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The management of water resources: a synthesis of goal programming and input-output analysis with application to the Iowa economy

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THE MANAGEMENT OF WATER RESOURCES: A SYNTHESIS OF GOAL PROGRAMMING AND INPUT-OUTPUT ANALYSIS WITH APPLICATION TO THE IOWA ECONOMY

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The management of water resources: A synthesis of goal programming and input-output analysis with application to the Iowa economy

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CHAPTER I. INTRODUCTION

Water is essential to human existence and to most economic activities. In most parts of the world, water has traditionally been used as a free good because of its abundance and because few institutional arrangements have been developed for its use in times and places of scarcity. Thus, the marginal cost to any user or potential user approximates zero. Even in areas of abundant average water supplies, temporary shortages force curtailment of economic activity.

Iowa is in a humid region and water shortages are localized and periodic in nature. Associated with increased water demands, Iowa faces increasingly limited supplies of water in relation to demand. Therefore, serious attention must be accorded the management (allocation and development) of water for future uses within the state. This study is concerned with the management of Iowa's water resources, with particular emphasis on its allocation.

Iowa's localized and periodic scarcities of water have quantity and quality as well as spatial and temporal dimensions. Inadequate supplies of water periodically in certain areas of the state demonstrate the quantity aspect of water shortages. Northwestern Iowa is a water-deficient region compared with other regions of the state. Even though adequate quantities of water may be available in a particular locality, the quality of water may preclude its usage in many economic activities. For example, a mineralized aquifer source may not be acceptable for crop irrigation. Also, the spatial occurrence of water in an aquifer whose water yields are insufficient may produce water shortages in certain areas. Finally, improper timing of water availability can produce temporal shortages. Although abundant rains came at the end of the 1977 central Iowa drought, the timing was too late to have any beneficial effect on crop yields. The crux of the water problem is that water may not be available in the right place, at the right time, and in the right amount, despite average annual water adequacies. This problem suggests that economic analysis be applied to decisions concerning water management including its use, allocation, and development.

Allocation of water in most parts of the Western World has been associated with land ownership rights. The primary institution governing the allocation in the 31 eastern contiguous states of the U.S. and also in Western Europe has been the riparian doctrine (12). Under this system, the ownership of land adjacent to a water course grants the landowner riparian rights to that body of water. This right also extends to land overlying an underground water course. A riparian owner may use all the water needed for domestic use, including household and livestock uses. Uses of water which do not fall in the above categories are termed artificial uses and include industrial, irrigation, and sewage disposal. These artificial uses are permitted to the extent that they do not violate domestic uses. As long as there is an excess supply of good quality water, the riparian system is adequate. But if there is competition for scarce water supplies, then the riparian doctrine becomes both inefficient and inequitable.

The 17 western states of the U.S. rely on a different institutional doctrine to allocate water known as prior appropriation (39, p. 22). Through prior use, an owner of land adjoining or overlying a water source may claim all or part of the water if he or she can prove that the water will be used for beneficial purposes. Beneficial uses consist of consumptive (domestic) and productive (manufacturing) uses, where the domestic use includes drinking, cooking, and bathing and where the productive use includes agriculture, manufacture (2, p. 16), etc.[1] The major drawback of the prior appropriations doctrine similar to that of the riparian system is the failure to allocate scarce water resources among competing uses in an efficient manner. The above two water doctrines lack the conceptual basis to

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[1]Water Use Concepts. Defining beneficial uses as domestic and productive (manufacturing) uses would imply that uses otherwise, such as street washing and fire-fighting are non-beneficial or detrimental. But these uses of water as well as other similar uses which help increase the lifespan of a productive plant or equipment are productive, hence, beneficial. Hence, the difference between what is a beneficial or detrimental use of water is not easy to see.

After agreeing on what a beneficial use is, then in technical terms, the beneficial use can be either consumptive or non-consumptive. A consumptive use implies a depletion of water through evaporation or in a form not returnable to a body of water to be used again. This includes water incorporated into products, water consumed by humans, livestock or used in irrigation (4, p. 207-208).

Consumptive uses can have quality or quantity dimensions. Water used in such a way as to alter its structure or temperature in a non-reversible manner can be said to have been consumed, while water drunk by humans or animals is not available physically.

be compatible with multi-sector and multi-use demand for water in today's complex and interrelated economy.

In 1957, Iowa modified its riparian system into the permit system under the state's revised water law (26). Under the permit system, a centralized decision-making body is responsible for all water allocation decisions involving withdrawal rates in excess of 5,000 gallons per day for individuals. This makes the permit system more flexible than the two previous doctrines and also more amenable to economic analysis.

With modern technology, most economic activities cannot be carried out without the use of water and energy. Water production (drilling and treatment) and transportation require energy while energy production also requires water. In fact, withdrawals of water for condenser cooling in thermal-electric plants constitute the largest use of water in the energy sector (37). In the state of Iowa, agricultural, industrial, and energy sectors constitute the largest water users. On the national level, the U.S. Geological Survey reported in 1970 that withdrawals of water for steam-electric power generation represented 45 percent of total withdrawals for all uses (19). Also, water is used to form the transportation system that moves goods and people. It becomes obvious that a shortage of water directly affects the state's economic activities.

Natural resources are put to a wide variety of uses in all sectors of the economy. These uses are not independent of each other.

Pulp mills, for example, require water, energy, chemicals, machinery, and other intermediate inputs which are produced by the other sectors of the economy. Agricultural production requires water, herbicides, pesticides, fertilizer, farm machinery, and energy as intermediate inputs; also, most of these intermediate inputs require the use of water. The above facts suggest that the management of natural resources cannot be carried out in isolation from the management of the other sectors of the economy. A natural resource shortage affects production and income. And through an inevitable income-consumption linkage, the shortage keeps working itself throughout the economy. Hence, any realistic analysis of natural resources in an economy must embrace this intersectoral dependence.

Recent Studies Concerned With Water Management in Iowa

Several studies have been carried out in the northwestern section of Iowa on the management of water and land resources. Rossmiller (53b) developed a goal programming model for comprehensive water and land management for northwestern Iowa. The purpose of his study was to explore the feasibility of using a multi-objective decision-making tool in water and land management problems. His study thus deviates from the traditional single-objective criteria often used in analyzing resource management problems. However, this study does not incorporate the intersectoral relationships within the economy. Any economy, in essence, is made up of various sectors, which are interrelated.

Babula (2) developed a model for analyzing the economics of supplemental irrigation and applied the model to a case study of a farm in the Moody Silty Clay Loam Association of Lyon County in northwestern Iowa. His model involved the use of water in agriculture and does not consider other sectors of the economy on which agriculture depends for intermediate inputs, and which, in turn, depend on agriculture. Colbert (13) also worked on the allocation of water in the agricultural sector and focused on the development of a model for ascertaining the marginal value product of irrigation water in northwestern Iowa.

In reality, the works of the above three researchers utilized what might be called a partial equilibrium analysis. They did not include effects of changes in water utilization in the agricultural sector on other sectors of the economy and the subsequent feedback effects. Rhee (53a), however, combined a linear programming model with an input-output analysis in analyzing the allocation of water resources in northwestern Iowa. Rhee's work is a general equilibrium analysis of the economy of northwestern Iowa. One basic limitation of Rhee's work is that he did not incorporate the income-consumption linkage in his model. In effect, his model did not provide adequately for the impact of a shock experienced in one sector of the economy on the other sectors. When there is an increase in the demand for a product produced by one sector of the economy, producers of that particular product react to the signal by increasing production (assuming there is excess capacity in the economy and the economy is not operating at full employment of resources). Since production requires the use of natural resources, owners of these resources receive more income. Through an income-consumption linkage in the economy, an increase in income shows up in an increase in consumption. This sends further signals to producers to increase production by increasing resource utilization. This procedure goes on until the process converges (assuming the system is stable). This means that the optimal quantities of resources computed by Rhee constitute underestimations since the income-consumption linkage is excluded from his model.

The Study Objectives

A summary of the economic and demographic projection series for Iowa (4) indicates that total income is expected to grow 2.85% per annum from 1975 to 2020. Population is expected to increase from 2,887,000 in 1975 to 3,217,000 by 2020, which implies an average growth rate of 0.24% per annum from 1975 to 2020. Employment and per capita income are also expected to grow at 0.51% and 2.94%, respectively, between the same period. Utilizing the above growth rates, the Iowa Office of Planning and Programming made long-term projections of population and economic activities to the year 2020 (43). Within this context, the major purposes of this study are to:

1) develop a multi-objective decision model for providing guidance in the allocation of water resources,

2) apply the model in the allocation of water between the economic sectors of the state of Iowa in order to investigate whether the state's water resources will be sufficient to meet its economic and demographic projections to 2020,

3) suggest improvements in the methodology for future research.

In pursuing these three purposes, three supplementary procedural objectives are involved. These are:

1) estimate the aggregate sectoral productions required to satisfy the projected growth,

2) find the associated water and energy utilization,

3) determine the effects of changes in the state's economic priorities on aggregate production and resource employment through sensitivity analysis.

Methods Utilized in Achieving Objectives

A combination of goal programming and input-output analysis will be developed and utilized in an attempt to meet the above-specified objectives. The common objective of most large-scale federal water projects has been to increase national economic efficiency (58). The U.S. Water Resources Council in 1971 identified four objectives in its water resources management approach. These were national economic development, environmental quality improvement, regional development, and social well-being. The Water Resources Council later decided to include the regional development objective in public water projects only when directed, and the objective of social well-being was dropped (14, 15, 57). The national economic development objective can be achieved by increasing the value and distribution of the national output of goods and services, as well as improving national economic efficiency. The employment of good management techniques can help in the achievement of the environmental quality objective.

Iowa's total output comprises all goods and services produced by all sectors of the economy. With the limited supply of the state's natural resources, the output of all goods and services cannot be increased simultaneously. Certain items will have to be sacrificed for others. There are many constraints which impede the achievement of the goals of a society, be it the goal of increasing the output of all goods and services or the distribution of the goods and services. These constraints come in many forms. They can be legal, financial, physical, social, technical, as well as a combination of institutional rules and regulations. Decision makers are thus in the need of a systematic process that will allow them to reconcile all the conflicting goals and constraints in the planning process.

Traditional decision-making tools of benefit-cost analysis and linear programming cannot readily handle problems with multiple conflicting goals and constraints because of the infeasibility problems. One of the most flexible mathematical optimization techniques for handling problems involving multiple conflicting objectives under complex constraints is goal programming (29, 47). In employing the technique of goal programming to the solution of a problem, one may not need to satisfy all the conflicting goals and constraints imposed on a society as strictly as linear programming demands. In any society, certain objectives command higher priorities than others and the aim of goal programming is to satisfy absolutely those objectives commanding highest priorities and afterwards attempt to satisfy the remaining objectives as nearly as possible.

One of the analytical tools often used to analyze an economy in a general equilibrium framework is the input-output analysis developed by Leontief (48). This analytical procedure goes a step beyond the national income and product accounts to add the inter-industry transactions of the economy. Hence, Leontief characterizes it as a "look under the hood" at the inside workings of the entire economic system. It brings all the sectors of the economy together and considers how the performance of one sector of the economy affects the remaining sectors. It thus includes a comprehensive multiplier analysis of the effects of a shock in one sector of the economy throughout the entire economic system. As mentioned already, when there is a shortage of water to farmers in a particular economy, all the remaining sectors of the economy feel the impact. Input-output analysis captures this intersectoral ramification. The combination of goal programming and input-output models used in this study is an attempt to capture the interdependence of the various sectors within the economy, while allocating the water resources of the state in such a way as to satisfy the growth projections to the year 2020. Also considered are energy allocations within the Iowa economy. Results of this study should be useful to planning agencies who have responsibilities for the management of water resources on behalf of the state and its citizens.

The Study Area

In this study, the state of Iowa has been divided into eight water supply areas in order to capture the differences in regional water usage.[1] Six of these areas coincide roughly with the six major interior river basins. These river basins also serve as conservancy districts for managing the state's natural resources. The conservancy districts are designated as Western, Des Moines, Southern, Skunk, Iowa-Cedar, and Northeastern river basins. For the purpose of this project, two additional water supply areas were added. These are the Missouri and Mississippi water supply areas.

Organization of Report

The first chapter of the report presents the importance of utilizing multi-objective models in water allocation and also outlines the specific objectives of the report. Methods used in pursuing these

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[1] Water supply areas and water supply regions as used in this report mean the same thing.

objectives are also introduced in this chapter. Chapter 2 develops the models utilized in achieving these objectives. Chapter 3 discusses the data requirements for the application of the model to Iowa's economy. It also includes a comprehensive discussion of the economic and demographic characteristics of the study area. The sectors of the Iowa economy, based on the Standard Industrial Classification of the U.S. economy are introduced in this chapter. This chapter also discusses the water supply situation in the study areas. The resource and income coefficients employed in the study are presented in this chapter, as well as a discussion of the inter-industry transactions matrix, which forms the main building block of any input-output model. This chapter concludes with the selection of the sectors of the Iowa economy which are the highest priority sectors.

Chapter 4 includes the result of the model application to the Iowa economy in general, and specifically to the eight water supply areas, while Chapter 5 contains summary and conclusion as well as suggestions for further improvements in the model.

CHAPTER II. THEORETICAL FRAMEWORK AND MODEL SPECIFICATION

In the theoretical framework, brief descriptions of the basic (open system) and the closed system input-output models will be presented. A comprehensive treatment of input-output analysis will not be presented here because this can be found in various texts (10, 20, 60). This discussion will be concluded by merging together the closed input-output and goal programming models into what will be called "synthesis" of goal programming and input-output models. Most of the symbols will be identical to the familiar symbols normally used in the literature (10, 50).

The Basic Input-Output Model

Consider an economy consisting of n producing sectors. In this analysis, the Iowa economy has been divided into 77 producing sectors, with agriculture consisting of four sectors, namely, livestock and livestock products; other agricultural products; forestry and fishery products; agriculture, forestry and livestock services. The following assumptions are considered to hold in the economy (18, p. 33):

a) each commodity (or groups of commodities) is produced by a single sector,

b) the inputs purchased by each sector depend on the level of output of the purchasing sector,

c) the total effect of carrying out several types of production activities is the summation of the separate effects.

Let

x_i = aggregate output of sector i,

x_{ij} = amount of intermediate input purchased by sector j from sector i,

f_i = final demand of a product produced by sector i.

This is also equal to the final output of sector i. The major final demand items are made up of household consumption, government expenditure, exports and investment.

The following two identities form the basis of the input-output analysis (20; 1, pp. 122-132). First, the total output of any sector is allocated between intermediate inputs (x_{ij}'s) and final outputs (f_i's). This identity can be expressed mathematically as follows:

$$x_i = x_{i1} + x_{i2} + \ldots + x_{in} + f_i, \; i = 1, 2, \ldots, n \tag{1}$$

Secondly, the level of output of any sector is a function of intermediate inputs purchased by that sector, i.e.,

$$x_j = x_j(x_{1j}, x_{2j}, \ldots, x_{nj}, x_{oj}), \; j = 1, 2, \ldots, n \tag{2}$$

where x_{oj} represents the total utilization of primary inputs in sector j and the functional relation is assumed to be homogeneous of the first degree. Assuming that

$$x_{ij} = a_{ij}x_j, \tag{3}$$

Equation 1 can be written as $(I - A)x = f$ (4)

where $A = ((a_{ij}))$ is a matrix of technical coefficients, called Leontief matrix, x_{nx1} is a vector of gross outputs of the producing sectors,

f_{nx1} is a vector of final outputs of producing sectors or vector of autonomous spending on final outputs (also called commodity expenditures). The technical coefficient, a_{ij}, represents the requirement of intermediate input from sector i per unit of output by sector j.

The equilibrium output levels in every sector of the economy can be computed as follows:

$$x = (I - A)^{-1}f \tag{5}$$

If the matrix A and the vector f are known, then x, the equilibrium output levels required to support f, can be computed. The inverse matrix $(I - A)^{-1}$ is called the Leontief inverse. The elements of this inverse matrix represent the total direct and indirect production required from sector i for each unit of output delivered to final demand by sector j. Making use of the growth projections of the economy of Iowa to the year 2020, the vector f can be computed. The most important application of the basic input-output model is to compute the vector x which can support the computed final demand vector. In the basic input-output model, the income-consumption linkage described in Chapter One is missing. This implies that the computed equilibrium levels of output (x) as well as the direct and indirect requirements are underestimations. In reality, when there is a change in final demand (f), production (x) changes; resource utilization (r) and income (Y) also change. As income changes, consumption changes and this further changes production and the process continues until it converges (in stable systems). The exclusion of the income-consumption linkage means that the basic model described above is not "closed," i.e., it is an open-system input-output model.

The Closed Input-Output System

The simplest way to close the basic model is to treat some element of final demand as dependent on the level of income (10, p. 63). In this study, a behavioral equation will be added to the above basic input-output model to explain those elements in the final demand vector, such as consumption, which depend in part on the level of income generated. These relations resemble the disaggregated Keynesian consumption function, but they contain some other variables which are specified in advance.

Assume that there are m primary and natural resources and n producing sectors in the economy, with each sector producing one homogeneous output. Let vectors $x = (x_1, x_2, \ldots, x_n)'$ and $r = (r_1, r_2, \ldots, r_m)'$ represent gross output and resource utilization, respectively. Let f_{nx1} represent final demand vector, and

$f_r = (f_{r1}, f_{r2}, \ldots, f_{rm})'$ = vector of final use of primary and natural resources, measured in physical units,

G = autonomous non-commodity expenditures (social security, welfare payments and other types of transfer incomes),

$v = (v_1, v_2, \ldots, v_n)'$ = vector of income coefficients of x,

$c = (c_1, c_2, \ldots, c_n)'$ = vector of disaggregated marginal propensity to consume goods and services,

$c_r = (c_{r1}, c_{r2}, \ldots, c_{rm})'$ = vector of disaggregated marginal propensity to consume primary and natural resources,

$\hat{c}$ = aggregated marginal propensity to consume primary and natural resources, and

B_{mxn} = a matrix of primary and natural resource requirements per unit of gross output.

