980	1,363	2,066	1,363
1990	1,122	1,111	1,122
2000	1,343	1,364	1,343
<u>Sector 10: Feedlot Livestock</u>			
1967	1,529	1,529	1,529
1970	3,474	3,474	3,474
1980	9,952	9,032	9,952
1990	10,493	9,523	10,493
2000	10,259	10,040	10,259
2010	8,569	8,871	8,569
<u>Sector 12: Crude Oil and Natural Gas</u>			
1967	3,314	3,314	3,314
1970	3,149	3,149	3,149
1980	1,851	1,851	2,372
1990	1,330	1,330	2,115
2000	950	950	1,886
2010	672	672	1,682

TABLE XIX (Continued)

Year	Base Projection	Alternate Groundwater Projection	Alternate Petroleum Projection
<u>Sector 15: Construction</u>			
1967	6,578	6,578	6,578
1970	6,663	6,589	6,875
1980	6,512	6,043	7,128
1990	6,257	6,181	6,988
2000	5,611	5,708	6,431
2010	4,843	5,006	5,721
<u>Sector 26: Machinery Manufacturing</u>			
1967	1,037	1,037	1,037
1970	1,059	1,043	1,078
1980	963	901	1,053
1990	844	838	962
2000	698	704	828
2010	546	565	679
<u>Sector 31: Electric Service</u>			
1967	1,262	1,262	1,262
1970	1,252	1,245	1,260
1980	1,242	1,169	1,304
1990	1,119	1,090	1,209
2000	979	962	1,082
2010	771	793	877
<u>Sector 38: Other Retail</u>			
1967	17,016	17,016	17,016
1970	17,371	17,293	17,430
1980	19,180	18,082	19,930
1990	17,852	17,442	18,989
2000	15,795	15,533	17,092
2010	12,628	12,980	13,979
<u>Sector 42: Other Services</u>			
1967	14,572	14,572	14,572
1970	15,654	15,579	15,724
1980	20,122	18,964	21,034
1990	20,999	20,419	22,535
2000	20,534	20,153	22,482
2010	18,076	18,568	20,329

projection to be discussed in the next section. In each sector, employment-output ratios are decreasing over time so that sector employment would decrease with constant output. Irrigated and dryland feed grains follow the patterns expected from the different water projections. As explained in the preceding subsection on sectoral outputs, feedlot livestock output is dampened sooner in the alternate groundwater projection and this is reflected in the employment trend. Employment in the crude oil and natural gas mining sector is equal in the base and alternate groundwater projection, reflecting the same supply output projections. Construction employment reflects the different timing of output changes that accompanies the two groundwater pumpage projections. The basic trends in machinery manufacturing, electric service, other retail, and other services employment are influenced very little by the different water pumpage assumptions.

#### Household Income

Total household income including transfer payments peaks at \$2,007,519,000 in 2001 for the alternate groundwater projection which is five years later and \$72,884,000 less than in the base projection. In 2010, total household income including transfers is \$1,920,499,000 as compared to \$1,872,294,000 in the base projection. Disposable income per capita rises at the same average annual rate, 0.9 percent, from base to terminal year with both water projections.

#### Alternate Petroleum

##### Output Projection

In the alternate petroleum output projection, crude petroleum and

natural gas production (sector 12) is allowed to increase from 1967 to 1970 when the peak output of \$420,701,200 is achieved. But, whereas the output of sector 12 decreases steadily after 1970 in the base projection (as described in Chapter IV), it is held constant at the 1970 level to 2010 for the alternate petroleum output projection.

Accordingly, for the 1970 to 2010 period, natural gas liquid (sector 13) output is held at its 1970 output level, \$141,894,000. And, the exports of sectors 22, 23 and 30 (chemicals manufacturing, petroleum product manufacturing and gas services, respectively) are held constant through the years simulated. Other specifications of the simulation model are the same as in the base projection.

### Population

Figure 8 displays graphically the simulated High Plains population from 1967 to 2010 for the base projection and the alternate petroleum output projection. The difference in the level of petroleum output does not significantly alter the trend of population growth and results in only small differences in the absolute population level. In the year of peak population in the base projection, 1981, there are an estimated 443,958 persons in the base projection as compared to 459,030 in the alternate petroleum output projection, a difference of 3.4 percent. In the terminal year of simulation, 2010, the estimates are 348,629 and 378,330, respectively, a difference of 8.5 percent. Although the gross dollar output of the mining sector is a significant portion of the High Plains economy, mining development, as presented in Table XVIII, was only 2.5 percent of total employment in 1967. Thus, sharp decreases in mining employment do not have a large impact on total employment and

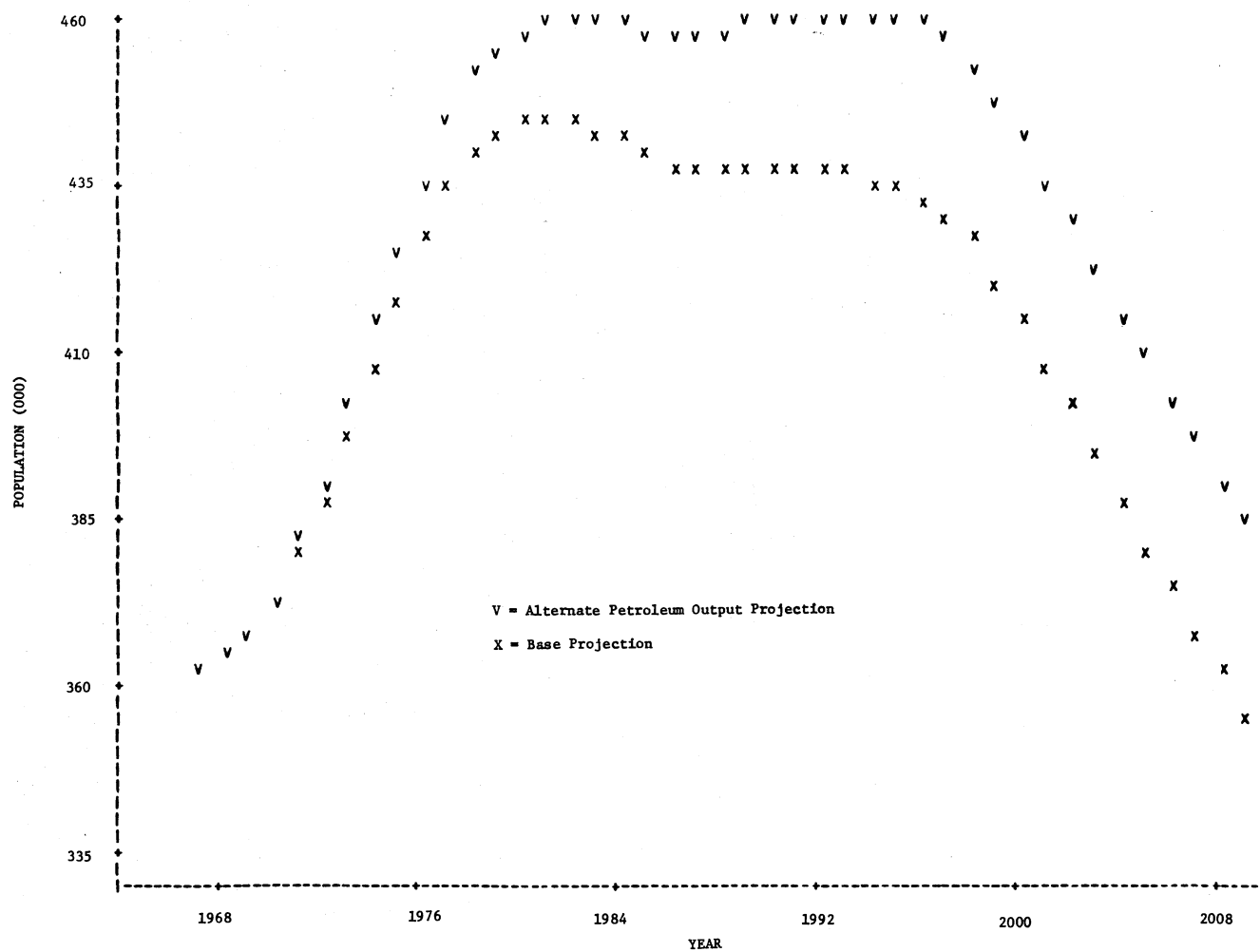


Figure 8. Population, Alternate Petroleum Output and Base Projections, High Plains of Oklahoma and Texas, 1967-2010

population. And, multiplier and accelerator effects of the mining sector are not large enough in the relatively open High Plains economy to generate significant indirect changes in total employment and population.

