

Adjustments Due to a Declining Groundwater Supply: High Plains of Oklahoma and Texas

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Preface

The following report is the result of an intensive study of expected regional impacts on the economy of the High Plains of Oklahoma and Texas due to natural resource mining, particularly that of ground water. Hopefully, from reading this report, the reader will gain a better understanding of the High Plains region and its dependence on natural resources, of regional economic systems, and of the processes of adjustments to substantial and sustained changes in regional environments.

There are important limitations of this study. Most have been flagged in the report. Modeling of the agricultural-irrigation subsector drew on past studies and were of the pre-energy price increase era. Nevertheless, the regional simulation model has subsequently been used and has been most helpful in determining the regional impact of alternative energy related policies.

Readers interested only in results and implications may skip Sections II and III. These Sections are important, however, if the reader wants to gain a perspective of regional systems and how they integrate with the adjustment processes.

This study was made possible through funding of the Oklahoma and Texas Water Resources Institutes and the Oklahoma Agricultural Experiment Station. Much was gained from working jointly with Agricultural Economists at Texas A & M University and Texas Technological University including James Osborn, Ronald Lacewell, Lonnie Jones and James Casey. Valuable review comments were received from Gerald Lage, Odell Walker and Evan Drummond.

ADJUSTMENTS DUE TO A DECLINING GROUND- WATER SUPPLY: HIGH PLAINS OF OKLAHOMA AND TEXAS

**Arthur L. Ekholm, Dean F. Schreiner,
Vernon R. Eidman and Gerald A. Doeksen***

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)¹, 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 (53, 55). This represented a decrease of 4.4 percent from the 1960 population

* Arthur L. Ekholm is assistant professor of economics at Northern Arizona University, Dean F. Schreiner is professor of agricultural economics at Oklahoma State University, Vernon R. Eidman is professor of agricultural economics at the University of Minnesota, and Gerald A. Doeksen is an economist for the U.S. Department of Agriculture.

Reports of Oklahoma Agricultural Experiment Station serve people of all ages, socio-economic levels, race, color, sex, religion and national origin.

¹In general, a SMSA is a county or group of counties which contains at least one city of 50,000 inhabitants or more.

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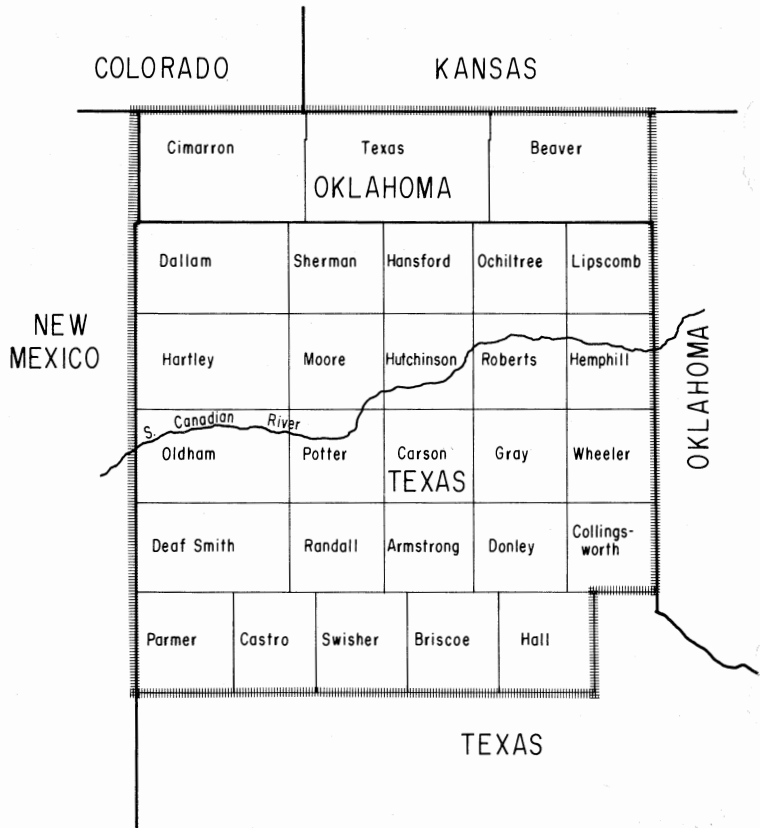


Figure 1. High Plains of Oklahoma and Texas

(52, 54). Forty percent of the region's population was located in the Amarillo SMSA in both 1960 and 1970. The study area delineation was based on the location of water formations, trade areas within a political boundary constraint, and the sources of funding for the project of which this study is a part.

Agricultural production of wheat, grain sorghum, and cattle and 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 (2). 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 (4). 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 (46, 47, 48, 49, 50, 51). 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 indicate this decline will continue (4, 59). 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.

Objective

The objective of this study is to 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 projected agricultural and petroleum output. The simulation model will describe the long-run structural adjustments to the year 2010 in terms of sector output and employment and regional income, employment and population.

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 (37, 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 (37, pp. 157-194 and 15, pp. 54-87). Both comparative static and dynamic models are represented in the recent literature. In a study of the West Virginia economy, Miernyk (26) 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 (38, 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.

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 (18, 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 markets. In its traditional form, as specified by Romanoff (39, pp. 121-122).

$$X_T = X_N + X_B \quad (1)$$

where subscripts T, N, and B represent total, non-basic, and basic industries, respectively, and the X_i represent respective aggregate

outputs. By assumption, $X_N = A X_I$ so that

$$X_T = A X_T + X_B \quad (2)$$

and the reduced form solution is

$$X_T = (1-A)^{-1} X_B. \quad (3)$$

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", $(1-A)^{-1}$ where A is the regional marginal propensity to spend. 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 (18). An explicit incorporation of the region's supply of inputs for the production process is needed. As stated by Pratt (35, 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 (42), Romans (40), and Borts and Stein (6). These models extend the closed economy, neoclassical models to the open regional economy.

A regional neoclassical model, as presented by Richardson (38, p. 26) is as follows:

$$y_i = a_i k_i + (1-a_i)1_i + t_i \quad (4)$$

$$k_i = s_i/v_i + \sum_j k_{ji} \quad (5)$$

$$1_i = n_i + \sum_j m_{ji} \quad (6)$$

$$k_{ji} = f(R_i - R_j) \quad (7)$$

$$m_{ji} = f(W_i - W_j) \quad (8)$$

where y , k , l , and t are growth rates in output, capital, labor 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 (4) is the standard growth equation for output in which the influence of the supply of inputs on the growth rate is explicit. Equations (5) and (6) are definitional, stating that the growth of factor inputs is composed of two elements: local inputs and net imported inputs (equation (6) assumes a constant labor force participation rate). In equations (7) and (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 (5, 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. (15) 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. (15, 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 (21) 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: (21, p. 49):

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.