Aggregate personal disposable income, Y, includes payments made by all the n producing sectors for primary and natural resources since these resources are the economy's only income earning inputs, i.e.

$$Y = Y_1 = Y_2 + \ldots + Y_n + Y_c + Y_G + Y_E \tag{6}$$

where Y_i = income received from producing sector i; Y_c = income received from household sector; Y_G = income received from the government sector; Y_E = income received from the foreign sector. It is recognized that income received from the household sector is what the household sector pays for the services of the primary and natural resources it utilizes. Assume that this household expenditure is related to aggregate income as

$$Y_c = \hat{c}Y + \bar{c} \tag{7}$$

where $\bar{c}$ is an autonomous component. Aggregate income can then be rewritten as

$$Y = \sum_{i=1}^{n} Y_i + \hat{c}Y + \bar{c} + Y_E + Y_G \tag{8}$$

Representing $\bar{c} + Y_E + Y_G$ by G (autonomous non-commodity expenditures), Equation 8 can be rewritten as

$$Y = \hat{n}(Y_1 + Y_2 + \ldots + Y_n + G) = \hat{n}(Y_1 + Y_2 + \ldots + Y_n) + \hat{n}G \tag{9}$$

where $\hat{n} = \frac{1}{1-\hat{c}}$. Incorporating the induced consumption of commodity outputs as well as the consumption of primary and natural resources which arise from changes in income, the bookkeeping identity of Equation 1 can be reformulated in the closed input-output context as

$$x_i = \sum_{j=1}^{n} x_{ij} + c_i Y + f_i,\ i = 1, 2, \ldots, n \tag{10}$$

$$r_i = \sum_{j=1}^{n} r_{ij} + c_{ri} Y + f_{ri},\ i = 1, 2, \ldots, n \tag{11}$$

The fixed coefficient input-output model implies that Equation 3 holds. Assuming fixed income and resource utilization coefficients, the purchase of resource i by sector j,

$$r_{ij} = b_{ij} x_j \tag{12}$$

and Y_j, the income accruing from sector

$$j = v_j x_j \tag{13}$$

Making use of Equations 3, 12, and 13, Equations 9-11 can be written in matrix notation as

$$(I - D)x = \hat{d} \tag{14}$$

where

$$x_{(n+m+1)x1} = (x_1, x_2, \ldots, x_n, r_1, r_2, \ldots, r_n, Y)', \tag{15a}$$

$$\hat{d}_{(n+m+1)x1} = (f_1, f_2, \ldots, f_n, f_{r1}, f_{r2}, \ldots, f_{rn}, \hat{n}G)' \tag{15b}$$

$$D_{(n+m+1)x(n+m+1)} = \begin{bmatrix} a_{11} & \cdots & a_{1n} & 0 & \cdots & c_1 \\ \cdot & & & & & \\ \cdot & & & & & \\ \cdot & & & & & \\ a_{n1} & \cdots & a_{nn} & 0 & \cdots & c_n \\ b_{11} & \cdots & b_{1n} & 0 & \cdots & c_{r1} \\ \cdot & & \cdot & \cdot & & \\ \cdot & & \cdot & \cdot & & \\ \cdot & & \cdot & \cdot & & \\ b_{m1} & \cdots & b_{mn} & 0 & \cdots & c_{rm} \\ \hat{V}_1 & \cdots & \hat{V}_n & 0 & \cdots & 0 \end{bmatrix} \tag{15c}$$

and

$$\hat{V} = \hat{n}V_i \ \ldots \tag{15d}$$

Recalling that (I-A) in the basic model is the original Leontief matrix, (I-D) in the closed model becomes the augmented Leontief matrix. $(I-D)^{-1}$ is the augmented Leontief inverse which translates the specified final demand vector, f, into the equilibrium amounts of the economy's gross production x, employment of primary and natural resources r, and total income Y when the income-consumption linkage is taken into account.

The augmented Leontief inverse, $(I-D)^{-1}$, can be shown to be equivalent to the following partitioned matrix (53, p. 94).

$$(I-D)^{-1} = \begin{bmatrix} (I-A-c\hat{v}')^{-1} & 0 & (I-A-c\hat{v}')^{-1}c \\ (B+c_r\hat{V}')(I-A-c\hat{v}')^{-1} & I_m & c_r+(B+c_r\hat{V}')(I-A-c\hat{v}')^{-1}c \\ \hat{V}'(I-A-c\hat{v}')^{-1} & 0 & 1+\hat{v}'(I-A-c\hat{v}')^{-1}c \end{bmatrix} \tag{16}$$

The $(I-A)^{-1}f = x$ of the open input-output model is thus transformed into

$$(I-D)^{-1}\hat{d} = x \tag{17}$$

in the closed input-output model. The open system assumes that c=o and $\hat{c}$=0 (25, 54), i.e., a change in income does not create a change in consumption of commodities and natural resources, and as a result, $\hat{n}$=1, $\hat{v}$=v. Thus, the employment of the open system simplifies $(I-D)^{-1}$ into

$$(I-D)^{-1} = \begin{bmatrix} (I-A)^{-1} & 0 & 0 \\ B(I-A)^{-1} & I_m & 0 \\ V'(I-A)^{-1} & 0 & 1 \end{bmatrix} \tag{18}$$

Multiplier Analysis

Input-output analysis provides an effective way of tracing the effects of a shock in one sector of the economy on all the remaining sectors. This is possibly due to the interdependence within the economic system. The food and kindred sector of the economy, for example, uses intermediate inputs from the agricultural sector which uses machinery and other inputs from the manufacturing sector. The manufacturing sector, in turn, uses intermediate inputs from other sectors of the economy. All the major sectors use water, energy, and labor. Assume that there is an increase in final demand (final output) for chemicals and chemical products, i.e., industrial inorganic and organic chemicals, fertilizers, pesticides, herbicides, and other agricultural chemicals. To support this increase in demand, the chemicals and chemical products sector of the economy needs intermediate inputs from other sectors of the economy. The major suppliers of inputs for the chemicals and chemical products sector are the agricultural, mining, crude petroleum and natural gas, maintenance and repair construction, food and kindred, plastic and synthetic materials, business services, and the transportation sectors. It also requires intermediate inputs from within the chemicals industry as well. All the major sectors which supply intermediate inputs to the chemicals industry also require intermediate inputs from other sectors of the economy.

The question that arises is, what is the aggregate increase in output, employment of primary and natural resources as well as income in the economy as a result of the increase in final demand from the chemicals and chemical products sector of the economy? This is the question that the multiplier analysis seeks to answer. Two types of multipliers can be derived from the input-output analysis, namely, the type I and type II multipliers. The type I and type II multipliers are derived from the basic input-output and the closed input-output models, respectively, and the significance of the income consumption linkage for the income effect is usually quantified in terms of the type II multiplier (6, 5, 27, 11). An increase in f_i, final demand from sector i, requires not only an increase in x_i directly, but also increases in x_j, where j ranges from 1 to n, indirectly due to the interdependence in production within the economy as described above. Since production requires the use of primary and natural resources, owners of these resources realize an increase in income. What the income consumption linkage says is that as income increases, consumption increases, too, leading to an induced increase in production. This induced increase in production requires a further increase in resource utilization (including water resources) which leads to further increases in income and production until the process converges.[1]

In the basic input-output model, $(I-A)^{-1}$, $B(I-A)^{-1}$, and $V'(I-A)^{-1}$ are the production multiplier matrix, resource employment multiplier matrix, and income multiplier vector, respectively. These multipliers do not include the income effect on consumption, production, and resource utilization. The sum of the elements of column j of the $(I-A)^{-1}$ matrix, k_j, represents how much output is ultimately increased as a result of one unit increase in final demand from sector j. The column sums of $B(I-A)^{-1}$ matrix give the resource employment multipliers for the corresponding economic sectors in the basic input-output model. In the closed input-output model, the output multiplier matrix is $(I-A-c\hat{v}')^{-1}$, while the resource employment and income multiplier matrices are $(B+c_r\hat{V}')(I-A-c\hat{v}')^{-1}$ and $\hat{V}'(I-A-c\hat{v})^{-1}$, respectively. It can be noted that the inclusion of the income effect changes $(I-A)^{-1}$, A, B of the open system into $(I-A-c\hat{v}')^{-1}$, $(A+c\hat{v}')$ and $(B+c_r\hat{V}')$, respectively. This implies that a_{ij} of the basic model is transformed

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[1]See Appendix A for proof.

into $(a_{ij} + c_i\hat{v}_j)$ and b_{ij} is transformed into $(b_{ij} + c_{ri}\hat{v}_j)$. Hence, instead of each unit of product j being associated with a_{ij} of sector i's output as in the basic model, it is now associated with $(a_{ij}+c_i\hat{v}_j)$ units of sector i's product and $(b_{ij}+c_{ri}\hat{v}_j)$ units of resource i.

An inspection of the augmented Leontief matrix shows clearly that its inversion will not be an easy task if the size of the matrix is large. Another reason for the increased computational burden to be expected from $(I-D)^{-1}$ is the inclusion of $(I-A-c\hat{v}')^{-1}$. The inclusion of the c vector in $(I-D)^{-1}$ also presents special problems. Since the c vector is a behavioral vector, its elements can be expected to be more volatile than the other elements of the augmented Leontief matrix (60, 51). This implies that when c changes, $(I-D)^{-1}$ has to be changed, and this process will unquestionably be too costly.

Fortunately, the following theorem in linear algebra helps to ease the computational burden (24, p. 211).

Theorem 1: If B is an nxn non-singular matrix and e and f are nx1 vectors, then $|B+ef'| = |B|\ (1+f'B^{-1}e)$. If the inverse of $(B+ef')$ exists, then it is given by

$$(B+ef')^{-1} = B^{-1} - \frac{(B^{-1}e)(f'B^{-1})}{1+f'B^{-1}e}$$

Making use of the above theorem,

$$(I-A-c\hat{v}')^{-1} = (I-A)^{-1} + \frac{((I-A)^{-1}c)(\hat{v}'(I-A)^{-1})}{1-\hat{v}'(I-A)^{-1}c} \tag{19}$$

$$(B+c_r\hat{v}')(I-A-c\hat{v}')^{-1} = B(I-A)^{-1} + \frac{(B(I-A)^{-1}c+c_r)\hat{v}'(I-A)^{-1}}{1-\hat{v}'(I-A)^{-1}c} \tag{20}$$

$$\hat{V}'(I-A-c\hat{v}')^{-1} = \frac{\hat{V}'(I-A)^{-1}}{1-\hat{V}'(I-A)^{-1}c} \tag{21}$$

$$c_r + (B+c_r\hat{v}')(I-A-c\hat{v}')^{-1}c = \frac{B(I-A)^{-1}c+c_r}{1-\hat{v}'(I-A)^{-1}c} \tag{22}$$

$$1 + \hat{v}'(I-A-c\hat{v}')^{-1}c = \frac{1}{1-\hat{v}'(I-A)^{-1}c} \tag{23}$$

Thus, $(I-D)^{-1} =$

$$\begin{bmatrix} (I-A)^{-1} + \dfrac{(I-A)^{-1}c\hat{v}'(I-A)^{-1}}{1-\hat{v}'(I-A)^{-1}c} & 0 & \dfrac{(I-A)^{-1}}{1-\hat{v}'(I-A)^{-1}c} \\ B(I-A)^{-1} + \dfrac{(B(I-A)^{-1}c+c_r)\hat{v}'(I-A)^{-1}}{1-\hat{v}'(I-A)^{-1}c} & I_m & \dfrac{B(I-A)^{-1}c+c_r}{1-\hat{v}'(I-A)^{-1}c} \\ \dfrac{\hat{V}'(I-A)^{-1}}{1-\hat{v}'(I-A)^{-1}c} & 0 & \dfrac{1}{1-\hat{v}'(I-A)^{-1}c} \end{bmatrix} \tag{24}$$

$(I-D)^{-1}$ can thus be reduced to elements of known submatrices $(I-A)^{-1}$, B, V which can be obtained from Dr. Barnard's revised input-output tables (59), and the vectors c and c_r can be computed from state macroeconomic data.

From $x = (I-D)^{-1}\hat{d}$, the equilibrium element of $x=x^* = (x_1^*, x_2^*, \ldots, x_n^*, r_1^*, r_2^*, \ldots, r_m^*, Y^*)'$ can be computed, when $\hat{d} = (f_1, \ldots, f_n, fr_1, \ldots, fr_m, nG)'$ is known. One basic argument about solutions to input-output systems is that the optimum x* computed does not take resource restrictions into consideration. This shortcoming is usually circumvented by reformulating the model in a linear programming framework (20, 45). Note that the closed system solution $x = (I-D)^{-1}\hat{d}$ is as follows:

Equilibrium output

$$x^* = (x_1^*, \ldots, x_n^*)' = (I-A-c\hat{v}')^{-1}(f+c\hat{n}G) \tag{25}$$

Equilibrium resource employment

$$r^* = (B+c_r\hat{v}')(I-A-c\hat{v}')^{-1}(f+c\hat{n}G) + f_r + c_r\hat{n}G \tag{26}$$

Equilibrium income

$$Y^* = \hat{v}'x^* + \hat{n}G \tag{27}$$

From Equation 25,

$$(I-A-c\hat{v}')^{-1}X^* = f + c\hat{n}G. \tag{28}$$

Substituting x* into Equation 26 and rearranging Equation 27, produces the following:

$$-(B+c_r\hat{v}')x^* + r^* = f_r + c_r\hat{n}G \tag{29}$$

$$-\hat{v}'x^* + Y^* = \hat{n}G. \tag{30}$$

Denoting primary and natural resource availabilities by $\bar{r}$, uses of resources $r^* \leq \bar{r}$.

Hence, from Equation 29, $(B+c_r\hat{V}')x^* = r^*-(f_r+c_r\hat{n}G)$ and

$$(B+c_r\hat{V}')x^* \leq \bar{r} - (f_r+c_r\hat{n}G) \tag{31}$$

In a linear programming framework, the above system of equations can be written as the maximization of (30), subject to (28) and (29). Equation 28 can be written as follows:

$$(I-A-c\hat{v}')^{-1}x^* \leq f + c\hat{n}G \tag{32}$$

because resource constraints can curtail the attainment of x and hence f might not be realized. In the linear programming model, the constraints would be the input-output system of equations with income effect incorporated, i.e., $(I-A-c\hat{v}')^{-1}x^* \leq f + c\hat{n}G$ and the primary and natural resource constraint equation (31).

In other words, when the closed input-output system is formulated in a linear programming (L/P) context, the aim is to have an objective function which can be optimized subject to resource constraints. In the above problem, the objective function to be optimized is aggregate disposable personal income. In real life, we might not have only one objective to be optimized. The real world decision making process employs multi-objective criteria, and the objectives are often conflicting. For an L/P solution to be feasible, all the constraints must be satisfied. But under certain conditions, we may not need to satisfy all the restrictions imposed on a model. Society usually has objectives and priorities and in actual practice certain objectives command higher priorities than others. This fact brings us into the domain of goal programming.

Goal Programming

In previous studies, the development of mathematical models of decision making problems have been done according to the following fixed set of rules:

1) the identification of the decision or control variables within the problem,
2) the formation of an objective, which is to be optimized, as a function of the decision variables,

3) the conversion of the resource limitations and any other restrictions into mathematical functions of the decision variables; such functions are noted as constraints,
4) the optimization of the single objective subject to the absolute satisfaction of the set of constraints.

A consideration of the shortcomings of single objective models and the attributes of real world problems reveals that the development of more valid models should include the following philosophy: The model should express the desire to have a compromise solution to a set of objectives.

Goal programming is one of the methods which have been proposed for dealing with the modeling, solution and analysis of decisions which involve the type of problems typically encountered in actual practice--problems with multiple objectives (9, 16, 32, 44, 46). Such multiple objectives may be either complementary or conflicting, and in addition the units of measure may be non-homogeneous in nature; for example, achieving x billion dollars of output from the manufacturing sector, irrigating Y acres of class I land, and using Z acre-feet of water from a certain alluvial groundwater source. We could also examine a state's long-range economic plan which evaluates the long-range objectives and resource requirements of the economy. In most cases, the resources required exceed the resources available. There exists competition for the resources among the various projects. If we are able to assign priorities to the competitive projects then this problem can be formulated in a goal programming framework with multiple objectives. The above example illustrates the weakness of linear programming, which is developed solely to quantify one goal as an objective function.

Some fundamental concepts of goal programming

Certain ideas and notions are important in the ultimate structure of the goal programming version of the multi-objective model. These will be introduced in this section, but unfortunately, the terminology is not standard. The following definitions (29) are aimed at clarifying the goal programming model, its rationale, and components.

Objective   This is a general statement reflecting either of the following:

1) the desires of the decision maker,
2) limited resources, or
3) any other restrictions, either explicitly or implicitly placed on the choice of the decision variables.

Typical objectives in the first class include maximization of profit or minimization of the use of energy in the transportation and household sectors of the economy. Objectives within the second class include the objective either not to violate or perhaps to minimize the violation of resource restrictions such as limited water supply or limited labor. Objectives within the final class could include satisfying or attempting to satisfy various legal restrictions such as a physical requirement that a variable or variables must equal or not exceed a certain minimum value.

Aspiration level This is a specific value which ties the objectives to reality. Typically, the aspiration level is expressed in terms of a specific measure of the achievement of an objective.

Goal An objective, in conjunction with an aspiration level, is termed a goal. For example, we may wish to pump at most X gallons of water from a particular groundwater supply source, use at most Y British thermal units of energy in the household sector, and create Z jobs in the economy. It can be realized that resource limitations and other restrictions, typically denoted as constraints, also find a representation within this framework.

Goal deviation The fact that not all aspirations can be achieved and not all restrictions may be strictly satisfied is a rather natural outcome in real life. Consequently, in all but trivial problems, we often encounter deviations from the problem goals, and normally we seek to minimize these deviations.

Achievement function The measure of the accomplishment of a single objective is represented by the objective function and its associated value. But when dealing with multiple objectives where we wish to minimize the deviation from aspiration goals, a more appropriate terminology exists in the concept of the achievement function. In goal programming, the achievement function represents the optimal compromise and its measure (31).

Constraints In single objective models, constraints are mathematical requirements which must be completely satisfied for the solution(s) to be mathematically feasible. However, the concept of a goal provides a more flexible framework for multi-objective models. If a goal is truly a constraint, it is termed an absolute goal and its non-satisfaction renders the solution unimplementable.

The goal programming model is formulated by bringing the above concepts together as follows: let

$f_i(\bar{x})$ = the mathematical representation of objective i as a function of the decision variables, where

$\bar{x} = x_1, x_2, \ldots, x_j$,

b_i = the aspiration level associated with goal i.

The function $f_i(\bar{x})$ is expected to be either equal or less than, equal or greater than, or strictly equal to the aspiration level b_i. Let n_i be the negative (under) deviation associated with goal i and p_i be the positive (over) deviation associated with goal i. Table 2.1 is a representation of any type of goal.

Table 2.1. Goal programming formulation[a]

Goal type	Mathematical form	Deviation variable to be minimized
$f_i(\bar{x}) \leq b_i$	$f_i(\bar{x}) + n_i - p_i = b_i$	p_i
$f_i(\bar{x}) \geq b_i$	$f_i(\bar{x}) + n_i - p_i = b_i$	n_i
$f_i(\bar{x}) = b_i$	$f_1(\bar{x}) + n_i - p_i = b_i$	$n_i + p_i$

[a]Source: (29, p. 16).

Table 2.1 shows that the accomplishment of a given goal may be represented solely in terms of the deviation variables. Hence, the achievement function is given strictly in terms of n_i and p_i, the deviation variables. The attempt to minimize the deviation from the achievement of a particular goal fits very well with the "satisficing" concept as advanced by March and Simon (49). This concept states that most human decision making problems involve the discovery and selection of satisfactory alternatives, and it is only in rare cases that decision making involves the discovery and selection of optimal alternatives. Except in very simple real world problems, it is usually unlikely that a decision maker could obtain a set of optimal solutions to major complex problems.