### Sectoral Output

The constant output from 1970 for the petroleum and directly petroleum related sectors results in a higher level of output than in the base projection for most demand output sectors. The strongest backward linkage effect among processing sectors (as measured by the size of the direct coefficient) is to the oil and gas service sector (sector 14). In the alternate petroleum output projection this sector has a maximum gross output of \$46,965,000 in 1998, 31.7 percent greater than the \$35,664,000 for that year in the base projection.

Machinery manufacturing (sector 26) and construction (sector 15) are relatively sensitive to the alternate petroleum projection due to both current account backward linkages and capital account accelerator effects. Both machinery manufacturing and construction sectors have their maximum output in 1996 in the two projections. For this year construction output is \$248,598,000 in the alternate petroleum output projection and \$216,765,000 in the base projection while machinery output is \$32,645,000 and \$28,137,000, respectively.

### Employment

Table XIX in the previous section shows the trend in employment for selected representative sectors as the petroleum output assumption is changed. Agricultural supply output sectors are not affected by the

alternate assumptions on petroleum output. In the terminal year, 2010, employment in sector 12, crude oil and natural gas, has decreased through productivity changes to 1682 in the alternate petroleum output projection. But, this is more than twice as large as the 672 employees estimated for 2010 in the base projection. Employment in other sectors of the economy, as illustrated for sectors 15, 26, 31, 38 and 42 in Table XIX, is maintained at a higher level for the alternate petroleum output projection.

#### Household Income

Total household income including transfers reaches \$2,261,336,000 in 1997 for the alternate petroleum output projection. This is 8.7 percent more than the peak for the base projection which occurred in 1996. Disposable income per capita increases to \$4,678 in 2010 in the alternate petroleum output projection which is only 3.7 percent more than the respective value for the base projection.

#### Variations in Selected Parameters

The following subsections conclude this chapter with brief reports on the sensitivity of the High Plains simulation model to variations in selected parameters: yield per acre, employment-output ratios, and the feedlot livestock growth adjustment factor. Only those differences from the base projection that are of special significance are reported. Total population is often used as the most comprehensive indicator of these differences.

### Yield Per Acre

In the crop output projections used in the base projection, yield per acre is increased annually as described in Chapter IV. A simulation of the High Plains economy was run with yield per acre held constant at the base year, 1967, levels and with other inputs and parameters the same as in the base projection. The resulting scenario of the High Plains economy is quite different from the base projection. Crop outputs in 1995, the year of the maximum acre-feet of water pumped for irrigation, for each of the eight crop sectors are reported in Table XX for the base projection and for the base projection with constant yield per acre. Significantly smaller outputs occur in all sectors. Figure 9 shows graphically the importance of yield changes as reflected in total population. A peak population of 397,434 is reached in 1976 for the simulation with no changes in yields and population declines steadily from 1976 to 2010. In the base projection the peak population is 443,958 in 1981 and the total population is relatively stable through 1996. Terminal year, 2020, population is 348,629 in the base projection and 236,989 in the projection with no changes in yield per acre.

### Employment-Output Ratios

As explained in Chapter III the employment-output ratios used in this study for the agricultural sectors were derived from the Census of Agriculture and represent the number of workers employed on farms during the year, regardless of the number of days worked. It was also noted in Chapter III that in constant-hour man-years one would expect agricultural employment to be somewhere between the Census of Agriculture and

TABLE XX

GROSS OUTPUT IN CROP OUTPUT SECTORS, BASE PROJECTION  
AND BASE PROJECTION WITH CONSTANT YIELD PER ACRE,  
HIGH PLAINS OF OKLAHOMA AND TEXAS, 1995

Sector		Gross Output in Thousands of 1967 Dollars	
<u>Number</u>	<u>Name</u>	<u>Base Projection</u>	<u>Base Projection With Constant Yield Per Acre</u>
1	Irrig. Cotton	21,772	17,598
2	Irrig. Food Grain	148,653	96,674
3	Irrig. Feed Grain	333,867	212,249
4	Other Irrig. Crop	46,221	33,838
5	Dry Cotton	12,991	11,332
6	Dry Food Grain	24,367	18,582
7	Dry Feed Grain	17,594	12,043
8	Other Dry Crop	9,961	7,414

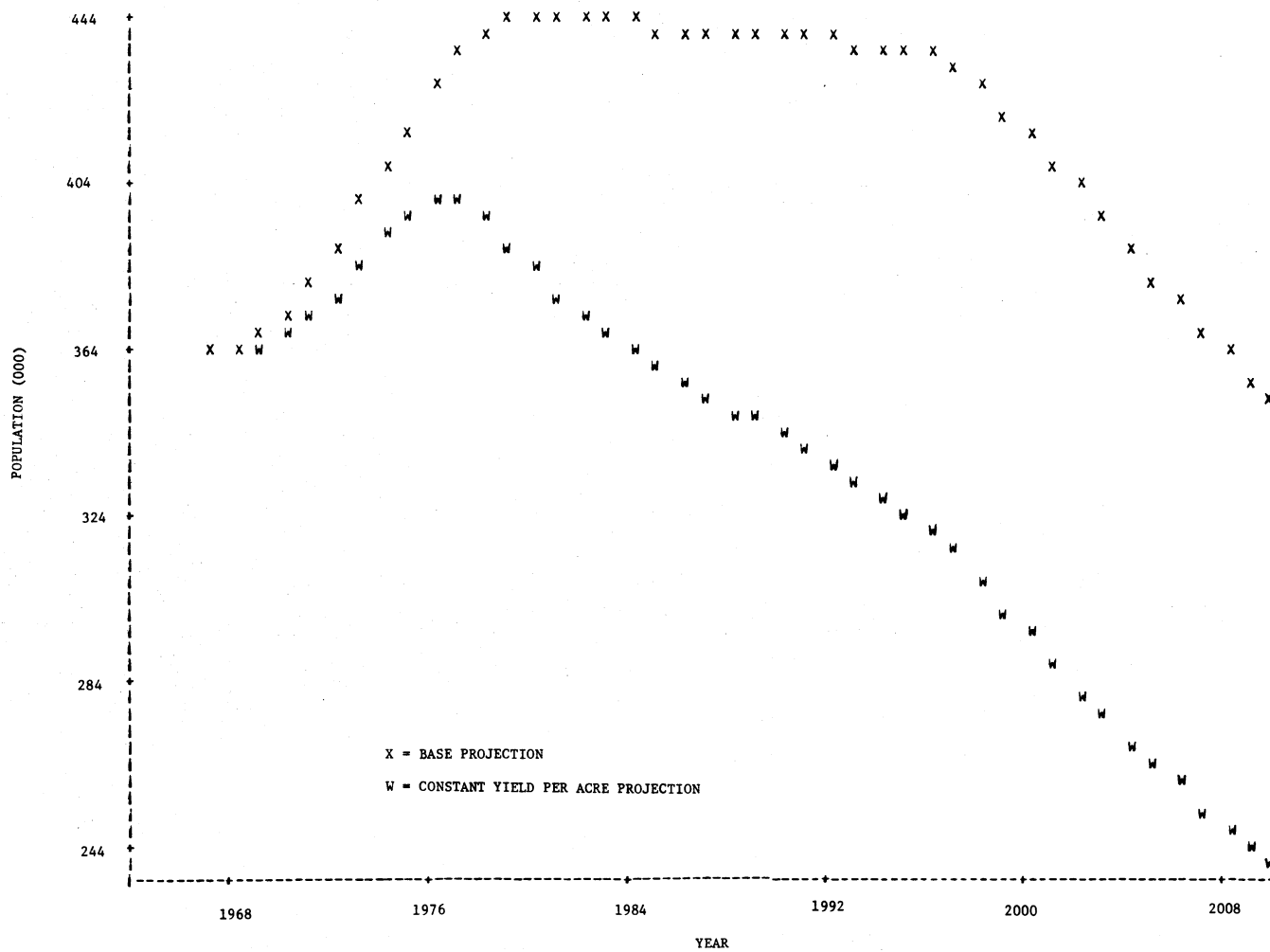


Figure 9. Population, Constant Yield Per Acre and Base Projections, High Plains of Oklahoma and Texas, 1967-2010