The impact of groundwater and petroleum depletion on the economy of the Texas Panhandle is being investigated by James Osborn (32) 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 (28) 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 (24), Mullendore (27), MacMillian (23), Doeksen (10), Byerlee and Halter (7), and Holloway (17) 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 Overview²

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. The rate of production of 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 and in

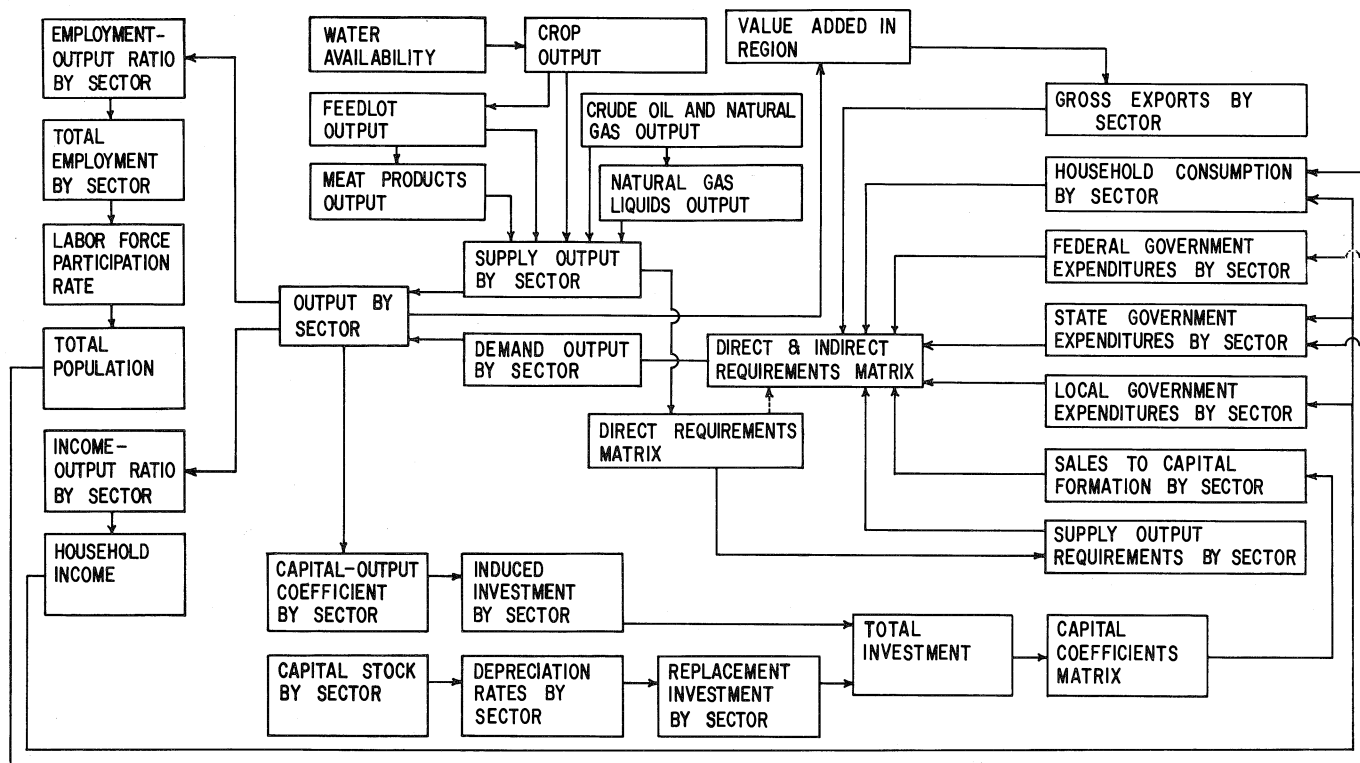
²A complete listing of equations, variables, matrices and parameters of the High Plains simulation model is included in the appendix.

Osborn's work on the Texas Panhandle. 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 (32) 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. Osborn's methodologies for translating annual groundwater pumpage into agricultural output by sector and for forward linkage mechanisms are 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 (37 , 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.

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 (16). Though regional accounts may be an element of the system, the regional information system is a more specific, 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 section 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 (34).

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 (22) 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 (13, 25). 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 (3, 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 (3, 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 Methodology³

The input-output model is generally presented in three parts: a transactions matrix, a direct coefficient matrix, and a total requirement or direct and indirect coefficients matrix.³ 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).⁴ 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 interrelationships of intermediate (processing) sectors. In an income and product accounting system, these intermediate flows are netted out because they represent "double-counting" of the final product.

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

³For a more complete presentation of the input-output model, see (25), (37), or (9).

⁴For a statement of producers' prices methodology, see (25).

	Intermediate or Processing Sectors					Final Demand	Gross Output
	1	2	...	j	...	n	
Intermediate or Processing Sectors	1	x_{11}	x_{12}				X_1
	2	x_{21}	x_{22}				X_2
	...						
	i			x_{ij}		Y_i	X_i
	n					Y_n	X_n
Quadrant I							
						x_{nn}	
Quadrant II							
Final Payments	Quadrant III					Quadrant IV	
	R_1	R_2	-----	R_j	-----	R_n	
Gross Outlay	X_1	X_2	-----	X_j	-----	X_n	

Figure 3. Schematic Arrangement of Input-Output Transactions Table

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 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:

$$\begin{aligned} X_1 &= \sum_{j=1}^n x_{1j} + Y_1 \\ X_2 &= \sum_{j=1}^n x_{2j} + Y_2 \\ &\vdots \\ X_n &= \sum_{j=1}^n x_{nj} + Y_n \end{aligned} \quad (9)$$

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:

$$\begin{aligned} x_{ij} &= a_{ij} X_j & (i = 1, \dots, n) \\ & & (j = 1, \dots, n) \end{aligned} \quad (10)$$

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:

$$\begin{aligned} a_{ij} &= \frac{x_{ij}}{X_j} & (i = 1, \dots, n) \\ & & (j = 1, \dots, n) \end{aligned} \quad (11)$$

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

$$X_i = \sum_{j=1}^n a_{ij} X_j + Y_i \quad (i = 1, \dots, n) \quad (12)$$

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

$$X = AX + Y \quad (13)$$

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

$$X - AX = Y \quad (14)$$

or

$$(I-A) X = Y \quad (15)$$

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

$$X = (I-A)^{-1} Y \quad (16)$$

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.

Demand Output

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 (39) partitioning for basic and non-basic industries. Using the same symbols used in the preceding paragraph with 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:

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} Q_{11} & Q_{12} \\ Q_{21} & Q_{22} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} \quad (17)$$

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:

$$X_1 = Q_{11}X_1 + Q_{12}X_2 + Y_1 \quad (18)$$

$$X_2 = Q_{21}X_1 + Q_{22}X_2 + Y_2 \quad (19)$$

The output of the supply output sectors, X_1 , is exogenous. It will be 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:

$$X_2 - Q_{22}X_2 = Q_{21}X_1 + Y_2 \quad (20)$$

which can be rewritten as:

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

or:

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

Equation (22) is similar to the "standard solution" shown in (16) except that 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.