Some specific goal programming methodologies

Most of the early works in multi-objective analysis and goal programming have laid emphasis on applied science and engineering. Dantzig (17) was the first to introduce the theoretical concepts of mathematical programming. Dantzig's work was mainly in search of techniques to solve logistic problems for military planning in the early 40s. Charnes and Cooper (7) joined Dantzig in the refinement of the techniques of linear programming, and through their continuing research, they developed the concept of goal programming. Incorporating the fundamental concepts of goal programming into non-linear models, Ignizio developed a methodology which was implemented in the determination of the deployment of the antennas for the Saturn S-II launch vehicle (28), the second stage of the launch vehicle which ultimately placed the Apollo space vehicle in moon orbit.

One of the better known discussions of goal programming appeared in the 1961 text by Charnes and Cooper. Goal programming as proposed by Charnes and Cooper dealt strictly with linear multi-objective models. The key to their approach was the use of deviation variables explained earlier in this study. By specifying aspiration levels and adding deviation variables to conflicting objectives, a linear multi-objective problem can be transformed into a conventional single-objective linear programming model. This approach used by Charnes and Cooper resulted in a version of goal programming termed "weighted linear goal programming" (8, 31).

The concept of weighted linear goal programming will be illustrated by the use of an example originally proposed by Zimmerman (61). The problem is to find values of x_1 and x_2 so as to:

$$\text{maximize } z_1 = 2x_1 + x_2 \tag{33}$$

$$\text{maximize } z_2 = -x_1 + 2x_2 \tag{34}$$

such that:

$$-x_1 + 3x_2 \leq 21 \tag{35}$$

$$x_1 + 3x_2 \leq 27 \tag{36}$$

$$4x_1 + 3x_2 \leq 45 \tag{37}$$

$$3x_1 + x_2 \leq 30 \tag{38}$$

$$x_1 \quad x_2 \geq 0 \tag{39}$$

Equations 33 and 34 are the objectives while Equations 35 through 39 are restrictions. The conversion of the above multi-objective problem into the weighted goal programming equivalent requires that specific values be assumed for the aspiration levels z_1 and z_2. In the example proposed by Zimmerman, it was assumed that z_1 is 40 units and z_2 is 20 units. It can be noted that only the negative goal deviations are minimized since the aim is to maximize z_1 and z_2. The next step in the solution of the problem is to assume weights for the objectives. It was assumed that objective one is two times as important as objective two. The above assumptions transform the original multi-objective problem into the following weighted linear goal programming model:

$$\text{minimize } n_1 + 2n_2 \tag{40}$$

such that

$$-x_1 + 3x_2 \leq 21 \tag{41}$$

$$x_1 + 3x_2 \leq 27 \tag{42}$$

$$4x_1 + 3x_2 \leq 45 \tag{43}$$

$$3x_1 + x_2 \leq 30 \tag{44}$$

$$G_1: 2x_1 + x_2 + n_1 - p_1 = 40 \tag{45}$$

$$G_2: - x_1 + 2x_2 + n_2 - p_2 = 20 \tag{46}$$

$$\bar{x}, \bar{n}, \bar{p} \geq 0 \tag{47}$$

where G_i represents goal i.

Equation 40 is the achievement function, Equations 45 and 46 are the two goals in the model, while Equations 41 through 44 are the absolute objectives (or rigid constraints). The solution to the above weighted linear goal programming problem occurs at $x_1 = 3$, $x_2 = 8$ as shown by x* in Figure 2.1.

Since this approach reduces the estimation technique to that of conventional linear programming, all the characteristics of linear programming solution are associated with the solution to the weighted linear goal programming.

The major problem with the weighted linear goal programming is the determination of the weights. Another version of goal programming, termed Lexicographic goal programming, circumvents the weighting problems encountered in weighted linear goal programming (29, 33, 47). In strict lexicographic goal programming, no weights are employed. The analyst simply has to rank each objective according to preference. Consider a problem with four objectives, z_1, z_2, z_3, z_4, where the subscripts refer to the rank order of the objective. Assume the aspiration levels are b_1, b_2, b_3, and b_4, respectively. Adding the aspiration levels and deviation variables to the objectives transforms the objectives into goals G_1, G_2, G_3, and G_4:

$$G_1\colon f_1(\bar{x}) + n_1 - p_1 = b_1$$

$$G_2\colon f_2(\bar{x}) + n_2 - p_2 = b_2$$

$$G_3\colon f_3(\bar{x}) + n_3 - p_3 = b_3$$

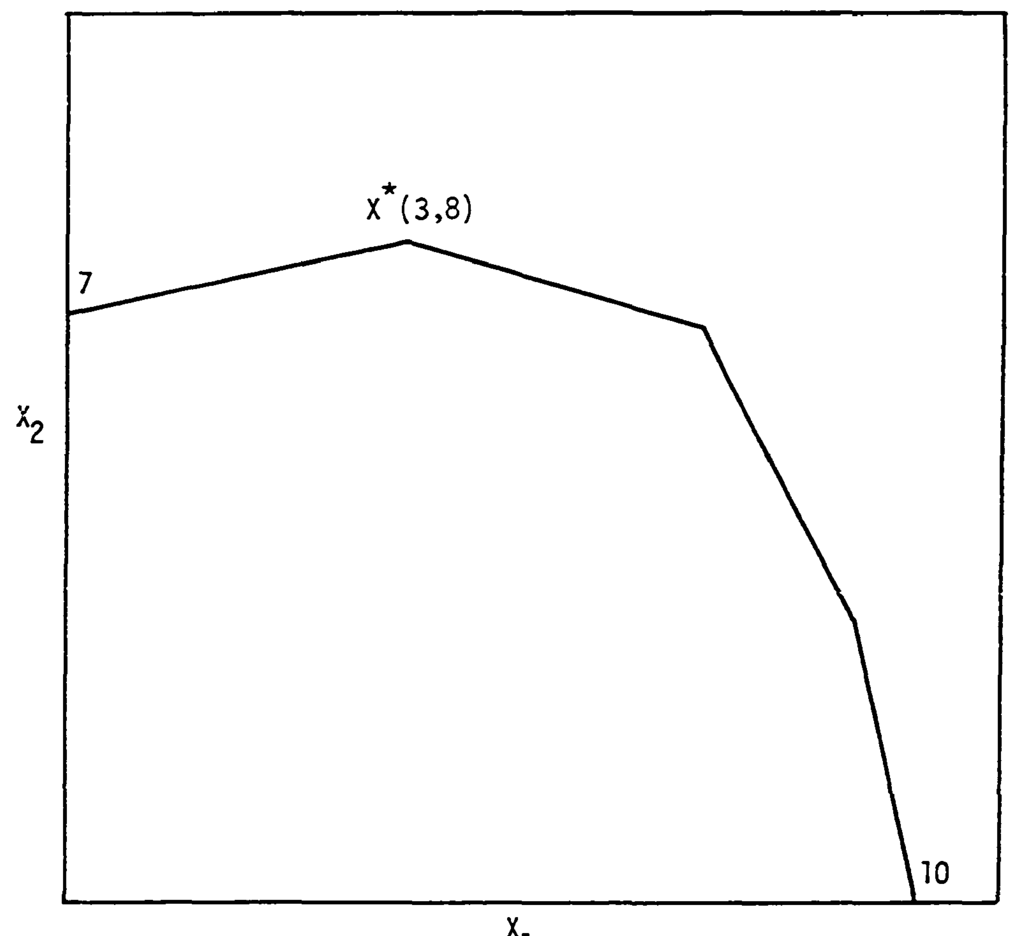

Fig. 2.1. Graph of weighted linear goal programming

G_4: $f_4(\bar{x}) + n_4 - p_4 = b_4$

The achievement function is represented in terms of the deviations of the above goals from their aspiration levels and is represented as $\bar{a}$, where

$$\bar{a} = \{g_1(n_1,p_1),\ g_2(n_2,p_2),\ g_3(n_3,p_3),\ g_4(n_4,p_4)\}$$

and $g_k(n_k,p_k)$ = a function of n_k and p_k, the deviation variables from goal k.

$$\text{Hence, } g_k(n_k,p_k) = \begin{cases} n_k \text{ if } f_k(\bar{x}) \geq b_k \\ p_k \text{ if } f_k(\bar{x}) \leq b_k \\ n_k + p_k \text{ if } f_k(\bar{x}) = b_k \end{cases}$$

The final problem formulation is of the following form: find $\bar{x}$ = $(x_1, x_2, \ldots, x_j)$ so as to minimize $\bar{a}$, such that G_i, i = 1, 2, 3, 4, hold. Since the goals have been ranked, the solution that provides the lexicographic minimum to this ranking is considered optimal. That is, the solution $\bar{x}$ to the lexicographic linear goal programming model is termed optimal if for this solution (termed $\bar{x}^*$) the corresponding value of $\bar{a}$ (termed $\bar{a}^*$) is the same or preferred to the value of $\bar{a}$ for any feasible solution. The vector $\bar{a}^*$ will be preferred to the vector $\bar{a}$ if the first non-zero component of $(\bar{a}^*-a)$ is negative given that all elements of $\bar{a}^*$ and $\bar{a}$ are themselves non-negative (29).

The lexicographic approach can be extended to include several weighted goals within each ranking, provided the goals within a ranking are commensurable. This procedure transforms the achievement function to:

$$\bar{a} = \{g_1(\bar{n},\bar{p}),\ g_2(\bar{n},\bar{p}),\ \ldots,\ g_k(\bar{n},\bar{p})\}$$

where $g_k(\bar{n},\bar{p})$ is a function of the associated weighted deviation variables for those goals at k-th level of ranking. This model is then called lexicographic, weighted goal programming and the problem is to seek the lexicographic minimum of $\bar{a}$.

In goal programming there is a need for the decision maker to determine the relative importance of the goals before any attempt is made to obtain a solution. The two major ranking procedures used in determining priorities of goals are:

1) pre-emptive ordering or ordinal ranking (mainly associated with lexicographic, weighted linear goal programming),
2) archimedian ordering or cardinal ranking (also referred to as weighted priority).

The notion of pre-emptive priorities (33) is based on the fact that the achievement of a set of goals, at priority K, is always preferred to those at any lower priority (>K) despite any scalar multiple associated with the lower ranked set of goals. Pre-emptive priorities can also be represented by the following notation:

$$p_{J+1} >>> np_J$$

which implies that the multiplication of p_J (priority level J) by n, where n is greater than one, cannot make p_J exceed or equal p_{J+1}.

Hence, the J-th decision making goal must be achieved as much as possible before an attempt is made to satisfy the goal associated with p_{J+1} priority level. The hierarchy of importance which is established in the problem formulation permits consideration of low-ordered goals only after the higher order goals have first been optimized over the given space.

Cardinal ordering is a method of ranking the goals in the objective function by assigning them specific weights. The cardinal value associated with each decision-making goal in the objective function indicates its weighted importance with respect to the other goals. Goals of higher importance are satisfied before goals of lower importance are considered. If the weights are known, the goal programming problem can be converted into conventional linear programming problem. The problem with cardinal ordering is that most often the exact values of the weights are simply not available. But this leads us into the realm of sensitivity analysis where the analyst alters the weights attached to the goals at each priority level and evaluates the effects of such changes on the problem solutions.

The Goal Programming Input-Output Model Employed in This Study

In the absence of the lexicographic goal programming model which is more flexible, the weighted linear goal programming model will be employed in this study despite its strict limitations. The IBM

Mathematical Programming System, MPSX (55, pp. 241-260), will be adapted to the Weighted Linear Goal Programming Model. Ten goals are selected based on sectoral output and employment considerations. The acceptable solution will be those which satisfy these ten goals completely. All ten goals are considered at the same priority level, that is, they are given unit weights in the achievement function, which implies that limited resources will be allocated to these ten sectors before any other remaining sectors are considered. The selection of only ten sectors of the economy as being the most important sectors is due to the realization, after many computer runs, that the MPSX version of the goal programming model was not flexible enough to accommodate more than ten goals. It was also found that any attempt to change the unit weights attached to the goals resulted in many infeasibility problems.

The goal programming input-output merger will be specified as follows: find $\bar{x}$ so as to minimize

$$\sum_{K=1}^{10} W_K(P_K - n_K) \tag{48}$$

Such that the following equations are satisfied:

$$(I-A-c\hat{v}')^{-1}x + \bar{n} - \bar{p} = \bar{f} \tag{49}$$

$$(B+c_r\hat{v}')\bar{x} + \bar{n} - \bar{p} = \bar{r} - \bar{f}_r \tag{50}$$

$$\hat{v}'\bar{x} + \bar{n} - \bar{p} = \bar{Y} \tag{51}$$

$$\bar{x}, \bar{n}, \bar{p} \geq \bar{0} \tag{52}$$

Equation 48 is the achievement function representing the minimization of the deviational variables associated with the ten goals which will be selected in this analysis. The W_K's are the weights (unit weights) attached to each deviational variable. Equations 49-51 are the closed input-output system, the resource constraint equations, and the disposable income equations, respectively, while Equation 52 represents the non-negativity constraint. As noted in the input-output discussions, $\bar{f}$ is the vector of final demands of goods and services. It is made up of household consumption expenditure, government expenditure, exports, and investment items. The aspirational level vector $\bar{r}$ represents the vector of total use of primary and natural resources (measured in physical units), while $\bar{f}_r$ represents a vector of final use of primary and natural resources (only the final use of water is considered).

Specification of model constraints

Since this study concentrates mainly on the allocation of water between all sectors of the Iowa economy, it is necessary to obtain detailed information on water availabilities in each of the eight water supply areas of Iowa. Three sources of water are considered in the study. These are surface runoff (or stream flow), reservoir water and groundwater. Groundwater is further broken into two categories: 1) alluvial water and 2) all other groundwater. These sources of water will be discussed in detail in the next chapter.

Let

RES^R = volume of reservoir water available in water supply area R in gallons, R = 1, 2, ..., 8;

$GW1^R$ = volume of alluvial groundwater available in water supply area R, R = 1, 2, ..., 8;

$GW2^R$ = volume of all other groundwater available in water supply area R, R = 1, 2, ..., 8;

SF^R = volume of surface runoff available in water supply area R, R = 1, 2, ..., 8.

It is assumed that only flood plain, class 1, class 2S and class 2E lands are irrigated and that corn is the only crop irrigated. Let

FP^R = acreage of flood plain land available in water supply area R, R = 1, 2, ..., 8;

$CL1^R$ = acreage of class 1 land available in water supply area R, R = 1, 2, ..., 8;

$CL2S^R$ = acreage of class 2S land available in water supply area R, R = 1, 2, ..., 8;

$CL2E^R$ = acreage of class 2E land available in water supply area R, R = 1, 2, ..., 8.

Two irrigation scenarios will be considered. These are 1) irrigate all class 1 (field crops) and class 2S lands, and 2) irrigate all flood plain, class 2S and class 2E, lands. Let

W^R_{RES} = gallons of reservoir water required to irrigate one acre of land in water supply area R, R = 1, 2, ..., 8;

W^R_{GW1} = gallons of alluvial groundwater (GW1) required to irrigate one acre of land in water supply area R, R = 1, 2, ..., 8;

W^R_{GW2} = gallons of all other groundwater supplies required to irrigate one acre of land in water supply area R, R = 1, 2, ..., 8;

W^R_{SF} = gallons of stream flow required to irrigate one acre of land in water supply area R, R = 1, 2, ..., 8;

FP^R_j = acreage of flood plain land irrigated from water supply source j in area R, R = 1, 2, ..., 8, j = reservoir water (RES), alluvial water (GW1), all other groundwater (GW2), stream flow (SF);

$CL1^R_j$ = acreage of class 1 land irrigated from water supply source j in area R, R = 1, 2, ..., 8, j = RES, GW1, GW2, SF;

$CL2S^R_j$ = acreage of class 2S land irrigated from water supply source j in area R, R = 1, 2, ..., 8, j = RES, GW1, GW2, SF;

$CL2E^R_j$ = acreage of class 2E land irrigated from water supply source j in area R, R = 1, 2, ..., 8, j = RES, GW1, GW2, SF;

w_i = water coefficient of industrial section i in gallons per dollar of output, i = 1, 3, 4, 5, ..., 77.

Then for irrigation scenario 1, the constraint on the water supply sources are as follows:

Reservoir water utilized in water supply area R should not exceed the available volume, i.e.,

$$W^R_{RES}CL1^R_{RES} + W^R_{RES}CL2S^R_{RES} \leq RES^R, \; R = 1, 2, \ldots, 8. \tag{53}$$

Alluvial water utilized in water supply area R should not exceed the available volume:

$$W^R_{GW1}CL1^R_{GW1} + W^R_{GW1}CL2S^R_{GW1} \leq GW1^R, \; R = 1, 2, \ldots, 8. \tag{54}$$

The utilization of all other groundwater supplies (GW2) in water supply area R should not exceed the available volume:

$$W^R_{GW2}CL1^R_{GW2} + W^R_{GW2}CL2S^R_{GW2} \leq GW2^R, \; R = 1, 2, \ldots, 8. \tag{55}$$

Stream flow utilized in water supply area R should not exceed the available volume:

$$W^R_{SF}CL1^R_{SF} + W^R_{SF}CL2S^R_{SF} \leq SF^R, \; R = 1, 2, \ldots, 8. \tag{56}$$

For irrigation scenario 2, the water supply constraints are as follows:

Reservoir water utilized in water supply area R should not exceed the available volume, i.e.,

$$W^R_{RES}FP^R_{RES} + W^R_{RES}CL2S^R_{RES} + W^R_{RES}CL2E^R_{RES} \leq RES^R, \tag{57}$$

$R = 1, 2, \ldots, 8.$

Alluvial water utilized in water supply area R should not exceed the available volume:

$$W^R_{GW1}FP^R_{GW1} + W^R_{GW1}CL2S^R_{GW1} + W^R_{GW1}CL2E^R_{GW1} \leq GW1^R, \tag{58}$$

$R = 1, 2, \ldots, 8.$

The utilization of all other groundwater supplies should not exceed the available volume:

$$W^R_{GW2}FP^R_{GW2} + W^R_{GW2}CL2S^R_{GW2} + W^R_{GW2}CL2^R_{GW2} \leq GW2^R, \qquad (59)$$

$R = 1, 2, \ldots, 8.$

Stream flow utilized in water supply area R should not exceed the available volume:

$$W^R_{SF}FP^R_{SF} + W^R_{SF}CL2S^R_{SF} + W^R_{SF}CL2E^R_{SF} \leq SF^R, \qquad (60)$$

$R = 1, 2, \ldots, 8.$

Aggregate Water Utilization Constraint: Aggregate water allocated to all industries plus water utilized for irrigation in all water supply areas plus final demand (residential water usage in each supply area) should not exceed the sum of water supply from all sources in the state. The aggregate water requirement constraint can be specified mathematically as follows for the two irrigation scenarios.