Census of Population estimates. While employment figures are significantly different with different employment-output ratios for the agricultural crop sectors, a run was made with lower employment-output ratios than those reported in Chapter III for these sectors to see if trends of other variables in the model are altered. This run used employment-output ratios for the eight agricultural crop sectors that were estimated such that the base run ratios are forty percent larger. Also, the ratio of population to total employment in the base year (variable  $H_t$  for  $t = 1$ ) is adjusted accordingly to give estimated base year population. No significant differences from the base projection in trends of variables were found nor were there significant differences in levels of variables other than agricultural crop employment. For example, population peaked in 1981 in the base projection and in the variation of the base projection at 443,958 and 449,691, respectively.

#### Feedlot Livestock Growth Adjustment Factor

As explained in the section on "Agricultural Livestock Output" in Chapter IV and as specified in Equation 5.39 of Chapter V, the variable  $G_t$ , which is one plus the annual rate of change in feedlot livestock output for the year  $t$ , is arbitrarily set at decreasing maximum levels so that  $G_t$  will adjust to the potential growth rate without an abrupt stoppage of feedlot growth.<sup>2</sup> If the maximum level of  $G_t$  is held at 1.33 for each year and other aspects of the base projection kept the same, the adjusted growth rate for feedlot livestock (sector 10) is the maximum 33 percent per year for the first six years simulated, one

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<sup>2</sup>This procedure also provides considerable computer cost savings for each simulation run.

year more than in the base projection. Then the rate decreases to 16 percent in 1974, 3.2 percent in 1975, an average of approximately 2.7 percent per year from 1976 through 1981, and an average of approximately 1.7 percent per year for 1982 through 1995. After 1995,  $G_t$  is less than one but never less than 0.992. This earlier and more precipitous decrease in the rate of growth of the feedlot livestock sector is reflected in the simulated total population trend. The peak population in this alternate run is 441,515 in 1978 relative to the 443,958 peak in 1981 for the base projection. The trend for the remaining years is approximately the same for this alternate and the base projection with a difference of less than 0.5 of one percent in the terminal year population. Outputs in sectors closely interrelated with the feedlot livestock sector, milling and feeds and meat product manufacturing, follow the feedlot livestock output trend for the different projections. Thus, the arbitrary set of decreasing maximum levels for  $G_t$ , while representing a smoother transition to the potential  $G_t$  and providing considerable savings in computer costs, does not distort the overall impact of this sector in the High Plains economy.

## CHAPTER VII

### PLANNING AND POLICY IMPLICATIONS

In the preceding chapter several scenarios of the economy of the High Plains of Oklahoma and Texas were presented. These projections may be used to serve a number of purposes. Denis F. Johnston has specified six functions of economic-demographic projections (33, p. 6):

1. ". . . anticipatory function - allowing the user to anticipate the probable magnitude or impact of some probable or postulated set of conditions or changes at some future time . . . ."
2. ". . . projections - or the forecast which is selected from among them - are an essential input for planning and program development."
3. ". . . program evaluation.--- to project the course of developments which might be anticipated in the absence of the particular program, so that comparison of this projection with actual post-program outcomes may yield an estimate, however crude, of program impact or 'benefit'."
4. ". . . essential links in a chain of conjecture; each projection includes among its underlying assumptions certain conditions which are derived from a prior projection, and most projections are likely, in turn, to provide inputs to other projections. . . ."
5. ". . . public information function."

6. ". . . exploratory or heuristic function, insofar as they may be developed in order to delineate the probable (or possible) consequences of alternative sets of initial conditions and determining factors."

In this chapter some of the planning and policy implications for regional development and public service provision are investigated. These implications cross the lines of several of the six Johnston functions for projections but are primarily concerned with the second function. The planning and policy discussions are made with primary reference to the base projection. As discussed in the preceding chapter, the alternate groundwater and alternate petroleum output projections result in only minor changes in the trend of aggregate measures of economic activity in the High Plains such as total employment. The base projection of population and employment has increases from 1967 to 1981, relative stability from 1981 to 1996, and a steady decline from 1996 to 2010. The decline is clearly precipitated by decreases in annual groundwater usage for irrigation and is compounded by the declining output of the petroleum sectors.

### Regional Development

The simulation model formulated in this study is a helpful tool for developing and testing alternative policies for regional development. From the insight into the structure of the High Plains economy derived from the economic information system and tests of the sensitivity of the simulation model to various parameters, potential patterns of future development can be discerned. Quantitative dimensions of these patterns can be measured and tested by application of the simulation model.

### Water Policies

A policy for maintenance of population, employment, income and output in the High Plains is the importation of water. The impact of water importation on the High Plains economy can be easily incorporated into the simulation model through changes in the annual water pumpage for irrigation and the consequent effect on the projections of crop output. The alternate groundwater projection reported in Chapter VI illustrates how different hypotheses on irrigation water can be incorporated. For example, investigations could be made using the simulation model to find what levels of water importation would be necessary to maintain the population and employment at the 1981 peak levels. Or, the effect of groundwater management can be simulated in the model.

### Exports of Demand Output Sectors

Rather than pursue water importation possibilities, other alternatives for maintain economic activity in the High Plains are considered in this study. One alternative is the development of exports of industries that do not consume water in the immense quantities required for irrigated crop production. A study of the feasibility of developing the exports of specific sectors of the High Plains economy is currently being made by Jim Osborn at Texas Tech University as a part of the overall project which funded this study. It is expected that simulation runs will be made to measure the impacts of the development alternatives specified in the Osborn study.

To investigate in a general way the question of export development, runs of the simulation model are made for alternative assumptions on the

exports of the demand output sectors, excluding the petroleum processing, chemicals, and gas services sectors which are heavily dependent on petroleum supplies. These runs give quantitative measures of the magnitude of export growth for sectors 11, 14, 15, 17-21, 24-29, and 31-42 that would be required for continued growth in population and employment to 2010. In the base projection exports of these sectors were endogenous, depending on the overall trend of value added by all processing sectors in the High Plains economy. The variable growth rate,  $R_t$ , (Equations 5.23 and 5.24 of Chapter IV) used for the exports of the demand output sectors listed above has a general downward trend from 1973 to 2010 in the base projection. In the base projection  $R_t$  is greater than three percent from 1967 to 1976, greater than two percent in 1977 and 1978, greater than one percent in 1979 and 1980, less than one percent but positive from 1981 through 1997, and negative but less than 1% from 1998 to 2010. Simulation runs assuming  $R_t$  to be constant at three percent and at five percent per annum provide scenarios of the High Plains economy that may exist if policies to develop these sectors are successful. Other assumptions of the base projection are held constant.