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. The data for this matrix was collected by Osborn and McCray (33) for 94 processing sectors, 6 final payments sectors, and 7 final demand sectors. This 56 county matrix was used by Osborn (32) to estimate an input-output model for the 25 Texas counties in the High Plains using a location-quotient technique. 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 1) estimates flows during 1967 in 1967 prices. To develop the table, gross outputs by sector for the three Oklahoma counties were estimated 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

Table 1. Input-Output Transactions Matrix — High Plains of Oklahoma and Texas, 1967 (Thousands of Dollars)

	1	2	3	4	5	6	7	8
1 IRR CUTTON	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 CUTTON	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 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	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 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	37.68	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	7.78	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 PROD	0.0	204.79	452.18	77.51	0.0	62.20	49.60	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	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	99.09	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	487.30	205.14	61.86
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	81813.75	16278.05	5250.58	9693.29	11759.11	4771.41
44 LOCAL GOVT	385.97	1639.26	3042.51	1035.49	82.97	519.95	276.83	38.05
45 STATE GOVT	4.89	19.65	35.77	12.99	1.35	6.32	3.49	0.29
46 FEDERAL GOVT	111.16	550.97	1226.79	709.20	24.62	268.01	168.15	41.62
47 IMPORTS	2343.46	8224.86	16677.28	2702.80	537.48	2929.41	1686.96	260.84
48 DEPRECIATION	1102.14	8321.90	14159.41	6878.54	222.91	2424.36	1429.40	91.34
GROSS OUTLAY	23936.20	69919.56	162596.69	43173.80	7529.80	23390.80	18767.10	5549.70

Table 1 (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 IRR 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 & PKI	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 PETRJ 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	44.82	547.47	42.79
30 GAS SERV	0.86	204.64	42.91	32.18	61.39	1.39	48.41	2.91
31 ELECTRIC SERV	154.57	356.96	195.40	261.10	134.03	17.44	165.69	63.52
32 WATER & SAN SERV	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 PETRJ 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	77.05	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	11.80	10.89	311.08	4.09
45 STATE GOVT	20.01	21.14	9.20	5525.82	406.93	126.57	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	179.21	2601.26	1622.29
GROSS OUTLAY	88847.56	218413.88	19197.50	397398.00	134034.56	33101.60	166352.56	49242.40

Table 1 (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	1453.74	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 & PKI	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	2.16	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	192.21	44.55	111.69	5214.04	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	1218.86	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	92.25	341.01	229.34	52.16
41 EDUCATION SERV	112.51	16.28	42.24	49.96	56.59	335.81	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	6897.67	16517.43	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	773.45	625.12	1833.48	5239.21	4094.67	717.48
47 IMPORTS	22343.41	1233.14	2163.97	4731.19	5056.88	26633.66	70346.06	4673.09
48 DEPRECIATION	1675.67	197.60	273.11	440.56	380.79	13951.10	7637.10	693.56
GROSS OUTLAY	50155.40	5349.10	14774.60	10624.60	15575.70	106908.75	177182.38	13321.00

Table 1 (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	27395.40	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	60.68	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	74.15	18.65	79.68	19.86
22 CHEMICALS	0.0	46.75	0.0	0.0	0.0	0.63	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	46.25	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	9178.96	0.0
31 ELECTRIC SERV	103.29	197.40	42.50	464.32	293.10	36.82	0.0	704.14
32 WATER & SAN SER	4.42	6.12	9.17	62.40	31.04	9.51	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	95.84	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	3.54	89.03	617.96	0.0
39 FINANCE	37.02	17.06	29.36	46.96	7.94	140.62	227.69	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	664.89	687.79	1359.72	0.0
42 OTHER SERV	41.64	348.41	211.91	1319.95	388.33	489.31	330.25	0.0
43 HOUSEHOLDS	4462.77	8439.57	1978.78	22083.99	10673.73	10223.69	28361.49	3369.65
44 LOCAL GOVT	31.72	28.41	13.74	243.61	747.29	875.28	1623.79	0.0
45 STATE GOVT	16.19	87.73	41.13	566.89	339.02	299.22	645.24	0.0
46 FEDERAL GOVT	588.10	1954.19	160.50	1882.09	5124.83	2070.03	8084.81	83.07
47 IMPORTS	7882.51	8166.28	7307.48	6413.96	7800.47	93807.13	1648.73	1630.08
48 DEPRECIATION	192.60	505.63	183.08	2842.38	5508.29	3273.19	7931.12	3083.06
GROSS OUTLAY	15007.10	20745.30	11334.10	46839.50	32471.90	142201.00	61609.70	11212.20

Table 1 (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 FEEDLOT LVSTK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 AG SERVICES	109.31	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	131.23	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	268.33	11.92	0.0	2643.80	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	2008.62	19.74	42.70	2845.71	503.95	298.08
30 GAS SERV	35.60	91.16	295.67	5.01	0.0	750.57	44.05	118.20
31 ELECTRIC SERV	70.30	455.86	1304.06	27.47	216.27	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	28893.17	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	46.64	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	4368.35	2170.68	1816.70
43 HOUSEHOLDS	3413.15	22152.73	93751.88	1528.23	5261.55	66453.63	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	14.50	344.09	59.84	523.72
46 FEDERAL GOVT	1025.27	462.62	7686.89	87.81	400.53	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	6006.93	256.11	203.80	4122.14	1132.23	1600.28
GRUSS OUTLAY	11560.90	37253.20	157917.38	2766.30	14897.60	166823.38	66202.00	32613.00

Table 1 (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 FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	20081.66	50193.66	-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	4628.41	4489.32	-3212.80
6 DRY FOOD GRAIN	0.0	0.0	0.0	0.0	0.0	8710.23	15985.15	-426.40
7 DRY FEED GRAIN	0.0	0.0	0.0	0.0	0.0	5372.01	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	1.18	2219.79	47840.07	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	5808.88	34339.68	-8475.60
18 TEXTILE PROD	7.08	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	224.28	3523.99	3663.11	0.0
29 COMMUNICATION	604.09	2434.03	14839.55	0.0	278.96	803.69	555.37	0.0
30 GAS SERV	431.40	299.28	9093.09	24.51	23.26	449.34	104374.19	0.0
31 ELECTRIC SERV	1216.68	1338.83	25804.44	86.27	144.17	380.64	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	50305.44	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	4584.66	1728.60	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.	2257.58	1821.31	2184.85	121.79	155.25	16.97	0.0	0.0
41 EDUCATION SERV	7.49	384.43	54191.95	0.0	0.0	7467.06	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	11509.41	126734.94	163443.00	0.0
44 LOCAL GOVT	11.44	409.57	8491.21	0.0	1878.05	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	6643.35	0.0	0.0	0.0	0.0	0.0	0.0
GROSS OUTLAY	84307.75	150047.56	1300577.00	31000.46	49820.80	379622.69	1626487.00	6467.16

Table 1 (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 SER	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	14897.60
38	OTHER RETAIL	350.50	166823.38
39	FINANCE	0.0	68202.00
40	INSUR & R. E.	0.0	32615.00
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	117926.63	6417136.00

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.

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, paid \$9,792,670 for Imports (row 47), and made other purchases as listed in the column. An examination of the sales distribution of a given processing 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 outlays 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.

Capital and Human Resources Accounts

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 1963 capital flow matrix (60).

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 (56) and from Oklahoma State University budget studies for agricultural sectors (14). 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. 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 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.

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 (32). 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 (59). 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 (31). 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 (4) 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 to land and management 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 rate 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 (8).

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 2 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.