Scenario 1.

$$W_1X_1 + \sum_{j=1}^{4} \sum_{R=1}^{8} W^R_j CL1^R_j + \sum_{j=1}^{4} \sum_{R=1}^{8} W^R_j CL2S^R_j + \sum_{i=3}^{77} W_iX_i + \sum_{R=1}^{8} FDW^R \leq W^S \qquad (61)$$

Scenario 2.

$$W_1X_1 + \sum_{j=1}^{4} \sum_{R=1}^{8} W^R_j FP^R_j + \sum_{j=1}^{4} \sum_{R=1}^{8} W^R_j CL2S^R_j + \sum_{j=1}^{4} \sum_{R=1}^{8} W^R_j CL2E^R_j + \sum_{i=3}^{77} W_iX_i$$

$$+ \sum_{R=1}^{8} FDW^R \leq W^S \qquad (62)$$

where

j = RES, GW1, GW2, SF;

X_i = gross output of industrial sector i;

W^S = aggregate state water supply; and

FDW^R = final demand for water in water supply area R.

It can be observed from the aggregate water supply equations that X_2 has been dropped. This is because in the analysis it is assumed that economic sector 2, which is the crop agricultural sector, utilizes water mainly for irrigation.

Land Constraints: Flood plain land irrigated in water supply areas R should equal the available acreage, i.e.

$$FP^R_{RES} + FP^R_{GW1} + FP^R_{GW2} + FP^R_{SF} = FP^R, \; R = 1, 2, \ldots, 8. \tag{63}$$

Class 1 land irrigated in water supply area R should equal the available acreage:

$$CL1^R_{RES} + CL1^R_{GW1} + CL1^R_{GW2} + CL1^R_{SF} = CL1^R, \; R = 1, 2, \ldots, 8. \tag{64}$$

Class 2S land irrigated in water supply area R should equal the available acreage:

$$CL2S^R_{RES} + CL2S^R_{GW1} + CL2S^R_{GW2} + CL2S^R_{SF} = CL2S^R, \tag{65}$$

$R = 1, 2, \ldots, 8.$

Class 2E land irrigated in water supply area R should equal the available acreage:

$$CL2E^R_{RES} + CL2E^R_{GW1} + CL2E^R_{GW2} + CL2E^R_{SF} = CL2E^R, \tag{66}$$

$R = 1, 2, \ldots, 8.$

Production Constraints: Production by each sector of the economy in 2020 should not fall below the 1975 level of production in the state, i.e.,

$$X_i > X_i', \tag{67}$$

where X_i' is the 1975 level of production by sector i in dollars.

Income constraint:

$$\sum_{i=1}^{77} V_i X_i > Y' - \sum_{i=1}^{4} \sum_{R=1}^{8} C_{i,R} \tag{68}$$

where Y' = the 1975 level of personal income and $C_{i,R}$ represents the unit cost of supplying water from source i in water supply area R.

The above constraints were incorporated into the goal programming input-output merger developed in this chapter in order to allocate the state's water resources to meet its 2020 growth projections.

CHAPTER III. DATA REQUIREMENTS FOR MODEL APPLICATION TO IOWA ECONOMY

Economic and Demographic Structures of the Study Area

The eight water supply areas of Iowa are made up of the state's 99 counties. The water supply areas are shown in Figure 3.1. The Missouri water supply area consists of the counties which border the Missouri River adjoining Nebraska and South Dakota. The Mississippi water supply area is also made of the counties bordering the Mississippi River adjoining both Wisconsin and Illinois. The counties which make up the Missouri water supply area were removed from the original Western and Southern interval river basins to avoid double counting. Similarly, the Mississippi border counties, which form the Mississippi water supply area, were removed from the original Northern, Iowa-Cedar, and Skunk river basins. Table 3.1 shows the counties which make up each water supply area.

Table 3.2 shows the population projections of the water supply areas between 1975 and 2020. These projections determine the final demands for produced commodities and water resources. The population projections were computed by summing up the projections for each of the counties within each water supply area. Des Moines water supply area has the largest population projection of 0.9 million by the year 2020, followed by Iowa-Cedar with 2020 projected population of almost 0.8 million. The Northeastern water supply area has the smallest projected population of 0.15 million by the year 2020.

Table 3.1. The counties which make up the water supply areas of Iowa

Water supply area	Counties
Western	Lyon, Osceola, Dickinson, Sioux, O'Brien, Clay, Plymouth, Cherokee, Sac, Crawford, Ida
Southern	Davis, Appanoose, Wayne, Decatur, Ringgold, Taylor, Montgomery, Page, Adams, Union, Adair, Cass, Shelby, Audubon
Des Moines	Van Buren, Wapello, Monroe, Lucas, Clarke, Madison, Warren, Marion, Guthrie, Dallas, Polk, Carroll, Greene, Boone, Calhoun, Webster, Hamilton, Pocahontas, Humboldt, Buena Vista, Palo Alto, Wright, Kossuth, Emmet
Iowa-Cedar	Johnson, Linn, Iowa, Benton, Poweshiek, Tama, Marshall, Grundy, Black Hawk, Butler, Floyd, Mitchell, Hardin, Franklin, Cerro Gordo, Worth, Winnebago, Hancock, Cedar
Northeastern	Howard, Winneshiek, Chickasaw, Bremer, Fayette, Buchanan, Delaware, Jones
Skunk	Story, Jasper, Mahaska, Keokuk, Washington, Jefferson, Henry
Missouri	Woodbury, Monona, Harrison, Pottawattamie, Mills, Fremont
Mississippi	Allamakee, Clayton, Dubuque, Jackson, Clinton, Scott, Muscatine, Louisa, Des Moines, Lee

Total personal and per capita income computed by Barnard (4, p. 29-30) for the six original interior river basins are shown in Table 3.3. It shows that the Des Moines and Iowa-Cedar areas rank highest in both total personal income and per capita income projections while the Southern river basin has a projected total personal income of 2.98 billion

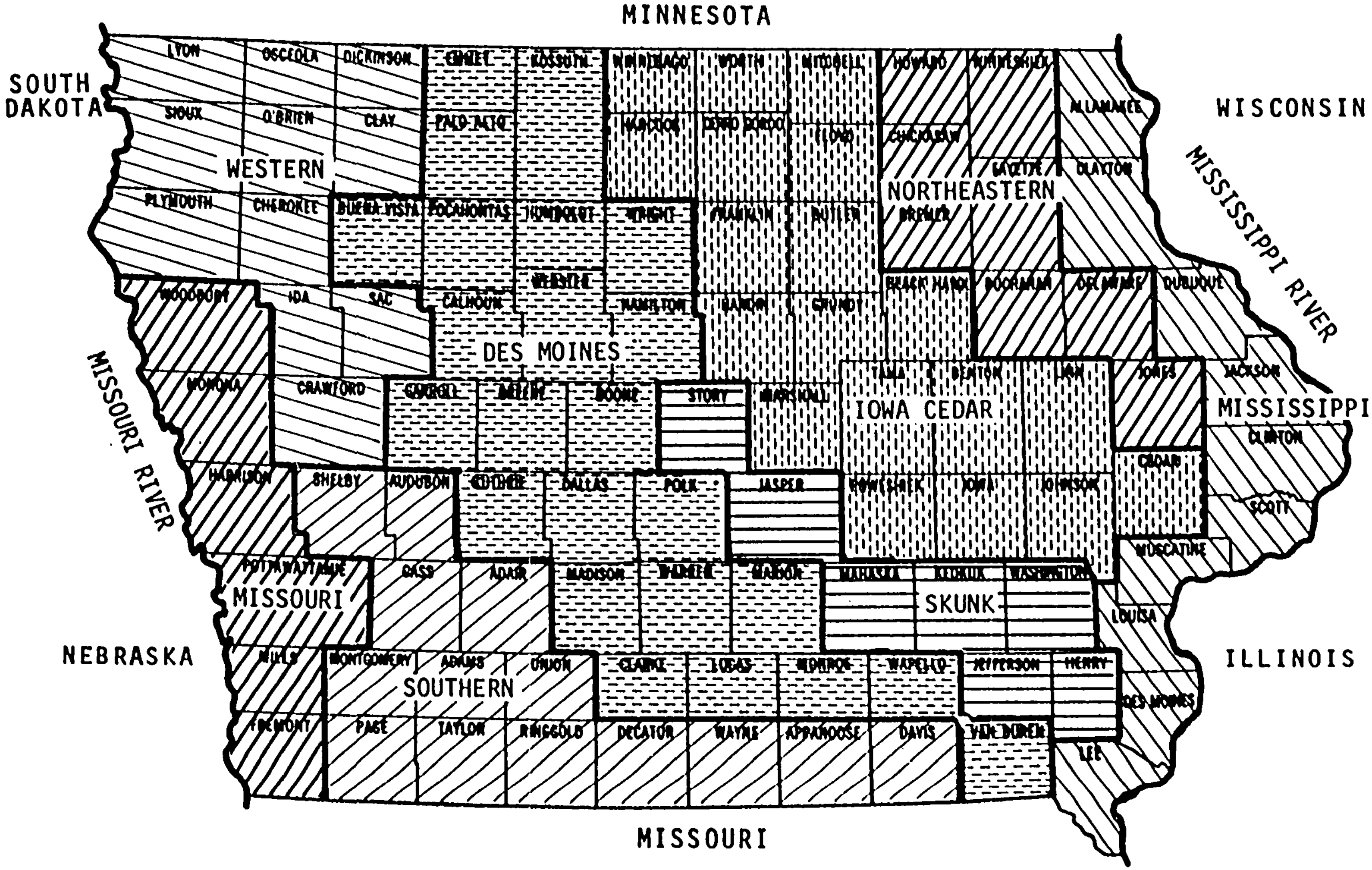

Fig. 3.1. Iowa water supply areas

Table 3.2. Projected population by water supply areas (1975-2020)[a]

Water supply area	1975	2020
Western	224,560	227,190
Southern	143,688	241,725
Des Moines	754,201	880,672
Iowa-Cedar	712,038	792,217
Northeastern	151,618	147,443
Skunk	193,339	235,742
Missouri	247,129	271,465
Mississippi	500,645	565,008
Total	2,927,218	3,361,462

[a]Source: Computed from (43).

dollars for the year 2020 and 18,500 per capita income. The Southern river basin ranks lowest in terms of both total personal and per capita income projections.

Sectors of the Iowa Economy

The Iowa economy has been categorized into 77 sectors according to the definitions and conventions used in the national input-output study reported in the Survey of Current Business, November, 1969. A list of the sectors of the economy is presented in Table 3.4, and a comprehensive classification of the U.S. economy upon which the classification of the Iowa economy is based is presented in Appendix B, Table B.1.

Table 3.3. Total personal and per capita income for the six original Conservancy Districts of Iowa (1975-2020)[a]

Conservancy district	Total personal earnings (billion $)		Per capita income (1000's)	
	1975	2020	1975	2020
Western	2.731	8.29	5.75	19.07
Southern	.988	2.984	6.07	18.5
Des Moines	4.807	19.247	6.37	21.85
Skunk	1.375	5.6	5.92	20.2
Iowa-Cedar	5.08	18.87	6.26	20.9
Northeastern	3.07	11.49	5.97	20.54

[a]Source: (4, p. 30).

The sectoral classifications begin with the agricultural sector of the Iowa economy which is made up of four separate categories. These are the livestock and livestock products sector, other agricultural products sector, forestry and fishery products sector, and the agricultural, fishery and forestry services sector. As is shown in Appendix B, the livestock and livestock products sector is made up of three subsectors. These are the dairy farm products, poultry and eggs, and meat animals subsectors. The other agricultural products sector includes cotton, food feed grains and grass seeds, fruits and tree nuts, tobacco, vegetables, oil bearing crops, forest, greenhouse and nursery products.

Iowa is basically an agricultural state with specialization in both crop and livestock agriculture. Of the 36 million acres which

Table 3.4. Sectors of the Iowa economy[a]

Specific sector	General sector
1. Livestock and livestock products	Agriculture, Forestry and Fisheries
2. Other agriculture products	
3. Forestry and fishery products	
4. Agriculture, forestry & fishery services	
5. Iron and Ferro alloy ores mining	Mining
6. Nonferrous metal ores mining	
7. Coal mining	
8. Crude petroleum and natural gas	
9. Stone and clay mining and quarrying	
10. Chemicals and fertilizer mineral mining	
11. New construction (residential, non-residential, highways, etc.)	Construction
12. Maintenance and repair construction	
13. Ordnance and accessories	Manufacturing
14. Food and kindred products	
15. Tobacco manufactures	
16. Broad and narrow fabrics, yard and thread mills	
17. Miscellaneous textile goods and floor coverings	
18. Apparel	
19. Miscellaneous fabricated textile products	
20. Lumber and wood products, except containers	
21. Wooden containers	
22. Household furniture	
23. Other furniture and fixtures	
24. Paper and allied products except containers and boxes	
25. Paper broad containers and boxes	
26. Printing and publishing	
27. Chemicals and selected chemical products	
28. Plastics and synthetic materials	
29. Drugs, cleaning and toilet preparation	

[a]Source: (3, pp. 17-22).

Table 3.4. Continued

Specific sector	General sector
30. Prints and allied products	Manufacturing (Continued)
31. Petroleum refining and related industries	
32. Rubber and miscellaneous plastics products	
33. Leather tanning and industrial leather products	
34. Footwear and other leather products	
35. Glass and glass products	
36. Stone and clay products	
37. Primary iron and steel manufacturing	
38. Primary nonferrous metals manufacturing	
39. Metal containers	
40. Heating, plumbing and fabricated structural metal products	
41. Screw machine products, bolts, nuts, etc. and metal stampings	
42. Other fabricated metal products	
43. Metal and turbines	
44. Farm and garden machinery	
45. Construction and mining machinery	
46. Materials handling machinery and equipment	
47. Metal working machinery and equipment	
48. Special industry machinery and equipment	
49. General industrial machinery and equipment	
50. Miscellaneous machinery except electrical	
51. Office computing and accounting machines	
52. Service industry machines	
53. Electrical industrial equipment and apparatus	
54. Household appliances	
55. Electrical lighting and wiring equipment	
56. Radio, television and communication equipment	
57. Electronic components and accessories	
58. Miscellaneous electrical machinery equipment and supplies	
59. Motor vehicles and equipment	

Table 3.4. Continued

Specific sector	General sector
60. Aircrafts and parts 61. Other transportation equipments 62. Professional, scientific and controlling instruments 63. Optical, ophthalmic and photographic equipment and supplies 64. Miscellaneous manufacture	Manufacturing (Continued)
65. Transportation and warehousing	Transportation
66. Communication, except radio and television broadcasting 67. Radio and television broadcasting	Communication
68. Electric, gas, water and sanitary services	Utilities
69. Wholesale and retail trade	Trade
70. Finance and insurance 71. Real estate and rental	Finance, Insurance and Real Estate
72. Hotels; personal and repair services except automotive repair 73. Business services 74. Eating and drinking places 75. Auto repair and services 76. Amusements 77. Medical, educational services and non-profit organizations	Services

form the total area of the state, the acreage in farms has remained roughly stable at 34 million acres or 94% of the state since 1950. Table 3.5 shows the major changes in Iowa's crop production between 1950 and 1975. While the acres in farms had not changed appreciably between 1950 and 1975, the acreage in corn increased from 9.8 million acres to over 13 million acres in the 25 year period. Soybean acreage also increased from 2 million acres to 7 million acres in the same period, but oats and forage declined in acreage. Of the estimated 25.7 billion dollars of output of goods and services in 1972, agriculture (comprising the first four sectors shown previously) contributed to 19.9 percent. In total value terms, livestock and livestock products accounted for 2.6 billion dollars while crop agriculture accounted for 2.4 billion dollars. Appendix B, Table B.2, shows the estimated output of goods and services of the Iowa economy in 1972 as computed with the revised input-output table of Iowa (59).

The mining sector also makes up a separate category in the Iowa economy, even though it does not compare adequately with the other sectors of the Iowa economy. The categories of mineral production in Iowa are cement, stone, sand and gravel, gypsum, and coal (40, pp. 29-30). Carbonate rocks, which are raw materials for portland cement, concrete, agricultural lime, and building stones, abound in Iowa. The gypsum of economic importance occurs in massive form called gypsum rock, and the State of Iowa currently ranks second in the nation in terms of gypsum production (40, p. 29). Coal is found

Table 3.5. Changes in Iowa agriculture (1950-1975)[a]

	1950	1960	1970	1975
Acres in farms	34,800,000	34,700,000	33,400,000	34,200,000
Acres in harvested crops	22,326,000	22,894,000	20,428,000	22,143,000
Acres in corn	9,798,000	12,607,000	10,717,000	13,150,000
Acres in soybeans	1,930,000	2,599,000	5,680,000	6,970,000
Acres in oats	6,520,000	4,100,000	1,711,000	1,500,000
Acres in cultivated forage	3,737,000	3,492,000	2,460,000	2,450,000

[a]Source: (35).

in the south central part of Iowa. The original coal reserves have been estimated at more than 7 billion tons, half of which is readily available. But Iowa coal is bituminous with average heat values ranging from 10,000 to 11,000 British thermal units[1] per pound, ash contents of 8 to 10 percent and an average sulfur content of 5 percent (40, p. 30). In 1972, coal production in Iowa was estimated at 6.4 million dollars (59).

Due to the low quality of Iowa coal, it needs purification before being used in sufficient amounts to meet the state's energy needs. But the process required to upgrade the quality of the coal, such as

[1]A British thermal unit is a unit of heat equal to about 252 calories; it is also the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit (18, p. 178).

coal gasification, requires a tremendous quantity of water.

The construction sector also accounts for a sizable portion of the Iowa economy, contributing to over four percent of the aggregate output of goods and services in 1972. The biggest sector of the Iowa economy is the manufacturing sector which is made up of such diverse components as ordnance and accessories, food and kindred, miscellaneous textile goods and floor coverings, apparel, furniture, paper and allied products, stone and clay products, and others, as shown in Appendix B. The food and kindred products sector within the manufacturing sector is the largest single contributor to the Iowa economy in terms of gross output of goods and services. This sector is made up of all the food processing industries in the economy and contributed to almost 5.5 billion dollars of output in 1972. The government enterprises sector is not included in this study since the latest (1972) input-output table of Iowa does not include this sector.

In reality, the economy of Iowa should be categorized into 69 sectors since eight specific sectors do not operate in the state. These eight sectors are iron and ferroalloy ores mining, non-ferrous metal ore mining, crude petroleum and natural gas, tobacco manufactures, chemical and fertilizer mineral mining, glass and glass products, office computing and accounting machines, and service industry machines. The output of these sectors will thus be represented by zeroes. It was decided to keep all the 77 sectors in the matrix in order to be in line with the 77 x 77 input-output matrix developed for the state's economy.