Figure 10 shows total population trends for the base projection, three percent export growth, and five percent export growth. With three percent export growth the High Plains population reaches a peak in 1996 at 461,034 as compared to a peak in 1981 of 443,958 in the base projection (1981 population with three percent export growth in 443,341). After 1996 both three percent export growth and basic projections of population show declines but the three percent export projection is not as precipitous. Population in 2010 is 348,629 in the

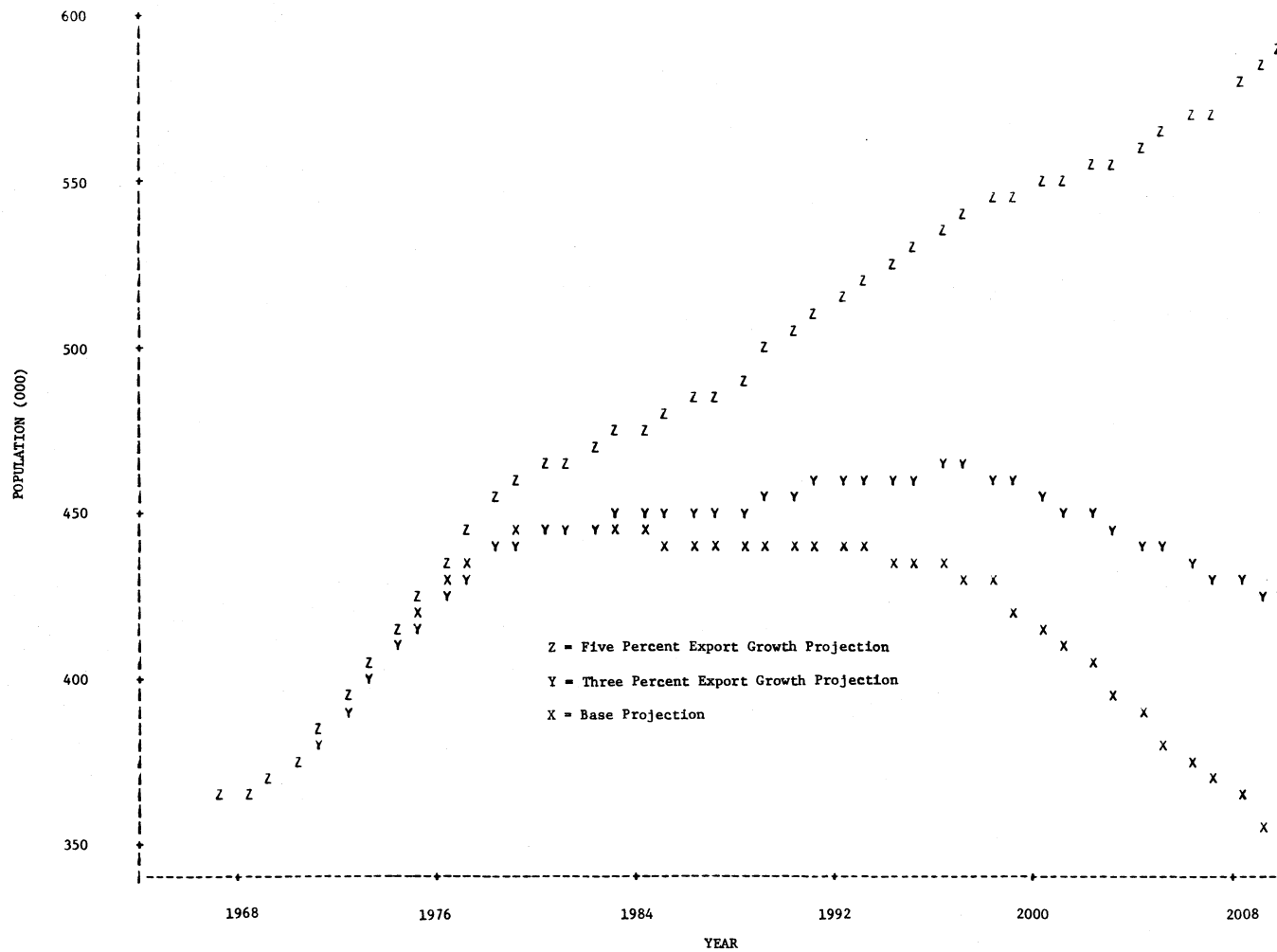


Figure 10. Population, Three Percent Export Growth, Five Percent Export Growth and Base Projections, High Plains of Oklahoma and Texas, 1967-2010

base projection (21.5 percent below the peak) and 422,696 in the three percent export projection (8.3 percent below the peak). The total direct employment to supply exports from the region for the 26 demand output sectors under consideration is 13,264 in 1967, the base year, and represents 8.7 percent of total regional employment. This increases to 15,991 in 1980 in the base projection where the direct employment for these exports is 8.4 percent of total employment and then decreases to 12,519 in 2010 when it represents 8.2 percent of total employment. With the three percent export growth projection total direct employment to supply exports by these 26 sectors reaches a peak of 28,934 in the terminal year 2010 when it represents 15.5 percent of total employment.

When the exports of these 26 demand output sectors are allowed to grow at five percent per annum there is continued growth in population from 1967 to 2010. From a 1967 population of 362,361, population increases to 587,956 in 2010, an average annual rate of about 1.1 percent. With the five percent export growth projection total direct employment to supply exports by these 26 sectors reaches a peak of 66,151 in 2010, about five-fold the base year direct employment, and represents 25.1 percent of total employment in the region in the terminal year. This is an average annual growth rate of about 3.7 percent per annum in direct employment to supply exports for these 26 sectors. Thus, promotion of the development of exports of these 26 sectors can provide an alternative policy for the continued economic health of the High Plains.

#### Agricultural Productivity

Increased expenditures in agricultural research aimed at increasing

the yield per acre are another policy alternative. Yield per acre in the base projection increases at a decreasing rate through the time period under consideration. With other parameters the same as in the base projection, a simulation run was made with crop output projections (sectors 1-8) which result from annual percentage increases in yield per acre of two percent. The two percent rate is not sufficient to provide a stable or growing High Plains population after the decreases in annual groundwater pumpage occur. In 1981, when the peak population of the base projection is reached at 443,958, the simulated population with two percent yield increases is 450,066 which is 1.6 percent larger. In the base projection, population then remains relatively level, decreasing to 432,263 in 1996 before declining at a more rapid pace to 348,629 in 2010. However, in the two percent yields per acre projection, population increases slowly from 1981 to a peak of 465,218 in 1996 and only decreases to 437,244 in 2010.

These simulation runs demonstrate some of the alternative development potentials that can be pursued in policymaking for the High Plains economy. Also demonstrated is the adaptability of the High Plains simulation model for testing the potential of alternate development policies. The simulations of this section have considered one alternative in each run to simplify the analysis but the simulation model can easily incorporate a combination of alternative development potentials. For example, three percent export growth and two percent per annum increases in the yield per acre could be combined in a simulation run.

#### Import Substitution

In Chapter III in the subsection entitled "Changes in Coefficients"

it is suggested that during periods of regional growth locally produced goods may be substituted for imports as "threshold" levels are met. In the base projection the input-output coefficients are held constant over time. Thus, the total requirements matrix,  $A_{13}$ , for determining the output of the 29 demand output sectors in Equation 5.43 is constant. A variation of the base projection to measure the effect of increases in the elements of the total requirements matrix illustrates the importance of import substitution. In this run the elements of the total requirements matrix,  $A_{13}$ , are increased by one percent each year. By 1981, the year of a peak population of 443,958 in the base projection, the total requirements coefficients are 14.9 percent larger than in the base projection and, as a result, total regional population is 517,776 or 16.6 percent larger. By 1996, the year of decline in irrigation water, population is 638,876 in this alternate projection and the total requirements multipliers have increased by thirty-five percent. After 1996, the effect of the one percent per annum increase in the total requirements coefficients is sufficient to overcome the effects of groundwater and petroleum depletion. Population continues to increase but at a slower rate and in 2010 the total population is 678,759 for an average annual increase of 1.4 percent from 1967. This rate of increase in the total requirements coefficients is hypothetical. Whether this import substitution process will occur in the High Plains, and, if so, in what quantitative dimensions is not known.

#### Public Service Provision

In the projections presented there is a level of public service provision determined by the model. For example, in the base projection

total local government expenditures increase from \$31,000,000 in 1967 to \$52,302,000 in 1997 and then decline to \$49,217,000 in 2010. This is an aggregate figure; the mix of public services provided for local, state and federal government sectors is not determined. In addition to these sectors in the final user class, there are some public services in the processing sectors. For example, public educational services and public water and sanitary services are included in sectors 41 and 32, respectively.