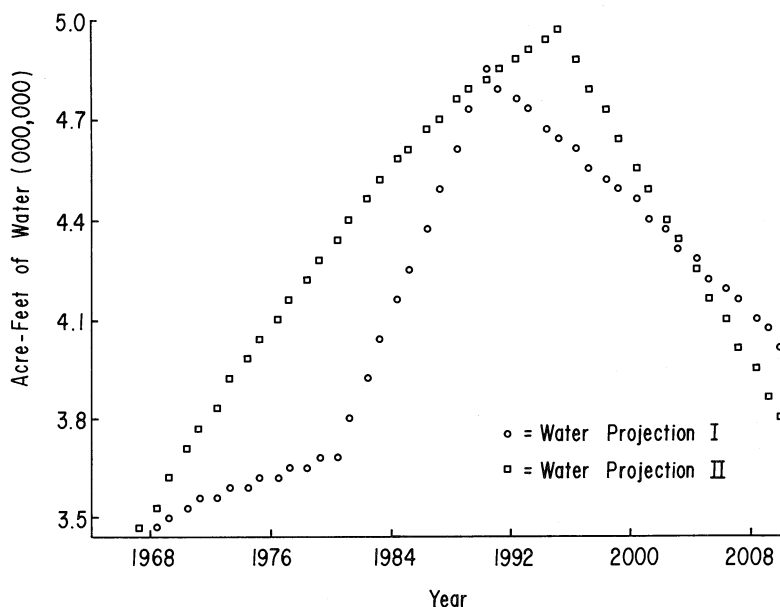


Figure 4. Annual Acre-Feet of Water Pumped for Irrigation, Water Projections I and II, High Plains of Oklahoma and Texas, 1967-2010

Yield Assumptions. Water Projections I and II are the bases for two separate projections of crop output. Constant yield per acre versus projected increases in yield per acre applied to the two

Table 2. 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	694,320	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

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 (44). 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 curvilinear regression model that projects yields to increase at a decreasing rate over time (44, 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 3, by sector and by state.

Table 3. Annual Percentage Change in Yield Per Acre by Sector for Oklahoma and Texas

State	Sector	Annual Percentage Change in Yield Per Acre		
		1967-80	1981-2000	2001-2010
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

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 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 (32) 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 (31), total acres planted by crop are from the United States Department of Agriculture (45), and revenue per acre by crop sector is estimated from 1967 acreages and input-output model gross dollar outputs.

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 (57). 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 (43). 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 (36). 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.

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 (28). 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 (58).

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 (28, 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 (41, 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 (29) 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 (30). 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 (32).

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. 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.

Results Of High Plains Simulation Model

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 full specification of the High Plains general type of model can be found in Doeksen and Schreiner's *Interindustry Models For Rural Development Research* (11).

Several scenarios of the High Plains economy from 1967 to 2010 are summarized in this section. 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. 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. And, 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.⁵

Base Projection

Water Projection II, which utilizes the Texas Water Development Board (59) projection of annual water pumpage for the Lower High Plains and the Bekure (4) 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 II, 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

⁵ The model was programmed in the Fortran IV language and computer runs for the 44 years from 1967 to 2010 cost approximately \$15 each.

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 (44) for the OBERS projections. Other data and the specification of the model are as discussed previously.

Population

The base projection of total population in the High Plains from 1967 to 2010 is illustrated in Figure 5 and recorded in Table 4. 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

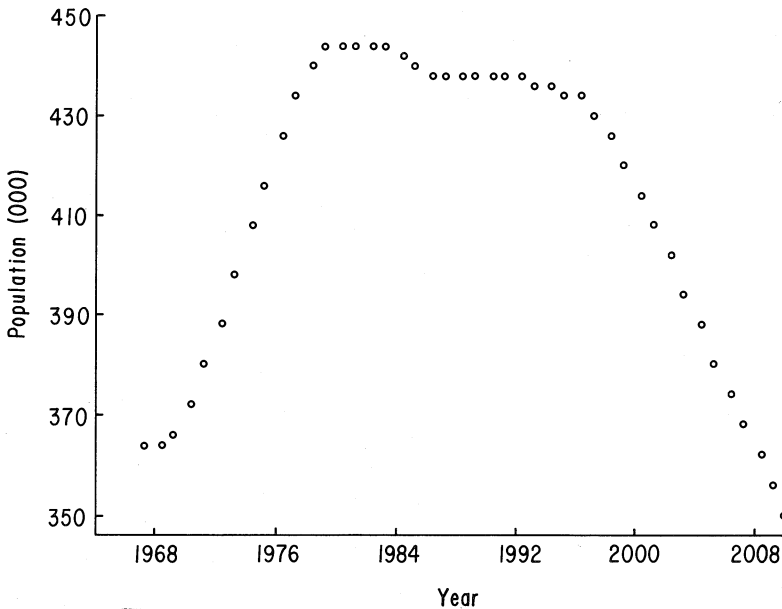


Figure 5. Population, Base Projection, High Plains of Oklahoma and Texas, 1967-2010

Table 4. 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
	Number	Number	1967 Dollars
1967	362,361	153,295	3,010
1968	363,084	155,074	3,081
1969	365,099	157,677	3,157
1970	370,857	161,086	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	189,488	3,835
1990	436,755	189,660	3,865
1991	436,806	189,646	3,893
1992	436,388	189,471	3,922
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

Year	Population	Total Employment	Disposable Income per Capita
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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 following section.

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 subsections on output, employment and income provide more detail. Of primary importance in the period of population increase are the forward linkages from feed grain 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.

Sector Output

Table 5 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 simulated model are difficult to comprehend in total. To avoid

Table 5. Gross Output By Sector, Base Projection, High Plains Of Oklahoma And Texas, 1967, 1995 And 2010

Sector		Gross Output in Thousands of 1967 Dollars		
Number	Name	1967	1995	2010
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	43,337
12	Crude Oil & Gas	397,398	237,705	168,081
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
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

this problem Table 5 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 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. 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 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 the 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 food 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 \$168,081,000 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 4) 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.

Table 6 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

Table 6. 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		
	1967	1995	2010	1967	1995	2010
Agriculture ¹	49,112	62,266	50,296	32.0	33.0	33.1
Mining ²	3,799	1,294	770	2.5	0.7	0.5
Construction ³	6,578	6,143	4,843	4.3	3.2	3.2
Manufacturing ⁴	9,610	12,725	9,494	6.3	6.7	6.2
Transportation & Utilities ⁵	6,866	5,481	3,959	4.5	2.9	2.6
Trade ⁶	34,215	36,523	27,083	22.3	19.4	17.8
Finance, Insurance & Real Estate ⁷	4,226	8,055	7,025	2.7	4.3	4.6
Services ⁸	24,240	34,705	29,682	15.8	18.4	19.6
Other ⁹	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
¹ Sectors 1-10 ² Sectors 12, 13 ³ Sector 15 ⁴ Sectors 16-27 ⁵ Sectors 28-32 ⁶ Sectors 33-38 ⁷ Sectors 39-40 ⁸ Sectors 11, 14, 41-42 ⁹ Households, Government						

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 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 1995, 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 1995. Disposable income per capita increases throughout the time span simulated, as illustrated in Figure 6 and Table 4. There is an annual average 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.