Projected Earnings from Economic Activities by Water Supply Areas

Total income which accrues to each sector of the Iowa economy has been projected to the year 2020 (43) for each county of the state. In carrying out these projections, the 77 specific sectors of the Iowa economy were categorized into ten general sectors. The agriculture, forestry and fisheries sectors were bulked together under one sector, while all mining activities were put under one sector, the mining sector. Table 3.4, which describes all sectors of the Iowa economy, shows this major classification of the economy into the ten general sectors.

The projected annual growth rates of income which accrues to each sector of Iowa economy between 1975 and 2020 is shown in the last column of Table 3.6. Aggregate earnings generated from all economic activities as represented by the ten major sectors was 11.824 billion dollars in 1975. In the year 2020, total income accruing to all sectors is expected to increase to 41.27 billion dollars, showing an annual growth rate of 5.5 percent.

Individual sectoral growth rates of income are expected to vary widely. The services sector is expected to record the highest growth rate in income of 8.94 percent per annum, followed by the communications sector which is expected to grow in income at an annual rate of 8.7 percent. The finance, insurance and real estate sector is expected to record an annual growth rate of 7.93 percent in income.

Table 3.6. Earnings from economic activities (1975-2020) for each water supply area[a]

General economic sector	Western 2020 est.[b] earn.[c]	Western % of state earn.	Southern 2020 est. earn.	Southern % of state earn.	Des Moines 2020 est. earn.	Des Moines % of state earn.	Iowa-Cedar 2020 est. earn.	Iowa-Cedar % of state earn.	Northeastern 2020 est. earn.	Northeastern % of state earn.
Agric., forestry & fisheries	.334	10.64	.348	11.09	.735	23.42	.79	25.18	.326	10.39
Mining	.006	6	.007	7.0	.033	33	.02	20	.001	1
Construction	.116	4.59	.114	4.51	.687	27.15	.658	26.01	.113	4.47
Manufacturing	.545	4.79	.269	2.37	2.728	24.00	.355	28.64	.44	3.87
Transportation	.066	4.58	.068	4.72	.515	35.74	.274	19.01	.065	4.51
Communication	.041	4	.027	2.63	.367	35.80	.267	26.05	.025	2.44
Utilities	.035	5.98	.039	6.67	.143	24.44	.13	22.22	.028	4.79
Wholesale & retail trade	.401	5.6	.392	5.50	1.967	27.47	1.657	23.14	.297	4.15
Finance, insurance & real estate	.134	4.03	.093	2.80	1.478	44.5	.617	18.58	.08	2.41
Services	.641	4.3	.32	2.98	3.044	28.39	2.635	24.57	.391	3.65
Total	2.139	5.18	1.677	4.06	11.697	28.34	10.303	24.96	1.76	4.28

[a]The sectoral earnings are expressed in billions of dollars.

[b]Est. = estimated.

[c]Earn. = earnings.

Table 3.6. Continued

General economic sector	Missouri		Mississippi		Skunk		State		
	2020 est. earn.	% of state earn.	2020 est. earn.	% of state earn.	2020 est. earn.	% of state earn.	2020 est. earn.	1975 earn.	Annual growth rate
Agric., forestry & fisheries	.112	3.57	.221	7.04	.272	8.67	3.138	1.645	2.02
Mining	.003	3	.025	25	.005	5	0.1	0.043	2.95
Construction	.223	8.81	.391	15.45	.228	9.01	2.53	.786	4.93
Manufacturing	.657	5.94	2.751	24.21	.702	6.18	11.365	3.294	5.44
Transportation	.188	13.05	2.07	14.37	.058	4.02	1.441	.481	4.44
Communication	.137	13.37	.116	11.32	.045	4.39	1.025	.209	8.7
Utilities	.058	9.91	.123	21.03	.029	4.96	.585	.175	5.2
Wholesale & retail trade	.668	9.33	1.243	17.36	.536	7.48	7.161	2.33	4.61
Finance, insurance & real estate	.31	9.33	.432	13.01	.177	5.33	3.321	.727	7.93
Services	.988	9.21	1.89	17.63	.994	9.27	10.723	2.134	8.94
Total	3.25	7.87	7.393	17.91	3.046	7.38	41.271	11.824	5.53

Comparatively low growth rates of 2.02 and 2.95 percent are expected from the agriculture and mining sectors, respectively.

Table 3.6 also shows the projected total earnings of each sector for each water supply area. The sectoral income ratios, which express the income accruing to each sector in a particular water supply area as a ratio of the income at the state level for that particular sector, are also shown in Table 3.6. Out of the 3.138 billion dollars of earnings expected from agriculture, forestry and fisheries sector, 25.18 percent or 0.735 billion dollars are expected from the Iowa-Cedar water supply area. The Des Moines water supply area is also expected to generate over 23 percent of the state's agricultural sector earnings in the year 2020. The least amount of earnings from agricultural activities is expected from the Missouri water supply area compared to the other areas of the state.

Income generated from the mining sector in all Iowa is projected at 0.1 billion dollars which is 0.24 percent of the projected state earnings from all sectors in the year 2020. This figure shows that the mining sector is the smallest component of the Iowa economy. The Des Moines and Iowa-Cedar water supply areas are expected to have 53 percent of the aggregate state earnings from mining operations by the year 2020.

The projected earnings show that the bulk of the economic activities are expected to center around the Des Moines and Iowa-Cedar areas. Between these two water supply areas, they are expected to contribute to 53.15 percent of the projected construction income earnings of 2.53 billion dollars, 52.64 percent of the 11.365 billion dollars expected from the manufacturing sector, and 54.75 percent of the 1.441 billion dollars of earnings expected from the transportation sector. The communications sector is expected to yield 1.025 billion dollars in earnings with Des Moines water supply area contributing to 35.8 percent, while the Iowa-Cedar area has a 26.05 percent share. The Northeastern water supply area is, however, expected to contribute the least to aggregate state income from the communications sector, 250,000 dollars or 2.44 percent of the state income from communications. The least amount of economic activities in terms of utilities, trade, finance, insurance and real estate is expected in the Northeastern water supply area compared to the remaining water supply areas of the state. In the manufacturing and services sectors, the Southern water supply area is expected to provide the least contribution in terms of earnings.

The last row of Table 3.6 shows the aggregate earnings from all economic activities for the year 2020 and the contribution of each water supply area. It shows the Des Moines and Iowa-Cedar water supply areas ranking high in that order with 28.34 and 24.96 percent of the states' earnings from all economic activities, followed by the Mississippi water supply area with 17.9 percent of the projected earnings from the state's economic activities. The least contribution in terms of earnings from all economic activities is expected from the Southern water supply area.

Final Demand for Goods and Services for the Year 2020 by Water Supply Areas

In his input-output study of the economy of Iowa in 1967, Barnard (3) computed the output of goods and services needed to satisfy the final demands by households, governments, exports and investment for each sector of the Iowa economy. Making use of projections of personal income and population prepared by Graham et al. (23), Barnard projected the 1967 final demands to 1975 and 1980. The income and population projections are part of an internally consistent set prepared for all states at the national level. Multiplying the Leontief Inverse matrix by the projected final demands for 1975 and 1980 yields the output projections needed to support the estimated final demands for 1975 and 1980. From the computed outputs of 1967, 1975 and 1980 annual rates of growth of output of goods and services were estimated. These rates of growth of outputs are thus consistent with the Iowa input-output model since they were computed from projected outputs which were calculated using the input-output matrix of the Iowa economy. Table 3.7 presents the estimated rates of growth of output of goods and services for the Iowa economy for the period covering 1967 to 1980.

Using the projected growth rates presented in Table 3.7, the computed output of goods and services which are consistent with the 1972 input-output model were projected to 1975 and 2020. It was assumed that the sectoral output growth rates for 1980 will continue

Table 3.7. Estimated rates of growth of output of goods and services for the Iowa economy (1967-1980)[a]

Sector	Annual rate of growth	
	1967-1975	1975-1980
Livestock agriculture	1.41	1.13
Other agriculture	1.37	1.22
Construction and mining	5.02	2.51
Food and kindred	1.47	1.22
Other nondurable goods	5.31	4.27
Farm machinery	3.23	3.35
Other durable goods	6.43	3.78
Transportation	4.61	3.02
Communication & utilities	4.13	3.62
Trade	3.05	2.80
Finance, insurance & real estate	3.79	4.27
Services	5.78	4.71

[a]Source: (3, p. 61).

to 2020.[1] The output projections for each sector at the state level for the year 2020 were scaled down to regional output projections for each water supply area. The scaling-down factors were the sectoral income ratios presented in Table 3.6 and the scaling procedure is shown in Appendix A.

The final demand for goods and services in the year 2020 in terms of household consumption, government expenditure, exports and investment

[1]Given the present condition of the global economy, considering in particular the energy situation, this assumption could be expected to represent the upper limit of sectoral growth rates.

were computed by making use of the projected outputs for the water supply areas, and the Leontief Inverse matrix (of the closed system) developed in Chapter 2.

The goal programming input-output synthesis was then used to investigate whether each water supply area can afford the growth projections considering regional water endowments. Tables 3.8 and 3.9 show a summary of the projected output of goods and services as well as the final demands at state and regional levels, respectively. These projections are presented in terms of the ten aggregate sectors of the economy. Details for each sector of the economy are presented in Appendix B, Table B.3.

Gross state output of goods and services is expected to equal 101 billion dollars by 2020 while the aggregate final demand is also expected to be 61.2 billion dollars. Manufactured items are expected to account for nearly 38 percent of the state final demand for goods and services, followed by the services sector which is expected to account for 17 percent of total state final demand; the trade and agricultural products sectors are also expected to contribute to approximately 12 percent and 7.3 percent of the final demand, respectively.

At the regional levels, the final demand for goods and services in the Des Moines and Iowa-Cedar water supply areas are expected to account for over 54 percent of the state aggregate partly by virtue of the concentration of the population and economic activities in

Table 3.8. Projected gross outputs by water supply areas for the year 2020 (thousands of $)

General economic sector	State	Western	Southern	Des Moines
Agric., forestry, & fisheries	9,018,620	959,582	1,000,166	2,112,163
Mining	250,231	14,646.35	17,205.15	83,735.25
Construction	4,249,488	195,051	191,652	1,153,736
Manufacturing	39,201,019	1,819,042	900,027	9,522,597
Transportation	2,769,847	126,859	130,737	989,943
Communication	1,239,764	49,590.4	32,605.8	443,836
Utilities	3,240,477	193,781	216,140	791,973
Trade	9,438,140	528,536	519,098	2,592,241
Finance, insurance & real estate	16,737,937	674,539	468,662	7,450,055
Services	14,851,465	638,613	442,574	4,216,331
Total	100,996,988	5,200,239.75	3,918,856.95	29,356,610.25

Table 3.8. Continued

General economic sector	Iowa-Cedar	Northeastern	Missouri	Mississippi	Skunk
Agric., forestry & fisheries	2,270,883	937,035	321,965	634,911	781,915
Mining	50,470.25	1,852.1	6,969.8	63,264.55	12,087.45
Construction	1,105,292	189,952	374,380	656,546	382,879
Manufacturing	11,284,675	1,469,664	2,255,763	9,602,346	2,346,905
Transportation	526,548	124,920	361,465	398,027	111,348
Communication	322,959	30,250.2	165,756	140,341	54,425.6
Utilities	720,034	155,219	321,131	681,472	160,728
Trade	2,182,570	391,683	880,578	1,638,461	705,973
Finance, insurance & real estate	3,110,745.5	403,384	1,561,650	2,177,606	892,132
Services	3,649,005	542,078	1,367,820	2,618,313	1,376,731
Total	25,223,181.85	4,246,037.3	7,617,477.8	18,611,287.55	6,825,124.05

Table 3.9. Projected final demand for goods and services by water supply areas by the year 2020 (thousands of $)[a]

General economic sector	State	Western	Southern	Des Moines
Agric., forestry & fisheries	4,428,146	478,451.27	488,684.7	1,053,132.06
Mining	179,119	10,808.5	12,430.8	61,135.95
Construction	2,974,642	124,980.9	130,565.64	823,113.18
Manufacturing	22,937,391	1,106,441.8	535,746	5,534,643.96
Transportation	565,049	25,506.03	26,024.22	203,985.78
Communication	623,601	24,927.82	16,292.27	223,504.16
Utilities	1,629,960	97,425.01	108,018.01	398,884.31
Trade	7,267,368	404,868.5	392,447.7	2,011,685.1
Finance, insurance & real estate	10,126,452	407,235.9	282,474.37	4,504,223.4
Services	10,470,283	449,895.66	312,672.99	2,972,884.7
Total	61,202,011	3,130,541.4 (5.1)	2,305,356 (3.8)	17,787,192 (29.06)

[a]Figures in parentheses are percentages.

Table 3.9. Continued

General economic sec.	Iowa-Cedar	Northeastern	Missouri	Mississippi	Skunk
Agric., forestry & fisheries	1,141,358.27	429,728.37	150,873.8	303,870.84	382,046.66
Mining	35,004.99	1,673.48	5,173.98	44,395.89	8,495.36
Construction	785,445.99	125,608.49	251,308.5	468,948.01	264,671.25
Manufacturing	6,572,046.42	873,355.71	1,290,873	5,601,460.1	1,422,824
Transportation	107,972.89	24,741.42	72,314.17	82,016.83	22,487.61
Communication	162,568.6	15,202.96	83,089.32	70,728.3	27,287.58
Utilities	362,507.68	78,022.14	161,002.11	343,502.5	80,598.28
Trade	1,692,186.0	296,119.74	664,853.65	1,271,477.7	5,533,729.61
Finance, insurance & real estate	1,883,438.12	243,210	947,491.9	1,317,723.4	540,654.63
Services	2,574,328.8	381,345	960,877.54	1,847,973.8	970,303.89
Total	15,316,858 (25.03)	2,469,008 (4.0)	4,587,858 (7.5)	11,352,097 (18.55)	4,253,098.9 (6.95)

in these two areas. The Mississippi water supply area is also expected to have a substantial share in the state aggregate final demand while the Southern water supply area accounts for only 3.8 percent of the state total in the year 2020. It is these projected final demands which serve as the target level of the final demand to be achieved in 2020 under the constraint of regional water supplies and requirements.

Water Availabilities by Supply Areas

The source of all water resources of a given locality is precipitation. About 20 percent of the precipitation that falls on the state of Iowa becomes runoff, 75 percent is returned to the atmosphere through evapotranspiration and the remaining 5 percent percolates into the earth to make up the groundwater resources of the state (40, p. 11). Precipitation in the state occurs as rain, snow, drizzle, ice pellets, and dew. Rainfall makes up almost 90 percent of the annual precipitation. The normal precipitation in the state varies between 35 inches in the southeast to 25 inches in the northwest. Over 70 percent of the precipitation occurs between April and September which happens to be the cropping season. The normal crop season precipitation varies from 20 inches in the northwest to 25 inches in the southwest.

The sources of water supply considered in this study are 1) surface water storage (reservoir), 2) groundwater, 3) the interior rivers and streams, and 4) the state's two border rivers which are the Missouri and Mississippi Rivers. Data on the availabilities of these sources of water were obtained with the assistance of Mr. Tom Moore of the Civil Engineering Department at Iowa State University (ISU). The estimated yield from potential reservoirs was computed for two different D/Q ratios[1], 0.5 and 0.2. For a D/Q ratio of 0.2, Skunk has the lowest volume of reservoir water of about 4,073 million gallons per year while Des Moines has the largest storage of 65,984.6 million gallons per year. Details of the water availability data by supply areas are presented in Table 3.10 later in this section.

Several different aquifers make up the groundwater resources of Iowa. An aquifer is defined as a body of natural earth material (soil or rock) of sufficient volume, permeability and porosity to store and transmit water (40, p. 23). Groundwater can be found near the surface in groundwater table aquifers or in confined aquifers which are much deeper. This vertical variation divides aquifers into two general categories: namely, the surficial (unconsolidated) and bedrock aquifers. Surficial aquifers are comprised of three types of aquifers known as glacial drift, alluvial and buried channel aquifers. Wells drilled into the glacial drift at shallow depths, usually less than 100 feet, yield small quantities of water. These drift wells penetrate local thin pockets of sand and gravel, and dry up during dry periods.

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[1]D represents demand of water; Q is the reservoir storage. According to Dr. Merwin Dougal of the Civil Engineering Department (ISU), the preferable reservoir construction D/Q ratio is 0.2.

The alluvial deposits which are associated mostly with the state's major rivers and streams form large parts of industrial and municipal water supply sources. The buried channel aquifers are found mostly in central and east central Iowa and occur in pre-glacial bedrock valleys which exist beneath the glacial drift aquifers (40, p. 39). Frequently, the buried channel aquifer functions as a single system with an overlying alluvial aquifer to which it is often connected.

Bedrock aquifers occur in the subsurface beneath the state's unconsolidated materials where bedrock formations of various ages of rock units exist. These rock formations form an alternating sequence of rock layers whose permeable fractures and crevices function as aquifers. The older rock units are known as Paleozoics while the younger units are referred to as the cretaceous rocks. The Palezoic rock formations consist of the Cambrian, Ordovician, Silurian, Devonian, Mississippi, and Pennsylvanian bedrock formations (40, p. 43). The rocks of the Paleozoic system consist of limestone, dolomite, shale, siltstone, and sandstone, while the cretaceous systems are dominantly comprised of shales and sandstones. Not all of the bedrock formations beneath Iowa produce water. Those bedrocks which comprise of slightly permeable siltstone, carbonate, and shale formations frequently form impermeable barriers called aquicludes which restrain the cross-flow of water between aquifer formations.

The important aquifers of Iowa are the Dakota, Mississippi, Silurian-Devonian, and Combro-Ordovician aquifer systems. The Dakota aquifer system occurs in the western-most counties of the state and contain considerable amounts of shale and water-bearing sands. The Mississippi aquifer system extends from north central Iowa to the southeastern corner of the state; it is also found in southwestern Iowa. The Silurian-Devonian aquifer system stretches from eastern Iowa to the western part of the state while the Cambro-Ordovician aquifer system underlies the entire state except for a few northwestern Iowa counties. The location of the various aquifers in the state of Iowa can be found in the Iowa Water Plan (40, pp. 38-57).

The groundwater supplies of each region were estimated in terms of alluvial aquifers on one hand, and the glacial drift, buried channel and bedrock aquifers on the other hand. This second category of aquifers is roughly put under a heading of bedrock aquifers for the purpose of this study. The reason for this categorization is basically due to the way the data was collected. It was not possible to estimate separate yield quantities for the other shallow and bedrock aquifers for each water supply area.

Table 3.10 shows the estimated availabilities of water from the various sources in each of the eight water supply areas. The values given for the original six conservancy districts do not include the border counties of the Mississippi and Missouri rivers. The data show that the Missouri border counties have the highest estimated yields of alluvial water supply ranging from a low of 144,514.5 million gallons per year to a high of 576,265.7 million gallons per year.