In addition to these data on public service provision, projected variables from the simulation model for population, sector outputs, and employment are information that can be used in planning facilities for specific public services such as education, sanitation, transportation, fire and police protection, and recreation. The demand for most of these services is heavily dependent on population, employment, and output levels.

Of major concern to policymakers and planners in the High Plains is the trend that primary public service demand shifters such as population and industrial output will take as the regional economy expands from increased groundwater use in agriculture and then eventually declines as a result of the depletion of groundwater and petroleum reserves. In the base projection the trend for population, the principle determinant of requirements for many public services, does not follow a trend that would result in any major problems for public infrastructure provision. Rather than strong growth to a peak population and heavy public service requirements followed by a sudden and rapid decline in population and the tax base, the base projection indicates that following growth from 1967 to 1981 there is a period of approximately 17 years of relatively

stable population in the High Plains. This trend would indicate that planners and policy makers should be able to provide public facilities with an adequate loan repayment period before the tax base starts to erode in the first decade of the 21st century.

Educational services (sector 41) in the High Plains simulation model include both public and private schools at all levels. Activity in this sector provides an example of the trend and level of provision of a public service in the High Plains from 1967 to 2010 as this sector is dominately public education provision. The dollar output of this sector in the base projection increases from \$84,219,000 in 1967 to \$128,496,000 in 1981, the year of the peak population. There are further increases in output to a peak of \$144,667,000 in 1997 which are followed by a decline to \$131,874,000 in 2010. Projected total investment is greater than zero for each year through 2010. For example, projected total investment for this sector in 2010 is \$4,832,000 although the induced investment component is negative. This indicates that, given the base projection, there will be no problem through 2010 of surplus educational infrastructure in the region although demand for educational services declines after 1997.

While the trends and levels of variables in the simulation model provide general information for estimating public service requirements, detailed and accurate studies of the effect of groundwater and petroleum depletion on public services requires the spatial allocation of changes in population and economic activity within the region. The study area includes subareas north and south of the Canadian River that have different trends in groundwater depletion and consequent differences in the trend of agricultural output. While Amarillo, the regional trade

center, may be expected to follow the regional trends in population and economic activity, quite diverse trends are expected in communities north and south of the Canadian River. Continuing studies at Oklahoma State University and Texas A & M University that are part of the project which includes this study are addressing the public service requirements problem and using the High Plains information system and simulation model as a data base.

## CHAPTER VIII

### SUMMARY AND EVALUATION

In this final chapter the objectives, procedures and results of this study are summarized in the first section. The concluding section is an evaluation of the study.

#### Summary

The economy of the High Plains of Oklahoma and Texas, 25 counties of the northern Texas Panhandle and the three counties of the Oklahoma Panhandle, is heavily dependent on exhaustible resources - groundwater, petroleum and natural gas. This study investigates the long-term structure adjustments of this regional economy as these mined resources are depleted. More specifically, the objective of this study is to develop an economic information system and a dynamic simulation model which determine the impact of declining groundwater and petroleum supplies in the High Plains as measured by sectoral output and employment and regional income, employment and population.

The economic information system developed for the High Plains is problem-oriented. Stocks, flows and their relationships are developed that are useful in the empirical evaluation of the impact of mined resource depletion with a dynamic simulation model. The information system consists of an interindustry transactions matrix, a capital account and a human resources account.

The High Plains interindustry transactions matrix for 1967 has 42 processing sectors, six final payments sectors and seven final demand sectors. This matrix is derived from a primary data matrix for 56 counties of northwest Texas. A matrix developed for the 25 Texas counties of the High Plains by Osborn (57) is extended to include the three Oklahoma counties with estimated border totals and the assumption that direct input coefficients are the same in the adjacent areas. From the transactions matrix direct requirements and total requirements matrices are derived. The transactions matrix is an empirical description of the flow of inputs and outputs in the High Plains economic system during 1967. The direct requirements matrix estimates the initial, direct effect on sectors of the High Plains economy when a given sector expands its output. The total requirements matrix estimates the initial, direct effect on sectors of the High Plains economy when a given sector expands its output. The total requirements matrix estimates the total direct and indirect effect on processing sectors in the High Plains from an increase in the final demand for the output of the processing sectors.

To formulate the analysis of the High Plains economy in a dynamic model a capital account is estimated. This includes estimates of a capital coefficient matrix, capital-output ratios, the capital stock and depreciation coefficients. The capital coefficient matrix is computed from a national capital flow matrix. Each capital coefficient is an estimate of the amount of capital goods purchased from a sector per dollar of capital expenditure for a given sector. The estimated capital-output ratios for each processing sector are average ratios of the net value of plant and equipment to output. These ratios are derived from

Internal Revenue Service data for nonagricultural sectors (102) and from Oklahoma State University budget studies for agricultural sectors (20). The same respective sources are used to derive depreciation coefficients. The depreciation coefficients represent annual depreciation per dollar of depreciable assets.

Estimates of population, employment, employment-output ratios and income-output ratios are included in the human resources account. Population estimates indicate a population of 362,361 persons in 1967 for the High Plains with 40 percent living in the Amarillo SMSA. Given sectoral outputs for the processing sectors of the input-output model, these data can be used to estimate employment and household income in the region.

Projections to 2010 of the annual output of the agricultural crop and range livestock, crude petroleum, natural gas, and natural gas liquids sectors are developed in Chapter IV. The impact on the total High Plains economic system of these projected outputs is measured by the simulation model. Output projections for the eight crop sectors are made from two estimates of the annual acre-feet of groundwater pumped for irrigation purposes. In Water Projection I annual groundwater pumpage for irrigation purposes increases slowly to 1980, increases rapidly from 1980 to 1990, and declines after 1990. In Water Projection II annual groundwater pumpage increases at a decreasing rate from 1967 to 1995 after which there is a decline. An additional variation in the crop output projections arises from assumptions of constant versus increasing yield per acre. Range livestock is projected at an exogenous average annual rate of increase of 3.2 percent from 1967 to 1980 and 1.7 percent from 1980 to 2010. Feedlot livestock output rates

of change are subject to the availability of feed grains produced in the High Plains and are determined within the simulation model.

Projections of petroleum output indicate a declining output in petroleum, natural gas and natural gas liquids from 1970 to 2010.

The High Plains simulation model is a series of difference equations arranged in a recursive sequence to describe the dynamic behavior of the regional economy. The model is in the Maki, et al. lineage of models described in Chapter II. These models are deterministic and are formulated around the input-output system of analysis. But, whereas the other models in this lineage are driven primarily by final demand estimates for each year, the principle driving force in the High Plains model is the supply of mined resources. Operation of the model for a given year involves (1) estimating final demand, (2) determining sector output subject to agricultural and petroleum output projections and with a feedback loop for determining the rate of growth of the feedlot livestock sector, and (3) determining sector and regional output, employment and income and regional population. Then the data generated on output, employment, income and population are utilized in the estimates of final demand in following years.