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. 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 the

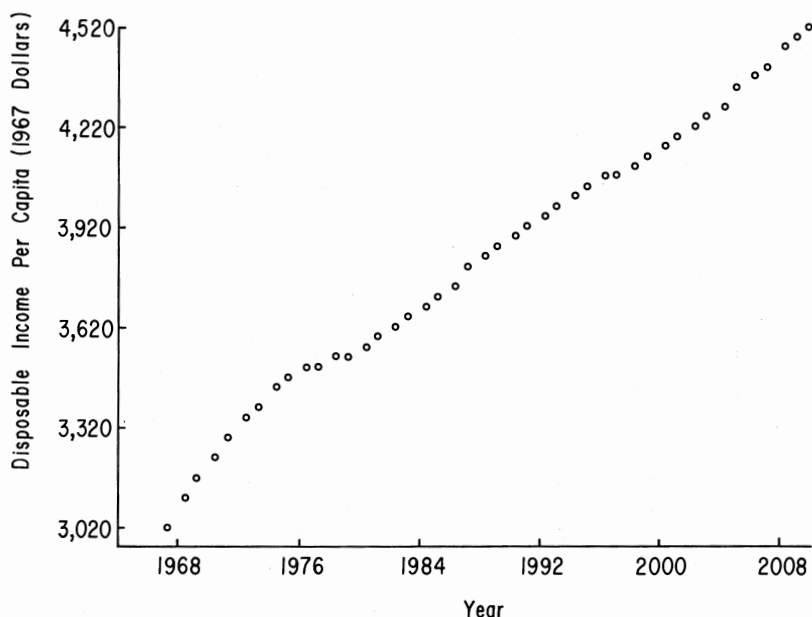


Figure 6. Disposable Income Per Capita, Base Projection, High Plains of Oklahoma and Texas, 1967-2010

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

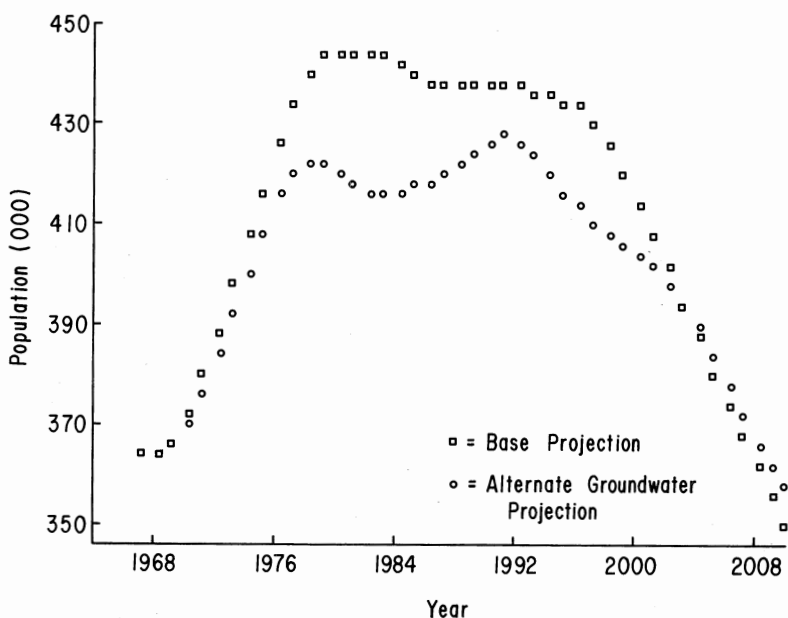


Figure 7. Population, Alternate Groundwater and Base Projections, High Plains of Oklahoma and Texas, 1967-2010

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.

Sector 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 7 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 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 pattern expected from the different water projections. As explained in the preceding

TABLE 7

Table 7. 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: Dry land 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
<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

Table 7 (Continued)

Year	Base Projection	Alternate Groundwater Projection	Alternate Petroleum Projection
<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

subsection on sectoral outputs, feedlot livestock output is dampened sooner in an alternate groundwater projection and this is reflected in the employment trend. Employment in the crude 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 pumpage assumptions.

Household Income

Total household income including transfer payment peak 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, 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 sector 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

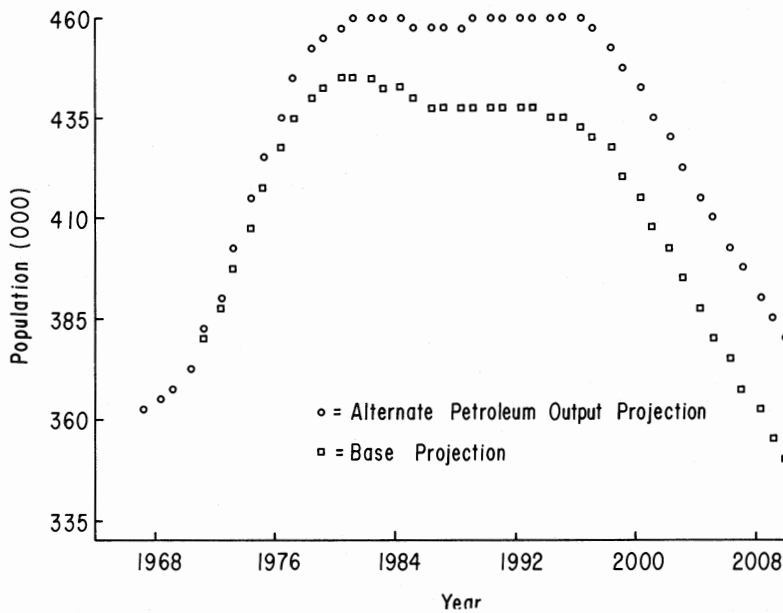


Figure 8. Population, Alternate Petroleum Output and Base Projections, High Plains of Oklahoma and Texas, 1967-2010

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 employment, as presented in Table 6, 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 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.

Sector 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 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 7 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 7, 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

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.

PLANNING AND POLICY IMPLICATIONS

In the preceding section 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 (19, 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 section 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 section, 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 simulated 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 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 maintaining 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 irrigation crop production.

To investigate in a general way the question of export development, runs of the simulated 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 used for 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 the growth rate 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 one percent from 1998 to 2010. Simulation runs assuming the growth rate 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 9 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 is 443,341). After 1996 both three percent export growth and base projections of population show declines but the three percent export projection is not as precipitous. Population in 2010 is

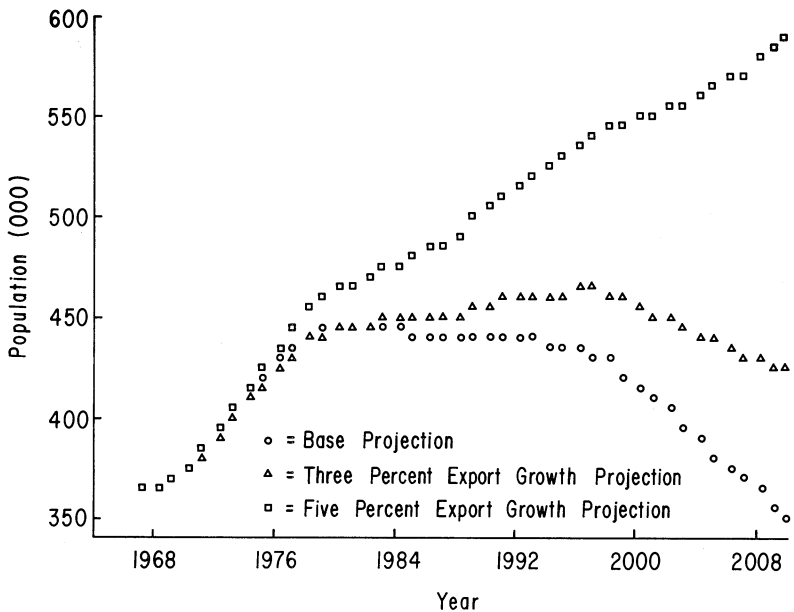


Figure 9. Population, Three Percent Export Growth, Five Percent Export Growth and Base Projections, High Plains of Oklahoma and Texas, 1967-2010

348,629 in the 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 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 alternative 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

During periods of regional growth locally produced goods may be substituted for imports as "threshold" levels are met. In 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 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.

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

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 dominantly 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.

economic activity, quite diverse trends are expected in communities north and south of the Canadian River.