Table 3.10. Water availabilities by sources for eight Iowa water supply areas[a]

Water supply area	Estimated yield from alluvial aquifers MGY[b]		Estimated yield from shallow and bedrock aquifers - total recharge MGY		
	Low	High	Low	Average	High
Northeastern	0.0	1,955.1	42,360.5	244,387.5	446,414.5
Iowa-Cedar	4,887.75	25,742.15	94,496.5	513,213.75	931,931
Skunk	3,258.5	18,247.6	26,068.0	161,295.75	296,523.5
Des Moines	8,797.95	51,973.08	58,653.5	322,591.75	586,530
Western	4,561.9	13,685.7	35,843.5	200,397.75	364,952
Southern	1,629.25	13,685.7	9,775.5	60,282.25	110,789
Mississippi	81,462.5	330,900.68	48,877.5	270,455.5	492,033.5
Missouri	144,514.5	576,265.7	19,551	105,901.25	192,251.5
Total yield/ MGY		1,032,455.71		1,878,525.5	
Supply cost $/1000 gallons	1.0			1.5	

[a]Source: (40).

[b]MGY represents million gallons per year.

[c]Average flow estimates were used as an upper limit to surface water availability. The 90% to 99% duration values could be introduced as conservative estimates. The yield for the 99% duration would be from 5% to 10% of the average values listed.

[d]This figure represents the average to high estimate of water availability in Iowa. A low estimate (low groundwater values and 99% duration for stream flow) would reduce this value to a range of 10^6 MGY to 1.6×10^6 MGY. This low estimate is considered to be unduly conservative.

Estimated yield from potential reservoirs D/Q = 0.2 MGY	Estimated yield from available rivers[c] MGY	Total yield MGY
50,669.68	684,285	981,297.28
32,259.15	1,238,230	1,809,445.05
4,073.13	619,115	802,731.48
65,984.63	1,335,985	1,776,534.5
15,314.95	423,605	653,003.4
29,489.43	814,625	918,082.38
16,455.43	2,948,942.5 (7449455)	4,316,209.11
5,702.38	3,356,255 (325850)	4,369,974.33
219,948.78	12,496,347.5	15,627,277.50[d]
2.5	1.0	

The Northeastern water supply area has the lowest quantity of alluvial water supply, a trivial upper limit of 1955.1 million gallons per year. With respect to the other groundwater resources, collectively called the shallow and bedrock aquifers, values for estimated yields are given in million gallons of total recharge. The volumes range from a low of 9775.5 million gallons per year in the Southern water supply area to a high of 931,931 million gallons per year in the Iowa-Cedar water supply area. Water supply cost data as presented in the preliminary report of the Iowa State Water Resources Research Institute by Moore et al. (52) are presented in the last row of Table 3.10.

The cost of supplying water from the Mississippi River is assumed to be equal to the cost of supplying water from the Missouri River as reported in the Iowa State University Water Resources Research Institute preliminary report.

The quantities of alluvial aquifer water supply to be used in this study will be based on the upper range values presented in Table 3.10. The reason, according to Mr. Tom Moore of the Civil Engineering Department (ISU), is that the estimation of the alluvial water quantities presented in Table 3.10 was based on the assumption of two wells per mile, but it would be more realistic to assume four wells per mile. The average total recharge values for the shallow and bedrock aquifers would be employed in this study.

The figures in brackets under the Estimated Yield from Available Rivers column in Table 3.10 are the yields from the interior streams of the Mississippi and Missouri water supply areas. It is assumed that only two percent of the yield from the state's border rivers can be used for consumptive purposes. The two percent of the flow from the Mississippi River which can be used for consumptive purposes equals 58,979 million gallons per year, while the corresponding quantity from the Missouri River equals 67,125 million gallons per year. The figures in the Total column of Table 3.10 represent the sum of the yields from the alluvial aquifer (high estimate), average yield from shallow and bedrock aquifers, estimated yield from potential reservoirs, and the yield from available rivers. The aggregate state water supply equals 15.63 trillion gallons per year. The Mississippi and Missouri water supply areas account for 28 percent each, and the remaining six water supply areas contribute to 44 percent of the total water supply. The Western water supply area has the smallest share of the state water supply (four percent). These water supply values will be used as the constraints on state and regional economic activities.[1]

Water Uses in Iowa

In this section, the uses of water are discussed in terms of total withdrawal and consumption. The quantity of water withdrawn from the groundwater and streams of Iowa for all types of uses was 1.3 trillion gallons or 3.99 million acre-feet in 1975. The estimated consumptive use that year was 460 million gallons per day

[1]See footnotes c and d of Table 3.10.

(38, p. 1). Water uses in this study are presented in terms of agricultural, industrial, and domestic (rural and urban household) uses. The agricultural uses are further broken into two categories: livestock and irrigation.

<u>Water utilization in the livestock agricultural sector</u>

Water requirement in the livestock agricultural sector is concentrated mainly in the beef and cattle industries. Figures for the 1970 water intake in the livestock sector show that 113.68 million gallons of water was withdrawn for use in the livestock industry. Almost half of the water withdrawn was used in the beef and cattle industries while 36.3 percent of the water withdrawn was utilized in the hogs and pigs category of the livestock sector. Table 3.11 shows the 1970 water utilization in the livestock sector of the Iowa economy. Although aggregate water utilization was greatest in the beef and cattle industries, water used per head in the milk cows industry exceeded all categories of the livestock sector.

The water requirement coefficient of the livestock sector of the Iowa economy which is used in this study is the 1967 estimated by Barnard and Dent (4, p. 75). It is estimated that to produce a dollar of output from the livestock sector, an aggregate intake of 14.435 gallons of water is required. Since none of the water is discharged in usable form after use, the consumptive use requirement is also 14.435 gallons per dollar of output from the livestock sector output.

Table 3.11. Estimated livestock water use (1970)[a]

Livestock category	Numbers (1000's)	Drinking MGD[b]	Other MGD	Total MGD	Per head gallon/day
Beef & cattle	7,181	42.68	13.57	56.25	7.8
Sheep & lambs	797	0.50	0	0.65	0.8
Hogs & pigs	16,322	30.19	11.03	41.23	2.6
Milk cows	486	7.26	6.32	13.58	27.9
Chicken, broiler & turkey	20,228	0.68	0.14	0.81	.04
Hens & pullets	13,506	0.88	0.28	1.16	.09

[a]Source: (38, p. 5).

[b]MGD represents million gallons per day.

<u>Water utilization in the crop agricultural sector</u>

Irrigation is the largest agricultural use of water in Iowa both in terms of withdrawal and consumption (38, p. 4), and as a result, water use in the crop agricultural sector of this study is based on irrigation water requirements. It is assumed that only corn is irrigated since over 95 percent of water requirement in crop production is for the irrigation of corn (2, p. 1). Water use in irrigation is considered a 100 percent consumptive use. The water coefficients for crop production used in this study are based on data collected from the Water Commissioner's Office of the Iowa Natural Resources Council (INRC) for 1979 (42). The water permit data show the number of permits granted, maximum amount of water required to be withdrawn, the source of water, and type of use (corn or specialty crop irrigation). The data also show that over 90 percent of the permits granted were for the irrigation of corn.

Table 3.13 shows the water coefficients computed from the INRC water permits for 1979 by source and water supply area for corn irrigation. The coefficients range from 0.76 acre-foot per acre (for reservoir water withdrawal) in the Iowa-Cedar water supply area to 1.14 acre-feet per acre (for groundwater withdrawal) in the Missouri water supply area. The INRC has indicated that the past and present irrigation situation and future trends are as follows:

Table 3.12. Irrigation trends in Iowa (1969-2020)[a]

Year	Authorized permits	Acres irrigated	Acre-feet of water used or authorized	Coefficient (acre-feet)
1969	649	93,200	99,300	1.065
1976	837	131,300	146,000	1.11
1977	1,429	230,000	280,000	1.217
2000	4,000	740,000	740,000	1.0

[a]Source: (41, p.15).

These figures suggest that while demands for irrigation water and acreages irrigated show an appreciable increase between 1969 and 2000, the coefficients of water usage remain virtually unchanged and compare well with the coefficients computed in Table 3.13.

Table 3.13. Water coefficients for corn irrigation for the eight water supply areas of Iowa (acre-feet per acre per year)[a]

Water supply area	Water supply source[b]		
	Groundwater	Reservoir	Stream flow
Western	1.01	.91	.87
Southern	0.95	0.89	0.99
Des Moines	1.03	1.0	0.94
Iowa-Cedar	1.02	.76	.94
Northeastern	1.04	.96	1.09
Skunk	1.0	1.0	.83
Missouri	1.14	1.01	1.01
Mississippi	.99	1.09	.92

[a]Source: (42).

[b]The units of the crop irrigation water coefficients employed in this study are in gallons per acre, where 1 acre-foot per acre is equivalent to 325,850 gallons per acre (40, p.35).

<u>Industrial and residential water use</u>

The 1967 input-output table of Iowa provides data for water use (withdrawal and consumption) in all sectors of the Iowa economy. The water use coefficients are presented in detail in Appendix B, Table B.4 which shows that the electric, gas, water and sanitary services sector had the largest withdrawal coefficient of 1,364.3 gallons per dollar of output, followed by the chemicals and selected chemical products sector which had a withdrawal coefficient of 159 gallons per dollar of output and the primary iron and steel sector with a withdrawal coefficient of 150 gallons per dollar of output. Water consumption coefficients ranged from zero gallon in the glass and glass products sector to 19 gallons per dollar of output in the electric, gas, water and sanitary services sector.

These coefficients of industrial water use, together with the water coefficients for corn irrigation in each of the eight water supply areas, and the state water requirement for the livestock and livestock products sector will be actually used in the model developed in Chapter 2. The remaining water utilization data required for the model application is the final demand for water. This is made up of water set aside for the domestic residential (rural and urban) uses. A state average of 54 gallons of final demand for water per capita per day estimated by Barnard and Dent (4, p. 69) is used in computing the final demand for water in each water supply area, using the projected populations of the water supply areas to 2020. These estimates include a 30 percent increase to account for losses connected with firefighting, municipal parks, and swimming pools. Aggregate final demand for the year 2020 is projected to be 181.4 million gallons per day with 49.7 percent of this figure originating from the Des Moines and Iowa-Cedar water supply areas as shown in Table 3.14. The Northeastern water supply area has the lowest projected final demand for water, mainly as a result of its low population.

Table 3.14. Final demand for water by water supply areas in 2020[a]

Water supply area	Final demand (gallons per day)
Western	12,268,260
Southern	13,053,150
Des Moines	47,556,288
Iowa-Cedar	42,779,718
Northeastern	7,961,922
Skunk	12,730,068
Missouri	14,659,110
Mississippi	30,510,432
Total	181,418,948

[a]Source: (4, 43).

Land Availabilities for Crop Irrigation by Water Supply Areas

In order to compute the quantity of water that will be required for crop irrigation, it is necessary to find out the amount of land available for irrigation. In this report, it is assumed that irrigation will be carried out on class 1 land including flood plain, class 2S and class 2E lands.

The Iowa Conservation Needs Committee (34) provides data on the availabilities of land by land capability classes in 1967 for each county in the state. From this land inventory report, the amount of land to be used for irrigation in this report was computed for class 1, class 2S and class 2E lands. Flood plain land availabilities were also computed from the 1967 land inventory report, which also provided details on aggregate cropland and land under field crops for each land capability class. Table 3.15 provides a summary of the amounts of land to be utilized for irrigation in this study by water supply areas. The 1967 land inventory report shows a total of 2.7 million acres of flood plain land in the state. The Des Moines water supply area has the largest percentage of flood plain land, 18 percent, followed by the Iowa-Cedar with 17.7 percent of the state's total flood plain acreage.

Total class 1 land under field crops in 1967 equaled 2.93 million acres, while the amount of class 1 cropland reported was 3.7 million acres. Under the class 1 field crop category, the Des Moines water supply area utilized 29.6 percent of the state total, followed by the Iowa-Cedar which utilized 23.6 percent of the state total. With respect to the class 1 cropland cultivated in 1967, the Des Moines water supply area utilized almost 29 percent of the state total, followed by the Iowa-Cedar water supply area which also employed 24.9 percent of the state total.

The class 2S cropland employed in 1967 in Iowa was just over 0.25 million acres. The Northeastern water supply area utilized 27.2 percent of this total, followed by the Iowa-Cedar water supply area which used 25.4 percent of the total class 2S cropland. The Skunk water supply area employed only 1,738 acres of 2S land in crop production

Table 3.15. Flood plain, class 1, class 2S, and class 2E lands available for irrigation by water supply areas[a]

Water supply area	Flood plain land Total	Flood plain land % of state	Class 1 land (field crops) Total	Class 1 land (field crops) % of state
Western	304,214	11.2	443,607	15.2
Southern	450,287	16.6	138,854	4.7
Des Moines	488,936	18.0	867,890	29.6
Iowa-Cedar	480,100	17.7	690,618	23.6
Northeastern	314,284	11.6	147,292	5.0
Skunk	221,814	8.1	196,951	6.7
Missouri	239,384	8.8	257,063	8.8
Mississippi	216,377	8.0	185,391	6.3
Total	2,715,396		2,927,666	

[a]Source: (34).

Class 1 land (all cropland)		Class 2S land		Class 2E land (field crops)		Class 2E land (all cropland)	
Total	% of state	Total	% of state	Total	% of state	Total	% of state
534,526	14.5	43,978	16.5	826,146	22.3	1,180,827	19.8
170,345	4.6	10,069	3.8	263,195	7.1	399,715	6.7
1,060,623	28.8	53,191	20.0	716,244	19.4	1,345,805	22.5
915,806	24.9	67,473	25.4	857,767	23.2	1,330,334	22.3
204,843	5.6	72,260	27.2	385,474	10.4	698,507	11.7
248,440	6.8	1,738	.65	241,947	6.5	306,188	5.1
308,950	8.4	6,230	2.3	211,703	5.7	321,078	5.4
234,829	6.4	11,008	4.1	195,241	5.3	395,195	6.6
3,678,362		265,947		3,697,717		5,977,613	

in 1967 which is equivalent to 0.65 percent of the state total class 2S cropland.

The 2E category of land utilized for field crops and aggregate crop production in 1967 was quite considerable compared to the other classes of land being considered in this study. Over 3.6 million acres of class 2E land were utilized in 1967 for field crops, and the Iowa-Cedar water supply area employed 857,767 acres which accounted for 23.2 percent of the total 2E land under field crops in the state. The Mississippi water supply area had the least class 2E land under field crops in 1967. The Des Moines and Iowa-Cedar water supply areas utilized almost 45 percent of the state total class 2E cropland in 1967 in almost equal quantities, while the Skunk, Missouri, Mississippi and Southern water supply areas altogether employed 23.8 percent of the state total. The figures presented in Table 3.15 are utilized in the irrigation scenarios described in this study.

Under irrigation scenario I where irrigation is to be restricted to all class I land (under field crops) and class 2S land suitable for irrigation as reported in the 1967 land inventory report, a total of 3.19 million acres will be irrigated in the whole state. Over 50 percent of the irrigation under scenario I will occur in the Des Moines and Iowa-Cedar water supply areas. Under irrigation scenario II, irrigation will be expanded to cover all flood plain land, class 2S and 2E total croplands reported in the 1967 land inventory report. This scenario represents approximately three times increase in irrigation over scenario I, a total of 8.63 million acres. As under scenario I, the Des Moines and Iowa-Cedar water supply areas have the largest acreages of irrigable lands.

Energy, Employment and Income Coefficients

The 1972 intput-output table also provided data on the amount of energy used in each sector of the Iowa economy. The values were provided in British thermal units in order to convert the different types of energy used to a common unit. The biggest energy using sector of the Iowa economy is sector 68, the utilities sector, which used 197,830.3 billion British thermal units (BTU's) of energy in 1972 (59). This was equivalent to 0.3415 million BTU's per dollar of output of goods and services produced by the utilities sector. The transportation and warehousing sector (sector 65) used the second largest quantity of energy in 1972, an amount of 68,799 billion BTU's which converts to an energy coefficient of 0.1072 million BTU's per dollar of output. The third largest user of energy in 1972 was the food and kindred products sector (sector 14) which employed 62,975 billion BTU's followed by the crop agricultural sector which also used 42,996 BTU's of energy and had an energy coefficient of 0.0181 million BTU's per dollar of output (59).

The number of jobs created by each sector of the Iowa economy in 1972 was also provided alongside the 1972 revised input-output table. The wholesale and retail trade sector provided the biggest employment in the economy in 1972 (59). Out of a total of 1,037,540 jobs created by the Iowa economy in 1972, the trade sector provided 0.02 percent, followed by the medical, educational services and non-profit organizations sector (sector 77) with 0.019 percent. All four sectors under agriculture provided 0.13 percent of the jobs created in 1972 (59).

Employment coefficients were computed from the 1972 input-output table in terms of jobs created per 10,000 dollars worth of output. Appendix B, Table B.5, shows that sector 77, which is the medical, educational and non-profit organizations sector, had the highest employment coefficient of 2.2 jobs per 10,000 dollars (unit) of output. Sector 72, which is the hotels and repair services sector provided the second highest employment coefficient of 1.15 jobs per unit of output.

In general, the sectors engaged in service activities and the trade sector provided higher employment coefficients than the manufacturing sector, except the apparel sector which had a job coefficient of 0.98 jobs per unit of output.

The agricultural sector provided a low employment coefficient. The livestock sector created 0.31 jobs per unit of output while the crop agricultural sector and the forestry and fisher products sector provided 0.2 jobs per unit of output each. Within the agricultural sector in general, the service sector (sector 4) provided an employment coefficient of 0.47 jobs per unit of output. The real estate and the rental service sector, however, had the lowest employment coefficient of 0.05 jobs per unit of output, followed by the food and kindred products sector with an employment coefficient of 0.077 jobs per unit of output.

The amount of income earned in terms of wages and salaries, fringe benefits and proprietors income was also estimated for the Iowa economy. These types of income are called participation income in the input-output model. Out of a total of 7.65 billion dollars of participation income, the wholesale and retail trade sector accounted for 1.34 billion dollars equivalent to 17.5 percent of the income generated. The agricultural sector generated an income of 1.48 billion dollars or 19.3 percent of the total income. In the manufacturing sector, the food and kindred products sector provided the single largest source of income, a little over half a million dollars in total remuneration. Income coefficients expressing the amount of income generated per dollar of output of each sector were computed from the 1972 input-output table. It shows that the medical, educational and non-profit organizations sector had the largest income coefficient of 0.81 cents per dollar of output, followed by the communications sector with an income generating capacity of 68 cents per dollar of output. The real estate and rentals sector had the lowest income coefficient of 4.5 cents per dollar of output. The employment, income, and energy coefficients of the economy are presented in detail in Appendix B, Table B.5.