The High Plains simulation model gives special attention to mechanisms for both expansion and contraction in the regional economy and forward linkages are recognized and built into the projection procedure. Also, the standard solution to the input-output model as presented in Chapter III,

$$X = (I-A)^{-1} Y$$

has been altered to accomodate the separation of the processing sectors of the High Plains economy into two groups. The first group includes

the supply output sectors whose outputs are determined from mined resource supply characteristics considered outside the model. The second group includes the demand output sectors whose outputs are determined by the final demand for their output and by the requirements of the supply output sectors. In accordance with this dichotomy of processing sectors, the disposition of output equation is partitioned into submatrices representing supply output and demand output sectors. Using the subscript "1" for supply output sectors and the subscript "2" for demand output sectors, the equation for disposition of output is written:

$$\begin{bmatrix} X_1 \\ -X_2 \end{bmatrix} = \begin{bmatrix} Q_{11} & Q_{12} \\ -Q_{21} & -Q_{22} \end{bmatrix} \begin{bmatrix} X_1 \\ -X_2 \end{bmatrix} + \begin{bmatrix} Y_1 \\ -Y_2 \end{bmatrix}$$

where the  $Q_{ij}$ 's are partitions of the direct coefficients matrix referred to as "A" above with the i and j row and column indices indicating supply output or demand output sectors. After rewriting this as two equations and solving for the output of the demand output sectors,  $X_2$ , given the exogenous output of the supply output sectors,  $X_1$ , the solution equation for the High Plains model is:

$$X_2 = (I - Q_{22})^{-1} [Q_{21}X_1 + Y_2]$$

In the base projection of the High Plains economy Water Projection II is utilized where the annual acre-feet of water pumped for irrigation increases at a decreasing rate until 1995, after which there is a steady decline to 2010. Increases in yield per acre described in Chapter IV are incorporated into the crop output projections. Other supply output projections are as summarized earlier in this section. In the base projection the total High Plains population increases at an average

annual rate of 1.7 percent from 1967 to 1979 and then has minor increases until a peak population of 443,958 is reached in 1981. This peak population is 22.5 percent greater than the base year 1967, population of 362,361. Then population is relatively stable to 1996 when population is 432,263. After 1996, population declines at an average annual rate of 1.5 percent to the terminal year 2010.

Thus, according to the base projection, while population does decline with the decline in groundwater pumpage, the decline comes after approximately 17 years of relatively stable population while groundwater pumpage is increasing. A number of interacting factors account for this trend. The major factors in the period of population increase are the growth of feedlot livestock production and the backward and forward linkages from this sector. After feedlot livestock production is restricted to the rate of increase in local feed grain output in 1978, population is relatively stable. Continued growth in most sectors of the High Plains economy is counterbalanced by decreases in employment-output ratios and petroleum output. After 1995 decreases in groundwater pumpage are reflected in crop output and, through backward and forward linkages, in other processing sectors. This is compounded by decreases in petroleum and petroleum related sectors and by continued decreases in employment-output ratios so that population declines. Empirical data on sectoral output and employment and regional employment and income are reported in Chapter VI.

Other runs of the High Plains simulation model are made to provide alternate scenarios of the regional economy as exogenous supply output data and selected parameters are changed. In the alternate groundwater projection with Water Projection I, annual growth in groundwater pumpage

increases rapidly from 1980 to 1990 and decreases after 1990. Other assumptions are the same as in the base projection. General trends and levels of population, employment, output and household income do not vary greatly from the base projection. In an alternate petroleum output projection petroleum sector outputs and petroleum related sector exports are held constant at their peak 1970 levels. Whereas employment and output of certain sectors are altered considerably, total population, total employment and household income per capita do not vary significantly from the base projection.

Tests are made of the sensitivity of the High Plains simulation model to variations in yield per acre, employment-output ratios and the feedlot livestock growth adjustment factor. When the model is run with yield per acre held constant at the base year levels and with other parameters and inputs the same as in the base projection, the scenario of the High Plains economy is quite different from the base projection. As a general indicator, population peaks in 1976 and then declines steadily from 1976 to 2010. Simulation runs with different employment-output ratios in the crop output sectors or without arbitrarily set decreasing maximum levels in the feedlot livestock growth adjustment factor do not significantly alter the results for aggregate variables.

Some of the planning and policy implications of the High Plains simulation model are discussed in Chapter VII. The quantitative dimensions of policies to change patterns of future development in the High Plains are measured and tested with the simulation model. The potential for using the simulation model to measure the impact of water importation on the regional economy is obvious from the ability of the model to produce the alternate groundwater projection. Some alternatives to

water importation are investigated that demonstrate the flexibility of the model. Runs are made with the exports of 26 demand output sectors increasing at annual rates of three and five percent, with other assumptions of the base projection the same. With a three percent increase in exports of demand output sectors the High Plains population peaks at 461,034 in 1996 and then declines to 422,696 in 2010. With the five percent increases population peaks at 587,956 in 2010 and direct employment used to supply the exports of the 26 demand output sectors has an average annual growth rate of 3.7 percent from 1967 to 2010.

Whereas yield per acre in the base projection increases at a decreasing rate over the time period studied, a simulation is run to see the effect of a constant two percent per annum increase in yield per acre that might occur as a result of increased agricultural research expenditure for the High Plains. As a result, population peaks at 465,218 in 1996 and then declines slowly to 437,244 in 2010.

The possibility of regional growth from import substitution and the consequent effects on input-output coefficients is simulated by increasing the total requirements coefficients by a hypothetical one percent per year. This has considerable impact on growth in the region as the population grows to 517,776 in 1996, the year of decline in irrigation water. In 1996, the regional total requirements coefficients are 35 percent larger than in the base projection. After 1996, the increases in the total requirement coefficients overcomes the forces resulting in population decrease and population continues to increase to 678,759 in 2010 for an average annual increase of 1.4 percent from 1967 to 2010.

The potential for using the primary public service demand shifters

projected by the model, such as population and industrial output, in planning for public service provision in the region is also discussed in Chapter VII. The base projection of population indicates that planners should be able to provide public service facilities to the peak population in the High Plains with an adequate period for loan repayment before the tax base starts to erode in the first decade of the 21st century. Analysis of the projected capital requirements for educational services indicates there will not be a problem of surplus educational facilities in the High Plains through 2010 although demand for educational services declines after 1997.

### Evaluation

The high-speed digital computer has allowed regional economists to develop large-scale models which are designed to simulate complex economic systems. These models are experimental tools that are used to acquire a basic understanding of regional economies and to evaluate the reaction of regional economies to a wide range of stimuli. These advances are not achieved without costs. Large-scale models of the economy are very demanding in their informational requirements for input data and behavioral parameters. However, these information problems can provide guidance to regional analysts in determining the data needs and behavioral relationships that have the greatest importance for decision-making by regional planners and policymakers. In their observations on the use of large-scale simulation models for regional economic analysis Kain and Meyer state (35, p. 179):

Indeed, the development of such models is almost a necessary prerequisite to better specifying data requirements and information systems for public investment evaluations. The

alternative, incidentally, of only asking the questions that can be answered directly by the available data often smacks of weak rationalization for avoiding the important or relevant questions.

The general lack of appropriate data is a major constraint for the High Plains information system and simulation model. The High Plains input-output model is good relative to secondary data regional models based on national coefficients. However, the input-output model would be more useful as an analytical tool if import and technical coefficients were separated for each sector so that analyses and projections of import substitution and technical coefficient changes could be incorporated. The use of fixed input coefficients over a 44 year projection period is one of the most serious limitations of this study. Of less importance, greater detail on the exports of the processing sectors in terms of geographic and industrial destination would promote a stronger analysis of export trade over the projection period.

In the capital account there are major data problems. Regional rather than national sources and marginal rather than average capital-output ratios are needed. In the human resources account a major improvement would be the standardization of the employment unit in man-years for the employment-output ratios. This is especially true in the High Plains with its large agricultural sector. Joint estimation of the capital-output and labor-output ratios through a production function might provide a means for developing better projections of changes in these ratios that account for their interdependence.

In the agricultural crop output estimates the total acres available for crop production is held constant and is apportioned to different crops on the basis of the base year usages. It is possible that the

total cropland will vary significantly during periods of increasing irrigation and of declining irrigation. The petroleum output projections do not account for the dramatic changes in the petroleum industry of the past few years. More thorough investigations of the petroleum sectors of the High Plains would be dependent on the release of proprietary information.

All of the behavioral relationships specified for the final demand sectors and parameters specified for these relationships need further development for the type of model developed in this study for the High Plains. This applies to the simple accelerator model where the lag structure and the importance of other variables such as expectations are not investigated and to the consumption function where income elasticities estimated at the national level are used for the High Plains. The assumption of exports of the region being tied to the lagged rate of growth of value added in all processing sectors is an oversimplification of the relation of the regional economy to the rest of the world. A naive demographic model is used in the simulation model. Age structure details and behavioral equations on migration to and from the High Plains would strengthen this portion of the model. For application to public service planning it would strengthen the usefulness of the model considerably if the population was spatially allocated within the region.