A Selected Bibliography

- (1) Adelman, Irma. "Simulation: Economic Processes." *International Encyclopedia of the Social Sciences*. Ed. David L. Sills. New York: The MacMillan Co., 1968, pp. 268-274.
- (2) American Gas Association, American Petroleum Institute, and Canadian Petroleum Institute. *Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the United States and Canada as of December 31, 1971*. Vol. 26 (May, 1972).
- (3) Baumol, William J. *Economic Theory and Operations Analysis*. 2nd ed. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1965.
- (4) Bekure, Solomon. "An Economic Analysis of the Intertemporal Allocation of Groundwater in the Central Ogallala Formation." (Unpublished Ph.D. Thesis, Oklahoma State University, 1971).
- (5) Bharadwaj, Krishna R. "A Note on Structural Interdependence and the Concept of 'Key' Sector." *KYKLOS*, Vol. XIX (1966), pp. 135-319.
- (6) Borts, G. H., and J. L. Stein. *Economic Growth in a Free Market*. New York: Columbia University Press, 1964.
- (7) Byerlee, Derek, and A. N. Halter. "A Macro-Economic Model for Agricultural Sector Analysis." *American Journal of Agricultural Economics*, Vol. 56, No. 3 (August, 1974), pp. 520-533.
- (8) Croxton, Frederick E., and Dudley J. Cowden. *Applied General Statistics*. 2nd ed. New York: Prentice-Hall, Inc., 1955.
- (9) Czamanski, Stan. *Regional and Interregional Social Accounting*. Lexington, Mass.: D. C. Heath and Co., 1973.
- (10) Doeksen, Gerald A. "A Social Accounting System and Simulation Model Projecting Economic Variables and Analyzing the Structure of the Oklahoma Economy." (Unpublished Ph.D. thesis, Oklahoma State University, 1971).

- (11) Doeksen, Gerald A. and Dean F. Schreiner. *Interindustry Models for Rural Development Research*. Stillwater: Oklahoma State University, Agricultural Experiment Station Technical Bulletin T-139, Sept., 1974.
- (12) Doeksen, Gerald A. and Dean F. Schreiner. *An Analysis of the Capital Structure by Private Sectors in Oklahoma*. Stillwater: Oklahoma State University, Agricultural Experiment Station Bulletin B-694, July, 1971.
- (13) Dorfman, Robert. "The Nature and Significance of Input-Output." *The Review of Economics and Statistics*, Vol. 36, No. 2 (May, 1954), pp. 121-133.
- (14) Eidman, Vernon R. Unpublished research. Stillwater: Department of Agricultural Economics, Oklahoma State University, 1974.
- (15) Hamilton, H. R., S. E. Goldstone, J. W. Milliman, A. L. Pugh III, E. B. Roberts, and A. Zellner. *Systems Simulation for Regional Analysis, An Application to River-Basin Planning*. Cambridge: The M. I. T. Press, 1969.
- (16) Hirsch, W. Z. *Regional Information Design for Public Decisions*. (MR-129). Los Angeles: Institute of Government and Public Affairs, University of California, 1969.
- (17) Holloway, M. L. "An Economic Simulation Model for Analyzing Natural Resource Policy." *Southern Journal of Agricultural Economics*, Vol. 6, No. 1 (July, 1974), pp. 171-178.
- (18) Hoover, Edgar M. *An Introduction to Regional Economics*. New York: Alfred A. Knopf, Inc., 1971.
- (19) Johnston, Denis F. "The Uses of Projections." *Monthly Labor Review*. Vol. 96, No. 7 (July, 1973), p. 6.
- (20) Kain, John F., and John R. Meyer. "Computer Simulations, Physio-Economic Systems, and Intraregional Models." *American Economic Review*, Vol. 58, No. 2 (May, 1968), pp. 171-181.
- (21) Kelso, M. M., W. E. Martin, and L. E. Mack. *Water Supplies and Economic Growth in an Arid Environment: An Arizona*

Case Study. Tuscon, Arizona: The University of Arizona Press, 1973.

- (22) Leontief, Wassily. "Quantitative Input-Output Relations in the Economic System of the United States." *The Review of Economics and Statistics*, Vol. 27 (August, 1936), pp. 105-125.
- (23) MacMillian, J. A. "Public Service System in Rural-Urban Development." (Unpublished Ph.D. thesis, Iowa State University, 1968).
- (24) Maki, Wilbur R., Richard E. Suttor, and Jerald R. Barnard. *Simulation of Regional Product and Income with Emphasis on Iowa, 1954-74*. Ames: Iowa State Agricultural and Home Economics Experiment Station Research Bulletin 5-48, September, 1966.
- (25) Miernyk, W. H. *The Elements of Input-Output Analysis*. New York: Random House, 1965.
- (26) Miernyk, W. H., et al. *Simulating Regional Economic Development: An Interindustry Analysis of the West Virginia Economy*. Lexington: Heath Lexington, 1970.
- (27) Mullendore, W. E. "An Economic Simulation Model for Urban Regional Development Planning." (Unpublished Ph.D. thesis, Iowa State University, 1968).
- (28) Nemir, Charles E. *Projections of Oil and Gas Production and Water Requirements for Secondary Recovery, Texas High Plains*. Austin, Texas: Texas Water Development Board, September, 1973.
- (29) Oklahoma Corporation Commission. Oil and Gas Conservation Division. "Quarterly Summary of Liquid and Gas Runs by Counties." Oklahoma City, 1968-1973. Mimeographed.
- (30) Oklahoma Energy Advisory Council. *Energy in Oklahoma*. Vol. I and II. Oklahoma City, February 1, 1974.
- (31) Oklahoma Water Resources Board. Appraisal of the Water and Related Land Resources of Oklahoma, Region 12, 1973. Oklahoma City: Mercury Press, 1974.

- (32) Osborn, James E. Unpublished research. Lubbock, Texas: Department of Agricultural Economics, Texas Tech University, 1974.
- (33) Osborn, James E. and William C. McCray. *An Interindustry Analysis of the Texas High Plains: Part I*. Austin: Office of the Governor, Division of Planning Coordination, State of Texas, April, 1972.
- (34) Perloff, Harvey S., and Charles L. Leven. "Toward an Integrated System of Regional Accounts: Stocks, Flows, and the Analysis of the Public Sector." *Elements of Regional Accounts*. Ed. W. Z. Hirsch. Baltimore: The John Hopkins Press, 1964, pp. 175-210.
- (35) Pratt, Richard T. "Regional Production Inputs and Regional Income Generation." *Journal of Regional Science*, Vol. 7, No. 2 (1967), pp. 141-149.
- (36) Purcell, Wayne D. *Cattle Feeding in the Southern Plains: Past, Present, Future Outlook*. Stillwater: Oklahoma State University Agricultural Experiment Station Bulletin B-688, January, 1971.
- (37) Richardson, Harry W. *Input-Output and Regional Economics*. London: Weidenfeld and Nicolson, 1972.
- (38) Richardson, Harry W. *Regional Growth Theory*. New York: John Wiley & Sons, Inc., 1973.
- (39) Romanoff, Eliahu. "The Economic Base Model: A Very Special Case of Input-Output Analysis." *Journal of Regional Science*, Vol. 14, No. 1 (1974), pp. 121-129.
- (40) Romans, J. Thomas. *Capital Exports and Growth Among U.S. Regions*. Middletown, Conn.: Wesleyan University Press, 1965.
- (41) Schurr, S. H. "Forward." *The Future Supply of Oil and Gas*. Ed. Bruce C. Netschert. Baltimore: John Hopkins Press, 1958.
- (42) Siebert, Horst. *Regional Economic Growth: Theory and Policy*. Scranton, Pa.: International Textbook Co., 1969.