Sectoral Marginal Propensities to Consume

The major coefficients which provide reinforcement of the linkages between all sectors of the economy are the marginal propensities to consume the goods and services in the economy. An accurate computation of the marginal propensity to consume the goods and services originating from each of the 77 sectors of the Iowa economy would require a detailed research on commodity-wise consumption functions. This is actually beyond the scope of the present study. The marginal propensity to consume commodities were computed roughly as follows.

Assume that the expenditure on commodity i is proportional to total consumption, then,

$$C_i = h_i C + \bar{C}_i, \tag{69}$$

where

C_i = consumptions expenditure on commodity i,

C = total consumption expenditure on all goods and services,

$\bar{C}_i$ = autonomous consumption expenditure on commodity i, and

h_i = coefficient.

Assume further that the aggregate consumption function can be written as follows:

$$C = cY + \bar{C}, \tag{70}$$

where C is defined above,

c = aggregate marginal propensity to consume goods and services,

Y = total income, and

$\bar{C}$ = autonomous component of the aggregate consumption function.

Then, substituting the commodity-wise consumption expenditure equation into Equation 70 gives

$$C_i = ch_iY + h_i\bar{C} + \bar{C}_i = c_iY + h_i\bar{C} + \bar{C}_i, \tag{71}$$

where

c_i = marginal propensity to consume commodity i.

Assume for simplicity that the autonomous components of the consumption Equations 69 and 70 are zero each (this is equivalent to assuming a long run consumption function), then h_i can be obtained by dividing household expenditure on commodity i, C_i, by the total consumption expenditure on all commodities, C, as given by Equation 69. Assuming that the national consumption function can be applied to the Iowa economy, then the aggregate marginal propensity to consume, c, is 0.88 as estimated by Dornbush and Fisher (21) from the national data for the period 1946 to 1975.

Multiplying h_i by 0.88 provides the estimates of the marginal propensity to consume each commodity in the economy. Comprehensive data on the personal consumption expenditures on goods and services in the Iowa economy were provided in the 1967 Iowa input-output table (3, pp. 91-92). The marginal propensities to consume goods and services were estimated according to Equations 69-70 from the 1967 personal consumption expenditure data. Since no data were provided on the personal consumption expenditures on water resources in an input-output framework, and also because it has not been possible to estimate a water consumption function for Iowa, it was decided to set the marginal propensity to consume water resources equal to zero.

The computations outlined above show that the marginal propensities to consume ranged from 0.18 in the wholesale and retail trade sector to almost zero in stone and clay mining and quarrying sector. The agricultural sector recorded a low value of 0.005 in the livestock sector and 0.007 in the crop agricultural sector. Details of the marginal propensities to consume (MPC) the various goods and services are provided in Appendix B, Table B.5. As outlined in Chapter 2, these MPC values are used to transform the basic Leontief matrix into the augmented Leontief matrix of the closed input-output model used in this analysis.

The Inter-Industry Transactions and Technical Coefficients (Direct Requirements) Matrices

The main feature of an input-output model is the specification of transactions and inter-industry linkages between all sectors of the economy. Since the matrix being used in this analysis is large, the transactions table will be presented in detail in Appendix B, Table B.5. The entries in the transactions table represent the inter-industry sales and purchases, i.e., the sales of one industry are the purchases of another. In reality, the most important information being used in this analysis is the inter-industry transactions matrix.

The most up-to-date transactions matrix of the Iowa economy is the 1972 transactions matrix developed by Barnard in (59). It shows that the livestock and livestock products sector purchased 688 million dollars worth of intermediate inputs within its own industry, while its purchases of intermediate inputs from the construction industry, for example, amounted to 13.6 million dollars. The chemical and fertilizer mineral mining sector sold 3.1 million dollars of intermediate inputs to the crop agricultural sector in 1972, while the transportation and warehousing sector purchased 19.4 million dollars of inputs from the construction industry. Appendix B shows the remaining inter-industry transactions.

The input-output transactions matrix can be converted into the direct requirements or technical coefficient matrix. The technical coefficient of production for a given sector expresses the direct requirement for inputs from other producing sectors per dollar of output. It is computed by dividing each sector's purchases of intermediate inputs, presented in Appendix B, Table B.7, by the gross output of that sector, also presented in Appendix B, Table B.2. These technical coefficients are utilized in forming the Leontief matrix which is the main building block of the input-output model presented in Chapter 2.

Selection of the Ten Highest Priority Sectors of the Iowa Economy Using Output and Employment Multipliers

The direct requirements coefficients do not include the effects of interdependence or linkages within the economy. The mathematics of input-output analysis, however, provides us the opportunity to incorporate the linkages in the technical coefficients by using the inverse of the Leontief Matrix. The elements of the Leontief Inverse are the direct and indirect requirements coefficients, and they measure the impact of one dollar increase in final demand throughout the entire economy. As explained in Chapter 2, due to the interdependence in production between the sectors of the economy, when there is an increase in the output of a given sector as caused by an increase in export demand, the effect is felt throughout the system. The increased demand spreads through the economy first to those sectors directly providing inputs of goods and services, and then indirectly to those sectors providing inputs to the sectors that are directly connected to the sector called on to supply the increased demand.

The direct and indirect requirements matrix provides a measure of the multiplier effects in the economy that result from the interdependence among producing sectors. In this study, the selection of the ten sectors of highest priority will be based on the output and employment multiplier. The output multiplier measures the value of output generated within the economy as a result of one dollar increase in the demand for the output of a given sector. The basic input-output model gives a measure of type 1 (simple) output multiplier, while the closed model yields the type 2 (total) output multiplier. It can be recalled that the type 1 multiplier does not include the income effect on production so it is a partial multiplier measure. The type 2 multiplier takes into account the induced effects arising from the increase in employment, income and consumption that is generated from an increase in output by any sector. Appendix B, Table B.7, gives the values of the type 1 and type 2 output and employment multipliers. It shows that one dollar increase in final demand for the output of the livestock sector is multiplied 2.72 times if the induced effects are not considered. But when these induced effects of income on consumption, production and employment are considered, the one dollar increase in the demand for the output of the livestock sector is multiplied 3.48 times. That is, it generates 3.48 dollars worth of output. The communications (except radio and television broadcasting) sector has the lowest type 1 output muliplier. A one dollar increase in the demand for the goods and services of this sector yields 1.27 dollars worth of output, but when the induced effects are taken into consideration, then a one dollar increase in the demand for the output of this sector generates 1.77 dollars worth of output.

In selecting the ten sectors of top priority (ten goals) in the economy based on the output mulipliers, emphasis will be placed on the type 2 multipliers in order to capture the induced income effects. Recognizing the importance of the agricultural sector in the economy of Iowa, the livestock and livestock products sectors as well as the crop agricultural sector, will be included in the top priority sectors of the economy even if the agricultural sector does not have higher output multipliers than the other sectors. Table 3.16 shows the ten sectors of highest priority in the economy based on type 2 output multipliers. The electric lighting and wiring equipment sector has the highest type 2 output multiplier. If there is an increase in the demand for the output of this sector by one dollar, it leads to a total of 5.82 dollars of increased output. The other agricultural (or crop agricultural) sector has been included in the priority sectors due to the importance of crop production in the Iowa economy. The sector number corresponds to the number of the industrial sector as designated in the U.S. Standard Industrial Classification (3).

As a kind of sensitivity analysis, the ten sectors of highest priority in the economy will be selected based on employment multipliers. The direct and indirect requirements matrix also provides a measure of the amount of employment or number of jobs created by a 10,000 dollar increase in final demand for the output of a given industry. Table 3.17 presents the ten sectors of highest type employment multipliers including the agricultural sectors. When the induced effects presented in the closed input-output model are not taken into consideration, then the type 1 employment multipliers show that for a 10,000 dollar increase in the final demand for the goods and services of any sector, the medical, educational and non-profit organizations sector has the highest employment multipliers of 2.46 jobs. An inclusion of induced effects increases the employment multiplier of the medical, educational and non-profit organizations sector to 4.9 jobs.

Table 3.16. The ten sectors of highest priority in the Iowa economy based on type 2 output multipliers

Sector	Sector number	Output multiplier
Electric lighting & wiring equipment	55	5.83
Miscellaneous fabricated textile products	19	3.9
Apparel	18	3.55
Livestock & livestock products	1	3.48
Primary non-ferrous metals manufacturing	38	3.44
Hotels & loding places, personal & repair services, except automobile repair	72	3.33
Medical, educational services & non-profit organizations	77	3.23
Food & kindred products	14	3.19
New construction	11	3.09
Other agricultural	2	2.12

The utilities sector has the lowest employment multipliers both in terms of type 1 and type 2 output multipliers. As can be expected, the crop agricultural sector has a very low employment multiplier compared to the other sectors of the economy.

Unit weights are attached to these ten goals of highest priority in the Iowa economy and the main objective of the study is to find out whether the water resources of the study areas will be sufficient to satisfy the projected growth rates of the economy. The computational procedure provides for the allocation of scarce resources to these ten sectors before any other sectors are considered.

Table 3.17. The ten sectors of highest priority in the Iowa economy based on type 2 employment multipliers

Sector	Sector number	Employment multiplier
Medical, educational & non-profit organizations	77	4.92
Hotels, personal & repair services except automobile repair	72	2.98
Apparel	18	2.79
Electric lighting & wiring equipment	55	2.28
Amusements	76	2.20
Broad & narrow fabrics, yarn & thread mills	16	1.94
Wholesale & retail trade	69	1.7
Miscellaneous textile goods & floor coverings	17	1.55
Livestock & livestock products	1	1.1
Other agricultural products	2	0.6

CHAPTER IV. ATTAINABLE GROSS PRODUCTION OF GOODS AND SERVICES IN 2020 UNDER WATER CONSTRAINTS FOR IOWA AND ITS EIGHT WATER SUPPLY AREAS

Attainable Gross Production of Goods and Services and Water Utilization in Iowa

The value of goods and services that can be produced in 2020 subject to the state's water resources are presented in the first column of Table 4.1. These values were those obtained under the output multipliers priorities option. They coincide with the projected levels of output which were computed by using the state's projected growth rates and the 1972 revised input-output matrix. The projected gross output of goods and services for the year 2020 was presented in Table 3.8 for the ten general sectors of the Iowa economy, and Appendix B, Table B.3, shows the details. It was computed that to achieve the target levels of final demand for goods and services in the year 2020, the state needed to produce an aggregate of 101 billion dollars of output. The values in column 1 of Table 4.1 show that, under the constraint of the state's water resources, an aggregate output of 101 billion dollars of goods and services could be achieved thus satisfying the projected levels of final demand. This implies that the state's available water resources do not constitute a binding constraint on the output of goods and services. The attainable gross production figure shows that the food and kindred products sector forms the largest component of the manufacturing sector, contributing to 9.84 billion dollars out of the aggregate manufacturing sector output of 39.2 billion dollars.

Table 4.1. Attainable gross production of goods and services subject to the water constraints and water requirements of the State of Iowa in 2020 and sectoral water multipliers (under type 2 output multiplier priorities)

Industry number[a]	Gross production (1000 $)	Water consumption (mil. gal.)	Water withdrawal (mil. gal.)	Water consumption multipliers (type 2)
1	4,555,210.0	65,754.46	65,754.46	31.73
2	4,277,431.0	1,002,644.04	1,002,644.04	10.06
		(2,812,085.5)	(2,812,085.50)	
3	17,678.3	0	0	2.13
4	168,310.6	0	0	5.57
5	0	0	0	0
6	0	0	0	0
7	22,619.0	268.85	192.04	21.54
8	0	0	0	0
9	227,612.0	4,391.09	18,390.37	32.68
10	0	0	0	0
11	3,646,371.0	13,743.17	13,743.18	10.88
12	603,117.0	2,237.56	2,237.56	7.56
13	1,361,339.0	0	405.67	3.54
14	9,842,492.0	12,529.49	148,346.04	12.48
15	0	0	0	0
16	84,620.9	200.38	1,945.33	14.19
17	106,647.0	549.77	1,649.19	15.84
18	159,307.0	0	710.51	6.70
19	253,462.0	0	1,409.25	9.78
20	579,573.5	4,458.08	27,218.53	17.45
21	48,024.8	879.0	4,109.55	34.35
22	275,832.4	352.79	6,359.03	8.17
23	225,370.7	16.90	821.92	5.48
24	480,295.3	2,657.95	25,665.52	16.07
25	596,420.0	2,465.0	8,246.7	13.57
26	2,255,307.0	0	0	4.13
27	253,151.0	4,529.63	40,235.82	33.75
28	171,134.4	2,042.5	14,810.88	27.84
29	590,078.9	298.58	4,004.87	5.13
30	294,297.7	172.75	3,913.28	11.73
31	128,771.6	436.92	1,775.38	7.23
32	2,114,664.3	1,676.93	43,211.04	9.23
33	80,562.1	0	0	8.93
34	429,992.4	436.87	7,920.45	
35	0	0	0	0

[a]Refer to Table 3.10 for details on industrial sector descriptions.

Table 4.1. Continued

Industry number	Gross production (1000 $)	Water consumption (mil. gal.)	Water withdrawal (mil. gal.)	Water consumption multipliers (type 2)
36	1,227,066.7	12,433.88	85,214.96	21.25
37	658,216.9	2,339.30	102,833.24	10.54
38	621,613.0	205.75	8,932.58	5.02
39	77,226.0	0	749.80	4.96
40	1,232,263.8	156.49	6,655.46	4.55
41	143,332.1	25.94	724.55	4.70
42	1,278,972.4	517.98	10,055.27	4.94
43	463,948.6	172.59	6,063.35	3.65
44	1,268,885.4	991.0	17,671.78	4.58
45	3,394,793.1	1,357.79	20,772.74	3.72
46	129,870.7	1.95	1,110.41	3.41
47	131,565.0	90.12	932.40	3.85
48	391,947.2	1,150.37	2,336.01	8.04
49	263,384.4	32.66	1,251.87	3.34
50	221,144.3	260.06	1,733.76	6.0
51	0	0	0	0
52	0	0	0	0
53	518,431	198.56	3,045.76	3.80
54	1,854,814.6	534.19	16,543.08	4.36
55	26,332.0	15.83	139.48	6.12
56	942,873.0	209.32	2,802.22	3.32
57	351,436.0	86.80	1,409.96	3.42
58	233,989.7	30.42	1,064.18	4.03
59	2,000,290.3	1,868.27	14,052.03	5.24
60	99,245.0	125.55	2,457.11	4.5
61	111,104.1	40.55	681.06	4.84
62	246,972.4	11.85	1,783.87	3.0
63	41,651.0	13.08	933.07	3.61
64	938,312.1	519.82	9,357.78	5.82
65	2,769,850.3	761.71	7,619.85	2.39
66	870,182.0	59.17	571.71	0.87
67	369,588.0	15.15	114.57	1.79
68	3,240,478.4	61,935.24	4,420,982.77	30.61
69	9,438,141.6	4,322.67	43,255.0	2.07
70	5,667,316.6	272.03	2,776.99	1.35
71	11,070,618.7	265.70	2,601.6	0.79
72	1,878,315.0	1,048.1	10,477.24	4.53
73	1,008,767.4	385.35	3,843.41	1.49
74	3,501,322.4	1,953.74	19,530.38	8.37
75	635,625.3	279.04	2,813.28	2.9
76	564,933.2	274.55	2,712.8	3.04
77	7,262,502.0	8,032.33	80,366.85	5.22

Table 4.1. Continued

Industry number	Gross production (1000 $)	Water consumption (mil. gal.)	Water withdrawal (mil. gal.)	Water consumption multipliers type 2
State total	100,991,308.3	1,309,649.43[b]	6,444,828.58[c]	
		(3,119,094.48)[d]	(8,254,273.63)[e]	

[b]This represents total water consumed under irrigation Scenario I for all economic activities.

[c]Represents total withdrawal under Scenario I.

[d]Represents total water consumed under Scenario II.

[e]Represents total withdrawal under Scenario II.

The goal programming technique of selecting certain sectors of the economy as top priority sectors means that water resources have to be allocated to satisfy the output levels of these priority sectors before any other sectors are considered. Under the output multiplier priorities, the ten sectors selected satisfied their 2020 projected output levels required to satisfy the final demands, which means that these sectors were allocated all their water requirements. But since it turned out that the available water resources do not constitute a binding constraint on production, more than enough water was left over to satisfy the production levels of the other remaining sectors.

In the other agricultural products row (sector 2), the figures under water consumption and water withdrawal columns represent the amount of water expected to be consumed (or withdrawn) for irrigation purposes in 2020. The figures without the brackets represent the quantities of water to be consumed (withdrawn) under irrigation scenario I while the bracketed figures stand for the water expected to be consumed (withdrawn) under irrigation scenario II. It can be recalled that irrigation is assumed to consume 100 percent of all water withdrawn.

Out of an aggregate quantity of 1.31 trillion gallons that would be consumed in satisfying all economic activities by 2020 under irrigation scenario I, one trillion gallons would be used for irrigation while 65 billion gallons would be utilized to satisfy the output of the livestock and livestock products sector (sector 1). Hence, the agricultural sector in general (sectors 1-4) would consume 82 percent of the water expected to be consumed under irrigation scenario I. The total water consumed under irrigation scenario I equals only 8.4 percent of the state's water supply which equals 15.6 trillion gallons per year. Comparing the water consumption data presented in Table 4.1 with the water supply data shown in Table 3.10, it can be seen that the aggregate water expected to be consumed in all economic activities by the year 2020 could not be supplied from the estimated yields of the state's alluvial aquifers alone. But the other cheap source of water supply which is the stream flow can satisfy all consumption water requirements of the state without any strain on the aggregate state stream flow, since 12.5 trillion gallons of water per year could be available from the state's rivers. Even under the conditions where only 2 percent of the stream flow from Missouri and Mississippi rivers could be made available for consumption purposes, 6.3 trillion gallons of the stream flow could be available for economic activities. Consumptive requirements would account for 21 percent of this amount under irrigation scenario I.

It should be recalled that irrigation scenario I allows for the irrigation of 3.19 million acres of all class I land (allocated to field crops in the 1967 land inventory report) and class 2S land. This irrigated acreage represents 14 times the amount of land irrigated in 1977 (41, p. 15). Irrigation scenario II which allows for the irrigation of all flood plain land, class 2S and class 2E total croplands in the state represents approximately three times the amount of land to be irrigated under scenario I. Under scenario II, 3.12 trillion gallons of water per year would be consumed in satisfying the attainable output of goods and services in 2020. Ninety percent of this amount would be consumed in crop irrigation while the remaining ten percent would be shared between the livestock sector and the other industrial sectors. The state's interior streams and two percent of the border rivers would be sufficient to satisfy the demand for water for all economic activities under scenario II, which means that the most expensive source of water supply, the reservoir water supply, may not be essential in periods of normal stream flow.