These many limitations are generally expected in large-scale models of complex economic systems. These models and data for them are still in an early stage of development. However, the performance of the High Plains simulation model appears reasonable and the most important adjustment effects are captured. Alternate projections and sensitivity tests

indicate that improvements in much of the data and in many of the behavioral relationships indicated above would not significantly effect the basic projected trend for the High Plains in terms of total population and total employment. The model does incorporate both supply and demand aspects of regional growth, is dynamic, and is easily adaptable to changes in assumptions and to improvements in the information base.

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APPENDIX A

ESTIMATED GROSS OUTPUTS FOR  
OKLAHOMA PANHANDLE

## APPENDIX A

### ESTIMATED GROSS OUTPUTS FOR OKLAHOMA PANHANDLE

As explained in Chapter III, estimates of gross output by sector for the three counties of the Oklahoma Panhandle, Beaver, Cimarron and Texas, are needed for expansion of the 25 county model developed by Osborn (57) into the High Plains Interindustry Transaction Matrix. These estimates are presented in Table XXI of this appendix. These estimates represent dollar flows in producers' prices for the year 1967 as measured in 1967 dollars. Sources of data for these estimates are described in the remainder of this appendix. The sectors are defined in terms of their component SIC classifications in Appendix B.

#### Processing Sectors

##### Sectors 1-11: Agriculture

The dollar value of agricultural crop outputs in 1967 for combined irrigated and dryland production is from the Oklahoma Crop and Livestock Reporting Service (52). Allocation of these dollar values to irrigated and dryland production is made on the basis of weights estimated from the physical outputs of specific crops in dryland and irrigated production. The physical outputs are calculated from irrigated and dryland acreage estimates interpolated for 1967 from data in the Census of Agriculture for 1964 and 1969 (80, 81) and estimated yield per acre for

TABLE XXI

GROSS OUTPUT ESTIMATES FOR OKLAHOMA  
PANHANDLE IN 1967

Sector Number	Gross Output	Sector Number	Gross Output
	<u>Thousands of 1967 Dollars</u>		<u>Thousands of 1967 Dollars</u>
1	0.0	22	10,815.0
2	5,004.4	23	0.0
3	17,074.3	24	0.0
4	0.0	25	300.3
5	0.0	26	2,621.9
6	6,946.0	27	0.0
7	7,026.8	28	4,751.0
8	0.0	29	2,080.0
9	10,743.0	30	6,542.0
10	35,072.0	31	2,835.0
11	2,512.1	32	515.0
12	101,100.0	33	3,033.0
13	38,100.0	34	1,730.0
14	4,100.0	35	5,079.0
15	13,718.8	36	245.0
16	4,107.7	37	1,188.7
17	0.0	38	9,921.7
18	0.0	39	1,302.0
19	701.0	40	2,038.0
20	109.0	41	5,331.0
21	772.9	42	7,305.0

irrigated and dryland production from the Oklahoma State University Experiment Station (26). The dollar value of government payments to farmers is from the U. S. Office of Economic Opportunity (103). Dollar output estimates for livestock (sectors 9 and 10) were specially prepared by the Oklahoma Crop and Livestock Reporting Service (12). Agricultural services (sector 11) are estimated by interpolation of the value of machine hire and customwork purchased by farmers as reported in the Census of Agriculture for 1964 and 1969 (80, 81).

#### Sectors 12-14: Mining

The gross dollar outputs of the mining sectors are developed from county data in the 1967 Census of Mineral Industries (90).

#### Sector 15: Construction

Construction output is estimated on the basis of 1967 construction employment in the Oklahoma Panhandle (77) and 1967 output per employee in the Texas High Plains (58).

#### Sectors 16-27: Manufacturing

Gross output for the manufacturing sectors in the Oklahoma Panhandle is estimated by disaggregating the total dollar value of shipments by manufacturing firms as reported in the 1967 Census of Manufactures (89). Disaggregation is accomplished by construction of weights based on the dollar value of output of each sector as estimated by multiplying the dollar output per employee in each sector for the state of Oklahoma (89) by the estimated employment in each sector (54, 98).

### Sectors 28-32: Utilities

Output of the utilities sectors is estimated from 1967 output per employee in the Texas High Plains (58) and employment in the Oklahoma Panhandle (98).

### Sectors 33-38: Trade

Output in the trade sectors is estimated with trade margins for the Texas High Plains (59) applied to sales data in the 1967 Census of Business (85, 87). Disaggregation is by employment from County Business Patterns (98).

### Sectors 39-40: Finance, Insurance and Real Estate

Data for 1963 output in sectors 39 and 40 from a study of the Oklahoma Panhandle (68) were adjusted to 1967 prices by the Consumer Price Index (76) and to the increase in employment in these sectors from 1963-1967 (98).

### Sectors 41-42: Services

Expenditures for public educational services in the Oklahoma Panhandle were obtained from the 1967 Census of Governments (88) and the Oklahoma State Regents for Higher Education (55). Private education expenditures were estimated from private education employment interpolated for 1967 from the Census of Population for 1960 and 1970 (92, 93). The Census of Business (86) and Census of Governments (88) provided information for the estimated total output of sector 42.

## Final Demand Sectors

### Households

Total income of households in the Oklahoma Panhandle is estimated from the "Regional Economic Information System" of the U. S. Bureau of Economic Analysis (77).

### Local, State and Federal Government

Total expenditures in the Oklahoma Panhandle of local and state government is estimated from the 1967 Census of Governments (88). Federal government expenditures in the three counties in 1967 is from the U. S. Office of Economic Opportunity (103).

### Sales to Capital Formation and Net Inventory Change

These data are developed by assuming the proportions of sales to capital formation and of net inventory change relative to gross outputs for the processing sectors are the same in the 25 county Texas area and in the Oklahoma Panhandle (57).

### Exports

Exports are determined as a residual in the process of incorporating the three Oklahoma counties into the 25 county Texas input-output matrix (57).

APPENDIX B

SECTORS OF HIGH PLAINS

INTERINDUSTRY MATRIX

TABLE XXII  
SECTORS OF HIGH PLAINS INTERINDUSTRY TRANSACTIONS MATRIX

High Plains Sector Number	High Plains Sector Name	Standard Industrial Classification Components
1	Irrigated Cotton	Irrigated part of 0112
2	Irrigated Food Grains	Irrigated food grain part of 0113
3	Irrigated Feed Grains	Irrigated feed grain part of 0113
4	Other Irrigated Crops	Irrigated parts of 0119, 0122 and 0123
5	Dryland Cotton	Dryland part of 0112
6	Dryland Food Grains	Dryland food grain part of 0113
7	Dryland Feed Grains	Dryland feed grain part of 0113
8	Other Dryland Crops	Dryland parts of 0119, 0122 and 0123
9	Range Livestock	0132, 0134, parts of 0135, 0136 and 0139
10	Feedlot Livestock	Parts of 0135, 0136 and 0139
11	Agricultural Services	0712 - 0731
12	Crude Oil & Natural Gas	1311
13	Natural Gas Liquids	1321
14	Oil & Gas Services	1011 - 1099, 1381 - 1389, 1411 - 1499

TABLE XXII (Continued)

High Plains Sector Number	High Plains Sector Name	Standard Industrial Classification Components
15	Construction	1511, 1611, 1621 and special trade contractors
16	Meat Products	2011 - 2015
17	Food Processing	2021 - 2037, 2051 - 2073, 2091 - 2099
18	Textile Products	2211 - 2399
19	Milling & Feeds	2041 - 2046
20	Beverages	2082 - 2087
21	Wood & Paper & Printing Products	2411 - 2794
22	Chemicals	2812 - 2899
23	Petroleum Products	2911 - 3231
24	Soil and Rock Products	3251 - 3299
25	Metal Products	3312 - 3499
26	Machinery	3511 - 3599
27	Other Manufacturing	3611 - 3999
28	Transportation	4011 - 4214, 4222 - 4721, 4742 - 4789
29	Communication	4811 - 4899
30	Gas Service	4922 - 4925, part of 4931 - 4939
31	Electric Service	4911, part of 4931 - 4939
32	Water & Sanitary Service	4941 - 4953