- (43) Texas Crop and Livestock Reporting Service. 1972 *Texas Livestock Statistics*. Bulletin 111. Austin, May, 1973.
- (44) U. S. Department of Agriculture. Economic Research Service. "Agricultural Yield Projections for Selected Commodities, by States, 1980, 2000, and 2020." Washington, April 14, 1972. Mimeographed.
- (45) U. S. Department of Agriculture. Soil Conservation Service. *Oklahoma Conservation Needs Inventory*. Stillwater, Oklahoma: March, 1970.
- (46) U. S. Department of Commerce. Bureau of the Census. *Census of Agriculture, 1950, Oklahoma*. Vol. 1, Part 25. Washington: Government Printing Office, 1952.
- (47) U. S. Department of Commerce. Bureau of the Census. *Census of Agriculture, 1959, Oklahoma*. Vol. 1, Part 36. Washington: Government Printing Office, 1961.
- (48) U. S. Department of Commerce. Bureau of the Census. *Census of Agriculture, 1969, Oklahoma*. Vol. 1, Part 36. Washington: Government Printing Office, 1972.
- (49) U. S. Department of Commerce. Bureau of the Census. *Census of Agriculture, 1950, Texas*. Vol. 1, Part 26. Washington: Government Printing Office, 1952.
- (50) U. S. Department of Commerce. Bureau of the Census. *Census of Agriculture, 1959, Texas*. Vol. 1, Part 37. Washington: Government Printing Office, 1961.
- (51) U. S. Department of Commerce. Bureau of the Census. *Census of Agriculture, 1969, Texas*. Vol. 1, Part 37. Washington: Government Printing Office, 1972.
- (52) U. S. Department of Commerce. Bureau of the Census. *Census of Population, 1960, Characteristics of the Population, Oklahoma*, Vol. 1, Part 38. Washington: Government Printing Office, 1963.
- (53) U. S. Department of Commerce. Bureau of the Census. *Census of Population, 1970, Characteristics of the Population*,

Oklahoma. Vol. 1, Part 38. Washington: Government Printing Office, 1973.

- (54) U. S. Department of Commerce. Bureau of the Census. *Census of Population, 1960, Characteristics of the Population, Texas*. Vol. 1, Part 45. Washington: Government Printing Office, 1963.
- (55) U. S. Department of Commerce. Bureau of the Census. *Census of Population, 1970, Characteristics of the Population, Texas*. Vol. 1, Part 45. Washington: Government Printing Office, 1973.
- (56) U. S. Department of the Treasury. Internal Revenue Service. *Statistics of Income, Corporation Income Tax Returns*. Washington: Government Printing Office, annual, 1954-1969.
- (57) U.S. Water Resources Council. *1972 OBERS Projections*. Vol. 1, Washington: Government Printing Office, September, 1972.
- (58) Vinson, James R. "Texas Input-Output Study Special Mining Industry Report." Abilene, Texas: Bureau of Economic and Business Research, Hardin-Simmons University, August 1, 1971.
- (59) Wyatt, Wayne. Unpublished research. Austin, Texas: Ground-water Protection Division, Texas Water Development Board, 1974.
- (60) Young, A. H., L. C. Maley, Jr., S. R. Reed, and R. A. Seaton II. "Interindustry Transactions in New Structures and Equipment, 1963." *Survey of Current Business*. Washington: Government Printing Office, August, 1971, pp. 16-23.

Appendix

Table 8. 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 8 (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
$(I_n)_t^i$	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
$(I_r)_t^i$	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 8 (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 8 (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 9. 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

Table 9 (Continued)

Matrix	Description
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
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 10. 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
a_{22}	Household payments — total local government purchases ratio

Table 10 (Continued)

Scalar	Description
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

An Economic Simulation Model For The High Plains Of Oklahoma And Texas

I. Estimating Final Demand

A. Capital Formation

1. Private Business Investment.

If $[(l_n^i)_{t-1} \geq 0]$ or

$$[(l_n^i)_{t-1} < 0 \text{ and } |(l_n^i)_{t-1}| < (l_r^i)_{t-1}] \quad (\text{A.1})$$

$$\text{then } K_t^i = K_{t-1}^i + (l_r^i)_{t-1}$$

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

If $(l_n^i)_{t-1} \leq 0$ and

$$|(l_n^i)_{t-1}| \geq (l_r^i)_{t-1} \quad (\text{A.2})$$

$$\text{then } K_t^i = K_{t-1}^i - (l_r^i)_{t-1}$$

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

$$K_t = \begin{bmatrix} K_t^1 \\ K_t^2 \\ . \\ . \\ . \\ K_t^{42} \end{bmatrix} \quad (A.3)$$

$$(I_r)_t = A_1 K_t \quad (A.4)$$

$$(I_n)_t = (A_2)_{t-1} A_3 (X_{t-1}^D - X_{t-2}^D) \quad (A.5)$$

If $[(I_n^i)_t \geq 0]$ or

$[(I_n^i)_t < 0]$ and

$$| (I_n^i)_t | < | (I_r^i)_t | \quad (A.6)$$

then $I_t^i = (I_r)_t + (I_n)_t$

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

If $[(I_n^i)_t < 0]$ and

$$| (I_n^i)_t | \geq | (I_r)_t | \quad (A.7)$$

then $I_t^i = 0$

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

$$I_t = \begin{bmatrix} I_t^1 \\ I_t^2 \\ \cdot \\ \cdot \\ \cdot \\ I_t^{42} \end{bmatrix} \quad (\text{A.8})$$

$$(CI)_t = A_4 I_t \quad (\text{A.9})$$

$$(CL)_t = A_5 (CI)_t \quad (\text{A.10})$$

2. Residential Investment.

$$\begin{aligned} (Y_L)_t = & a_1 [(Y_{t-1} - Y_{t-2})/.5 (Y_{t-1} + Y_{t-2})] \\ & + a_2 [(Y_{t-2} - Y_{t-3})/.5 (Y_{t-2} + Y_{t-3})] \end{aligned} \quad (\text{A.11})$$

$$\begin{aligned} & + a_3 [(Y_{t-3} - Y_{t-4})/.5 (Y_{t-3} + Y_{t-4})] \\ (CHP)_t = & (CHP)_{t-1} + a_4 (Y_L)_t (CHP)_{t-1} \end{aligned} \quad (\text{A.12})$$

$$(CH)_t = P_t (CHP)_t \quad (\text{A.13})$$

3. 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.