TABLE XXII (Continued)

High Plains Sector Number	High Plains Sector Name	Standard Industrial Classification Components
33	Wholesale Agriculture Products	4221, 4731, 5052 - 5059
34	Wholesale Petroleum Products	5092
35	Other Wholesale Trade	5012 - 5049, 5063 - 5091, 5093 - 5099
36	Agricultural Supplies	5962, 5969
37	Gasoline Service Stations	5541
38	Other Retail Trade	5211 - 5531, 5591 - 5953, 5971 - 5999
39	Finance	6011 - 6161
40	Insurance & Real Estate	6211 - 6799
41	Education Services	8211 - 8299
42	Other Services	7011 - 8111, 8411 - 8999

APPENDIX C

PARAMETERS FOR ESTIMATION OF CROP  
OUTPUT BY SECTOR

## APPENDIX C

### PARAMETERS FOR ESTIMATION OF CROP OUTPUT BY SECTOR

For the Texas subregions of the High Plains the parameters for estimating crop output by sector are from projections by Osborn (57). For the Oklahoma Panhandle the base year, 1967, total water pumped for irrigation is estimated at 397,231 acre-feet by the Oklahoma Water Resources Board (56). Other data from the OWRB are the ratio of water pumped for irrigation by sector to total water pumped for irrigation and the water requirements in acre-feet per acre by sector. Total acres planted by crop are from the U. S. Department of Agriculture (75). Revenue per acre by crop sector is estimated from the 1967 acreages and input-output model gross dollar outputs. These data are presented in Table XXIII of this appendix.

TABLE XXIII  
PARAMETERS FOR ESTIMATION OF CROP OUTPUT BY SECTOR

	Texas Lower 2A	Texas Upper 2A	Oklahoma Panhandle
<u>Sector</u>	<u>Ratio of Water Pumped for Irrigation To Total Water Pumped for Irrigation</u>		
1	0.053920	-	-
2	0.275457	0.407178	0.246587
3	0.467481	0.576285	0.753413
4	0.203142	0.016537	-
Total	1.000000	1.000000	1.000000
<u>Sector</u>	<u>Water Requirements in Acre-Feet Per Acre</u>		
1	0.561472	-	-
2	0.811215	1.302800	1.224500
3	1.060870	1.762600	1.790700
4	1.547643	1.900670	-
<u>Sectors</u>	<u>Total Acres Planted</u>		
1, 5	206,675	-	-
2, 6	1,209,265	1,762,062	794,358
3, 7	819,957	872,179	343,629
4, 8	232,444	72,888	-
<u>Sector</u>	<u>Revenue Per Acre in 1967 Dollars</u>		
1	176.56	-	-
2	69.43	63.35	64.94
3	141.18	110.47	106.04
4	223.79	122.59	-
5	105.90	-	-
6	8.55	8.08	9.68
7	31.08	27.35	38.48
8	52.29	52.29	-

APPENDIX D

MATRICES AND SCALARS NOT PRESENTED  
IN HIGH PLAINS ECONOMIC  
INFORMATION SYSTEM

TABLE XXIV  
 DIAGONAL ELEMENTS OF MATRICES  $A_5$  AND  $A_6$   
 OF HIGH PLAINS SIMULATION MODEL

Sector	Diagonal Elements of $A_5^a$	Diagonal Elements of $A_6^b$
1	0	0
2	0	0
3	0	0
4	0	0.64431
5	0	0
6	0	0
7	0	0
8	0	0.64431
9	0	0.25744
10	0	0
11	0	1.02590
12	0	0
13	0	0
14	0	0
15	1.00000	1.00000
16	0	0.61959
17	0	0.61959
18	0	0.68034
19	0	0
20	0	0.61959
21	0	0.86603
22	0	0
23	1.00000	0.58585
24	0	0.73688
25	0.48295	0
26	0.27519	0.91949
27	0.05942	0

TABLE XXIV (Continued)

Sector	Diagonal Elements of $A_5^a$	Diagonal Elements of $A_6^b$
28	0.13400	0.97352
29	0.13400	1.77590
30	0	1.08628
31	0	1.08628
32	0	1.08628
33	0.13400	0
34	0	0.87403
35	0.13400	0.87403
36	0	0
37	0	0.87403
38	0.13400	0.87403
39	0	1.34606
40	0	1.34606
41	0	1.31660
42	0	1.17125

<sup>a</sup>Source: Estimated using Equations 5.4 - 5.8 of simulation model with estimated changes in output for 1965 to 1966 and data from the base year, 1967, input-output transactions matrix final demand column on regional sales to capital formation in the region.

<sup>b</sup>Source: Walter E. Mullendore and Arthur L. Ekholm, Projections of Final Demand for Texas, Office of Information Services, Office of the Governor, State of Texas, August, 1972, Table 7.

TABLE XXV  
SCALARS OF HIGH PLAINS SIMULATION MODEL

Scalar	Source
$a_1 = 0.472$	Adopted from weights specified by Milton Friedman (25, p. 147) by truncating the declining weights at three years and increasing them proportionately to sum to one.
$a_2 = 0.316$	
$a_3 = 0.212$	
$a_4 = 1.000$	Estimated by Richard F. Muth in (49, p. 71).
$a_5 = 0.342$	Calculated as ratio of consumption expenditures for goods & services produced in the region to total household income in 1967 from High Plains input-output transactions matrix plus ( $a_6$ ) and minus ( $a_5$ ) five percent.
$a_6 = 0.378$	
$a_7 = 0.984$	Calculated as one plus the average annual rate of growth (negative) in crude petroleum and natural gas production in High Plains from supply output projections.
$a_8 = 0.984$	
$a_9 = 0.984$	
$a_{10} = 0.006529$	Estimated from High Plains input-output transaction matrix for 1967.
$a_{11} = 0.037696$	
$a_{12} = 0.003354$	
$a_{13} = 1.031$	Estimated as one plus the average annual growth rate for government non-defense national expenditures per capita in constant dollars from 1950 to 1970 from data in (76).
$a_{14} = 0.225455$	Estimated from High Plains input-output transactions matrix for 1967.
$a_{15} = 0.002$	Arbitrarily established from investigation of initial trial computer runs.

TABLE XXV (Continued)

Scalar	Source
$a_{16} = 0.9538$	Estimated as one plus the average annual rate of growth (negative) in direct employment by households in the High Plains from 1960 to 1970 as reported in the <u>Census of Population</u> for these respective years (92, 93).
$a_{17} = 0.1130$	Estimated from employment data on state and local government employment in (88) and federal government employment in (97) and purchases data in High Plains input-output transactions matrix for 1967.
$a_{18} = 0.1154$	
$a_{19} = 0.0067$	
$a_{20} = 0.999$	Estimated from U. S. Department of Labor, Bureau of Labor Statistics projected average annual rate of change in labor force participation rate for the total U. S. to 1980 (101, p. 41).
$a_{21} = 4.053$	Estimated as payments to household income by households in High Plains input-output transactions matrix for 1967 divided by the number employed by households in 1967 which is estimated by interpolation from the <u>Census of Population</u> for 1960 and 1970 (92, 93).
$a_{22} = 0.226598$	Estimated as the direct coefficient for household payments from the respective government final demand sectors.
$a_{23} = 0.231016$	
$a_{24} = 0.066830$	
$a_{25} = 0.451050$	Estimated from High Plains input-output transactions matrix and estimated 1967 High Plains population as reported in Chapter III.
$a_{26} = 0.279735$	
$a_{27} = 0.839987$	Estimated from High Plains input-output transactions matrix.

## VITA

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