4. Summation of Capital Formation.

$$(CA)_t = (CL)_t + (CHV)_t \quad (A.14)$$

B. Household Purchases

$$C_{t-1}^P = C_{t-1} \frac{1}{P_{t-1}} \quad (A.15)$$

$$C_t^P = C_{t-1}^P + (Y_L)_t A_6 C_{t-1}^P \quad (A.16)$$

$$C_t^U = P_t C_t^P \quad (A.17)$$

$$SUMC_t^U = iC \quad (A.18)$$

$$SUMCY_t = SUMC_t / Y_{t-1}^T \quad (A.19)$$

$$\text{If } a_5 \leq SUMCY_t - a_6 \quad (A.20)$$

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

$$\text{If } SUMCY_t > a_6, \quad (A.21)$$

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

$$\text{and } C_t = (B_1)_t C_t^U, \text{ or}$$

$$\text{If } \text{SUMCY}_t < a_5, \quad (\text{A.22})$$

$$\text{then } (B_2)_t = a_5 / \text{SUMCY}_t$$

$$\text{and } C_t = (B_2)_t C_t^u$$

C. Exports

$$R_t = [(\text{TVA})_{t-1} - (\text{TVA})_{t-2}] / .5 [(\text{TVA})_{t-1} + (\text{TVA})_{t-2}] \quad (\text{A.23})$$

$$E_t^* = (1 + R_t) E_{t-1}^* \quad (\text{A.24})$$

$$E_t^{22} = a_7 E_{t-1}^{22} \quad (\text{A.25})$$

$$E_t^{23} = a_8 E_{t-1}^{23} \quad (\text{A.26})$$

$$E_t^{30} = a_9 E_{t-1}^{30} \quad (\text{A.27})$$

$$E_t = \begin{bmatrix} E_t^* \\ \text{---} \\ E_t^i \end{bmatrix} \quad (\text{A.28})$$

D. Government Purchases

$$(L_T)_t = A_8 X_{t-1}^D + a_{10} Y_{t-1}^T \quad (\text{A.29})$$

$$+ a_{11} (S_T)_{t-1} + a_{12} (F_T)_{t-1}$$

$$L_t = A_9 (L_T)_t \quad (\text{A.30})$$

$$(SPC)_t = [1 + (Y_L)_t] (SPC)_{t-1} \quad (A.31)$$

$$(S_T)_t = P_t (SPC)_t \quad (A.32)$$

$$S_t = A_{10} (S_T)_t \quad (A.33)$$

$$(FPC)_t = a_{13} (FPC)_{t-1} \quad (A.34)$$

$$(F_T)_t = P_t (FPC)_t \quad (A.35)$$

$$F_t = A_{11} (F_T)_t \quad (A.36)$$

E. Total Final Demand

$$Z_t = (CA)_t + C_t + E_t + L_t + S_t + F_t \quad (A.37)$$

$$(ZG)^{**} = (CA)_t + C_t + L_t + S_t \quad (A.38)$$

II. Estimating Sector Output Subject to Agricultural and Petroleum Output Projections

A. Supply Output

$$\bar{X}_t^{10} = G_t \bar{X}_{t-1}^{10} \quad (A.39)$$

$$\bar{X}_t^{16} = a_{14} \bar{X}_{t-1}^{10} \quad (A.40)$$

$$\bar{X}_t = \begin{bmatrix} \bar{X}_t^1 \\ \bar{X}_t^2 \\ . \\ . \\ . \\ \bar{X}_t^{10} \\ \bar{X}_t^{12} \\ \bar{X}_t^{13} \\ \bar{X}_t^{16} \end{bmatrix} \quad (A.41)$$

B. Demand Output

$$W_t = A_{12}\bar{X}_t + Z_t \quad (A.42)$$

$$X_t^d = A_{13}W_t \quad (A.43)$$

$$(EG)_t = (\bar{X}G)_t^{**} - A_{14}(\bar{X}G)_t^{**}$$

$$-A_{15}(\bar{X}GX)_t^{**} - A_{16}X_t^d \quad (A.44)$$

$$-(ZG)_t^{**}$$

$$(GEG)_t = i (EG)_t \quad (A.45)$$

$$\text{If } (GEG)_t \geq 0, \quad (A.46)$$

go to Equation (A.48), or

If $(GEG)_t < 0$,

$$\text{then } G_t = G_t - a_{15} \quad (\text{A.47})$$

and return to Equation A.39

C. Sector Output

$$X_t^D = \left[\frac{\bar{X}_t}{X_t^d} \right] \quad (\text{A.48})$$

III. Estimating Employment, Population, Income and Value Added

A. Employment

$$L_t^e = (A_{17})_{t-1} A_{18} X_t^D \cdot 10^{-1} \quad (\text{A.49})$$

$$\begin{aligned} (TE)_t &= iL_t^e + a_{16} L_{t-1}^0 + a_{17} (L_T)_t \\ &+ a_{18} (S_T)_t + a_{19} (F_T)_t \end{aligned} \quad (\text{A.50})$$

B. Population

$$P_{t+1} = a_{20} H_{t-1} (TE)_t \quad (\text{A.51})$$

C. Income

$$Y_t^* = A_{19} X_t^D \quad (\text{A.52})$$

$$Y_t^T = iY_t^* + a_{21} L_t^0 + a_{22}(L_T)_t + a_{23} (S_T)_t + a_{24} (F_T)_t \quad (\text{A.53})$$

$$+ a_{25} P_t + a_{26} P_t$$

$$Y_t^D = a_{27} Y_t^T \quad (\text{A.54})$$

$$Y_t = Y_t^D / P_t \quad (\text{A.55})$$

D. Value Added

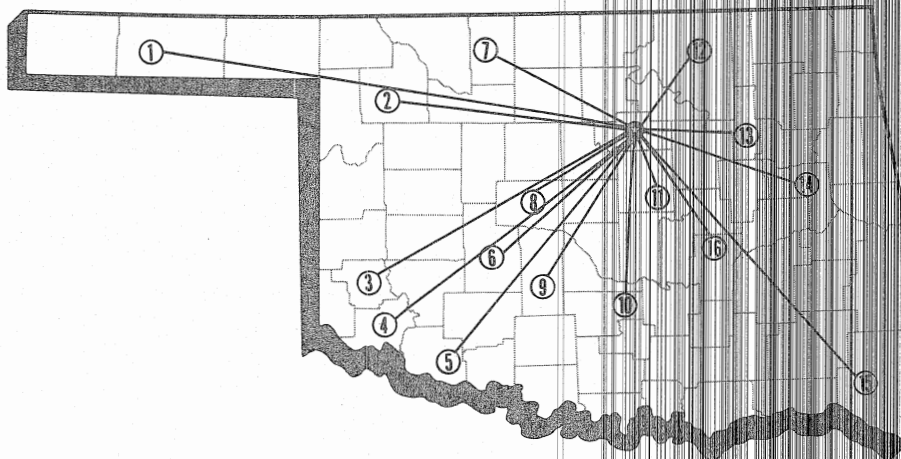
$$(VA)_t = A_{20} X_t^D \quad (\text{A.56})$$

$$(TVA)_t = i (VA)_t \quad (\text{A.57})$$

OKLAHOMA

Agricultural Experiment Station

System Covers the State



Main Station — Stillwater, Perkins and Lake Carl Blackwell

1. Panhandle Research Station — Goodwell
2. Southern Great Plains Field Station — Woodward
3. Sandyland Research Station — Mangum
4. Irrigation Research Station — Altus
5. Southwest Agronomy Research Station — Tipton
6. Caddo Research Station — Ft. Cobb
7. North Central Research Station — Lawton
8. Ft. Reno Livestock Research Station — El Reno
9. South Central Research Station — Chickasha
10. Agronomy Research Station — Stratford
11. Pecan Research Station — Sparks
12. Veterinary Research Station — Pawhuska
13. Vegetable Research Station — Bixby
14. Eastern Pasture Research Station — Muskogee
15. Kiamichi Field Station — Idabel
16. Sarkeys Research and Demonstration Project — Lamar