Table 4.1 also shows that the largest water using sector, apart from the agricultural sector, is the utilities (electric, gas, water and sanitary services) sector (sector 68). Approximately 62 billion gallons of water would be consumed in satisfying the 3.2 billion dollars of output of goods and services which would be produced by the utilities sector in 2020. But this represents only 0.5 percent of the yield from the state's rivers. The water withdrawal column of Table 4.1 shows that 6.4 trillion gallons of water would be withdrawn in producing the goods and services required to satisfy the final demand projections in 2020 under irrigation scenario I. The largest amount would be withdrawn in the utilities sector which would require 4.4 trillion gallons or 68.6 percent of the aggregate withdrawal. But since this sector has a low water consumption coefficient, it would not impose any direct strain on the state's water resources.

On the whole, 20 percent of the water withdrawn for all economic activities under irrigation scneario I would be consumed (mainly in crop irrigation), while almost 38 percent of the water withdrawn under scenario II would be utilized for consumptive purposes. The two irrigation scenarios specified can be seen to be very ambitious plans. But even under these very strenuous irrigation plans, the state as a whole can be sure of adequate water supplies for all industrial and domestic requirements without utilizing its reservoir water resources in normal years. The total quantities of water withdrawn or consumed which are presented in this section include a total of 66.2 billion gallons required to be set aside for domestic or residential usage. This figure represents only five percent of aggregate water expected to be consumed under scenario I. Hence, the domestic population is not expected to place any appreciable strain on water usage, given that the present use rates continue to 2020.

Water consumption multipliers for all sectors of the Iowa economy are reported in Table 4.1. The water consumption coefficients described in Chapter 3 and presented in Appendix B, Table B.4, account for the direct water requirements by each industry. It shows that stone and clay mining sector (sector 9) consumes 19.3 gallons of water for each dollar of output it produces, while the livestock sector consumes 14.4 gallons per dollar of output. Recognizing the importance of indirect requirements, water consumption multipliers were estimated for each sector of the economy of Iowa. These water multipliers take into account the additional water consumed directly and indirectly by all sectors when there is a unit increase in final demand from any sector. They are thus type 2 water consumption multipliers. The multipliers show that even though the livestock sector consumes only 14.4 gallons of water directly per unit of output, when there is a unit increase in final demand from this sector, 31.73 gallons of water are consumed, mainly due to the induced production effect. The chemical products sector (sector 77) which has a direct water consumption coefficient of 11.9 gallons of water per dollar of output has a water consumption multiplier of 33.75 gallons per dollar of output delivered to final demand, almost three times the direct water requirement. Other sectors with high consumption multipliers are the wooden containers (sector 21), plastics and synthetic materials (sector 28), and the utilities sector. It was estimated that the utilities sector would consume over 60 billion gallons of water to satisfy its output of goods and services by 2020. Given that this sector has a high water consumption multiplier, it can be expected that a unit increase in final demand from the utilities sector would exert the heaviest burden on Iowa's water resources in periods of water shortage, through its water impacts spread over the other industries.

Attainable Gross Production of Goods and Services and Resource Utilization by Water Supply Areas in 2020

Tables 4.2 to 4.9 report on the quantity of water that would be required to support the attainable 2020 gross production of goods and services and the target levels of final demands for each water supply area. Irrigation water requirements are not included in these tables and will be presented in Tables 4.10 and 4.11. Hence, the water consumption and withdrawal requirements reported in the agricultural sector are for the livestock sectors of the economies of each region. Tables 4.2. to 4.9, therefore, present only industrial water requirements while crop agricultural water requirements are reported separately. These water requirements, like those reported for the state as a whole in Table 4.1, are both direct and indirect requirements since the input-output portion of the goal programming input-output synthesis takes care of indirect linkages within the economy.

Energy requirements by each general sector of the economies of the water supply areas are also presented here. These energy requirements are those required to satisfy the 2020 target levels of final demands or to support the 2020 attainable gross production requirements. It may be recalled that the major constraints in the model specification were regional water constraints, so that the computed energy requirements can be interpreted as the amounts of energy that ought to be made available for the attainable productions to be possible. As with the water requirements, the energy requirements reported for the agricultural sector do not include crop irrigation requirements.

The ten general sectors of the Iowa economy for which these regional water and energy resource utilizations have been computed are those described in Table 3.4. So the agricultural sector comprises the first four sectors of the economy, the mining sector consists of sectors 4 through 10, while the construction sector consists of sectors 11 and 12. It was found out from the analysis of Table 4.1 that the state of Iowa as a whole has more than enough water to support its projected population and economic growth to the year 2020 even under irrigation scenario II. But the regional water availability data for Iowa shows that certain areas of the state may not be as fortunate as the state in general in terms of water supply. A case in point is the Western water supply area which has the least aggregate water supply quantity in the state. Table 3.10 shows that while the state as a whole can boast of 15.6 trillion gallons of water per year, the Western water supply area has only 0.65 trillion gallons per year from all its water supply sources. Hence, in the regional level, water requirements associated with ambitious expansions in economic activities could impose substantial burdens on the regional water supplies. But our results at the regional levels show that the attainable production of goods and services by each water supply area in 2020 is equivalent to the projected 2020 gross output under the type II output multipliers priorities option.

Industrial water and energy requirements in the Western water supply area in 2020

The water and energy requirements by the Western water supply area are presented in Table 4.2. Water requirements are reported both in terms of water consumption and water withdrawal. Occasional references will have to be made to Table 3.10 for comparisons with regional water availabilities by sources. Table 4.2 shows that to support the attainable gross production of goods and services in the Western water supply area, 27.6 billion gallons of water would be consumed. This figure does not include residential and irrigation water requirements under both irrigation scenarios. The manufacturing sector is the largest water consuming sector in this region. This sector consumes 15.1 billion gallons or 54.7 percent of the amount of water expected to be consumed by the industrial (non-irrigation and non-residential) sectors of the Western water supply area. The livestock sector is the next largest water consuming sector in this region,

Table 4.2. Attainable gross production of goods and services and resource utilization by the Western water supply area in 2020

General economic sector	Gross output (1000 $)	Total water consumption MGY[b]	Total water withdrawal[a] MGY	Energy utilization TBTUY[c]
Agric., forestry & fisheries[d]	959,592	6,996.27	6,996.27	3.92
Mining	14,646.4	279.60	1,114.94	0.68
Construction	195,051	733.51	733.51	3.41
Manufacturing	1,819,042	15,109.27	30,729.58	27.37
Transportation	126,859	34.89	348.97	13.6
Communication	49,590.4	2.97	27.45	0.98
Utilities	193,781	3,703.74	264,375.42	66.18
Trade	528,536	242.07	2,422.28	7.19
Finance, insurance & real estate	674,539	21.67	216.76	4.88
Services	638,613	514.84	5,149.0	14.62
Total	5,200,239.8	27,638.83	312,114.18	142.83

[a]Since much of the water withdrawn at a point is returned as effluent or recycled, the same flow can be withdrawn several times as it progresses downstream in a river basin. This implies that the total water withdrawn can exceed the annual average or low flow yield of a stream or river.

[b]MGY stands for million gallons per year.

[c]TBTUY stands for trillion British thermal units per year.

[d]Irrigation requirements not included.

accounting for 7 billion gallons of water or 25 percent of the aggregate water consumed by all industrial sectors. The utilities sector also uses a fair amount of the consumed water and ranks third behind the livestock sector in terms of water consumption in the Western water supply area.

But in terms of water withdrawal, the utilities sector is the largest water withdrawing sector in this region. To support its component of the attainable output of goods and services in 2020, the utilities sector withdraws 264 trillion gallons out of the total of 312 trillion gallons of water expected to be withdrawn for industrial activities in the Western water supply area.

The water supply data of Table 3.10 show that, disregarding the irrigation water requirements, the yield from the interior streams of the Western water supply area, which equals 423 trillion gallons per year, far exceeds the 27.6 trillion gallons of water expected to be consumed in producing enough goods and services required to support the 2020 final demand of the region.

Table 4.2 also shows that to achieve the required production in 2020, the Western water supply area will have to utilize 142.8 trillion British thermal units of energy, with the utilities sector being the largest energy consuming sector in this region.

Industrial water and energy requirements in the Southern water supply area in 2020

The Southern water supply area, which has more water resources than the Western water supply area, requires 14.38 billion gallons of consumptive water to support its 2020 output of goods and services. This is less than the amount required in the Western water supply area. The aggregate consumptive requirements (excluding irrigation and residential) in the Southern water supply area can be supplied from the interior streams which yield an average quantity of 814.6 trillion gallons per year. In this region, the livestock sector is the largest water consuming sector. Over 7 billion gallons of water are expected to be consumed by the livestock sector in order to support its share of the output of goods and services. The utilities sector is also a major water consuming sector in the Southern water supply area as shown in Table 4.3.

Considering the aggregate withdrawal of water which is expected to stand at 326.3 billion gallons, enough water resources are available from the interior streams to support this withdrawal. The energy utilization column of Table 4.3 shows that the Southern water supply area requires 130.17 trillion British thermal units to support its 2020 output of goods and services, with the utilities sector accounting for 73.8 trillion British thermal units or 57 percent of the total energy requirements.

<u>Industrial water and energy requirements in the Des Moines water supply area in 2020</u>

This region is expected to be the center of economic activity in the state in 2020, just as it has been in the previous years. The 2020 attainable gross output of this region is 29.4 billion dollars

Table 4.3. Attainable gross production of goods and services and resource utilization by Southern water supply area in 2020

General economic sector	Gross output (1000 $)	Total water consumption MGY	Total water withdrawal MGY	Energy utili- zation TBTUY
Agric., forestry & fisheries	1,000,166	7,292.17	7,292.17	4.08
Mining	17,205.1	326.2	1,300.76	.86
Construction	191,652	720.73	720.73	3.35
Manufacturing	900,027	1,265.94	15,619.88	15.14
Transportation	130,737	35.95	359.66	14.05
Communication	32,605.8	1.95	18.05	.26
Utilities	216,140	4,131.08	294,879.8	73.81
Trade	519,098	237.75	2,379.03	7.06
Finance, insurance & real estate	468,662	15.06	150.6	1.43
Services	442,574	356.8	3,568.37	10.13
Total	3,918,856.9	14,383.63	326,289.05	130.17

of goods and services, as shown in Table 4.4. This value, like the outputs of all the regions, coincides with the target level of output required to support the final demand in 2020 under the region's water supply constraints. Out of the aggregate water supply in the region which stands at an average of 1.78 trillion gallons per year, 54.95 billion gallons are expected to be consumed in supporting the 2020 gross output of goods and services. The alluvial aquifers of the region have an average yield of 51.97 billion gallons per year while the average yield from the other shallow and bedrock aquifers is 322.59 billion gallons per year. Hence, the estimated yield from the groundwater resources of this region, which total at 374.56 billion gallons, is enough to support the consumptive requirements of the industries of this region. An estimated 1.3 trillion gallons per year can also be obtained from the rivers in the Des Moines water supply area, thus providing for enormous excess supply of water for economic activities in the region.

Considering the sectors of economic activities in the region, the livestock sector is the largest water consuming sector in the region, accounting for 15.4 billion gallons of water out of the estimated 54.95 billion gallons expected to be consumed in all economic activities (excluding irrigation and residential) in the region. The utilities sector will consume 15.1 billion gallons.

On the whole, 1.3 trillion gallons of water are expected to be withdrawn in order to support the economic activities of the region

Table 4.4. Attainable gross production of goods and services and resource utilization by Des Moines water supply area in 2020

General economic sector	Gross output (1000 $)	Total water consumption MGY	Total water withdrawal MGY	Energy Utilization TBTUY
Agric., forestry & fisheries	2,112,163	15,399.69	15,399.69	8.63
Mining	83,735.25	1,537.78	6,132.2	3.72
Construction	1,153,736	4,338.77	4,338.77	20.19
Manufacturing	9,522,597	13,409.21	158,176,01	154.19
Transportation	989,943	272.23	2,723.33	106.12
Communication	443,836	26.61	245.69	3.49
Utilities	791,973	15,136.98	1,080,488.76	270.46
Trade	2,592,241	1,187.44	11,882.15	35.26
Finance, insurance & real estate	7,450,055	239.28	2,393.47	22.86
Services	4,216,331	2,399.17	33,995.3	96.52
Total	29,356,610.25	54,947.16	1,315,775.35	721.44

by the year 2020 and the utilities sector, as usual, is the greatest contributor. This sector needs to withdraw 82 percent or 1.08 trillion gallons out of the aggregate water withdrawal of the region. The utilities sector is also the largest energy utilizing sector in the region. Out of the aggregate of 721.44 trillion British thermal units of energy which will be needed to support the gross production of the region in 2020, the utilities sector consumes 270.46 trillion British thermal units or 37 percent of the aggregate energy utilization in the region. As shown in Table 4.4, the services, manufacturing and transportation sectors, also require substantial amounts of energy to support their gross production of goods and services in 2020. But with respect to its water resources, the Des Moines water supply area has enough groundwater resources to support consumptive water requirements in industrial production by the year 2020. Consumptive water requirements account for only 14.7 percent of the available groundwater supplies, not considering the yield from rivers which equal 1.33 trillion gallons per year or the reservoir water supplies.

Industrial water and energy requirements in the Iowa-Cedar water supply area in 2020

The Iowa-Cedar water supply area ranks second in the concentration of economic activities in the state of Iowa, producing 25.2 billion dollars of goods and services out of the attainable state output of 101 billion dollars in the year 2020. The attainable gross output of goods and services in this locality as well as the consumptive water and energy requirements are presented in Table 4.5. It can be seen that to support this component of the state's gross output of goods and services in 2020, 55.6 billion gallons of water would be consumed. But a comparison with the regional water supply information of Table 3.10 reveals that the available water supplies from the groundwater resources of the region, which equals 538.96 billion gallons, is almost ten times the consumptive water requirements and over four times the water withdrawn. Just as in the Des Moines water supply area, the livestock sector of the economy of the Iowa-Cedar water supply area accounts for the largest component of the industrial water consumption requirements; but unlike the Des Moines area, the manufacturing sector requires an almost equal quantity of consumptive water as the livestock sector in order to achieve the projected final demands in 2020.

The biggest water consuming sectors of the Iowa-Cedar water supply area, the livestock sector, the manufacturing sector and the utilities sector, contribute to 83 percent of the consumptive water requirements or 46 billion gallons, an equivalent of 3.7 percent of the yield from the interior streams and rivers in the region which equals 1.24 trillion gallons per year. This implies that even under the projected growth rates in population and economic activites to 2020 as well as inclusion of the direct and indirect linkages in the model, this water supply area is not likely to experience curtailment of economic growth as a result of its water supplies, given the present yields of its water resources.

Table 4.5. Attainable gross production of goods and services and resource utilization by Iowa-Cedar water supply area in 2020

General economic sector	Gross output (1000 $)	Total water consumption MGY	Total water withdrawal MGY	Energy utilization TBTUY
Agric., forestry & fisheries	2,270,883	16,556.97	16,556.97	9.27
Mining	50,470.25	931.99	3,716.48	2.26
Construction	1,105,292	4,156.6	4,156.6	19.34
Manufacturing	11,284,675	16,001.57	188,756.64	183.99
Transportation	526,548	144.8	1,448.53	56.45
Communication	322,959	19.36	178.77	2.54
Utilities	720,034	13,762.01	982,342.39	245.9
Trade	2,182,570	1,000.3	10,009.28	29.7
Finance, insurance & real estate	3,110,745.5	99.91	999.34	9.54
Services	3,649,005	2,941.8	29,421.01	83.53
Total	25,223,181.85	55,615.31	1,237,586.01	642.52

Enormous water withdrawal is expected from the utilities sector, almost one trillion gallons or 79.4 percent of the aggregate 1.24 trillion gallons required to be withdrawn for industrial production in 2020. With respect to energy requirements, this region needs to make available 642 trillion British thermal units of energy in 2020 to support its industrial activities, with the greatest quantity allocated to the utilities, manufacturing, and services sectors.

Industrial water and energy requirements in the Northeastern, Missouri, Mississippi, and Skunk water supply areas in 2020

Tables 4.6 to 4.9 present the attainable gross outputs and resource utilization by the remaining water supply areas of the state of Iowa. It can be observed that all the water supply areas can attain the target levels of gross production as presented in Table 3.8, under their water resource constraints. The Northeastern water supply area, which ranks close to the Southern water supply areas in terms of the volume of economic activity, requires 13.39 billion gallons of consumptive water requirements to support its share of the state's output of goods and services in 2020, which stands at 4.25 billion dollars. This consumptive water requirement forms only 1.7 percent of the aggregate yield of 246.3 billion gallons per year from the region's groundwater resources. Table 4.6 gives details on water and energy requirements of the Northeastern water supply area. Given the low volume of economic activity in this region, only 117.7 trillion British thermal units of energy are required to support the attainable output

Table 4.6. Attainable gross production of goods and services and resource utilization by Northeastern water supply area in 2020

General economic sector	Gross output (1000 $)	Total water consumption MGY	Total water withdrawal MGY	Energy utili- zation TBTUY
Agric., forestry & fisheries	937,035	6,831.88	6,831.88	3.83
Mining	1,852.1	46.6	185.84	0.12
Construction	189,952	714.34	714.34	3.3
Manufacturing	1,469,664	2,162.24	25,514.43	24.87
Transportation	124,920	34.35	343.63	13.39
Communication	30,250.2	1.81	16.71	0.24
Utilities	155,219	2,966.7	211,525.71	53.01
Trade	391,683	179.39	1,795.03	5.33
Finance, insurance & and real estate	403,384	12.96	129.63	1.24
Services	542,078	437.02	4,370.65	12.41
Total	4,246,037.3	13,387.29	251,427.85	117.7

of goods and services in this region in 2020.

The Missouri water supply area also contributes to only 7.6 billion dollars of the attainable output of goods and services and has enough water resources to support its growth. The aggregate 2020 consumptive water requirements in this region is only 15.02 billion gallons or 2.6 percent of the yield from the alluvial aquifer of the region, not including the other sources of its water supplies such as the other shallow and bedrock aquifer which stand at an average of 105.9 billion gallons per year, and the flow from the Missouri River which equals an average of 3.36 trillion gallons per year. Additionally, the interior streams of the Missouri water supply area can yield an average of 325,850 million gallons per year, enough to support over 20 times the consumptive water requirements of the region in 2020. But even though the region has excessive amounts of water to support its growth projections, an amount of energy equivalent to 224 trillion British thermal units must be supplied in 2020 to achieve the gross productions which were feasible under the region's water constraints. Table 4.7 gives the details of the attainable output levels, water, and energy allocation in the Missouri water supply area.

Another region of massive concentration of economic activities is the Mississippi water supply area. This region ranks third in terms of the concentration of economic activities, behind the Des Moines and Iowa-Cedar water supply areas. As can be seen in Table 4.8, the Mississippi water supply area consumes 37.86 billion gallons

Table 4.7. Attainable gross production of goods and services and resource utilization by Missouri water supply area in 2020

General economic sector	Gross output (1000 $)	Total water consumption MGY	Total water withdrawal MGY	Energy utilization TBTUY
Agric., forestry & fisheries	321,965	2,347.43	2,347.43	1.31
Mining	6,969.8	139.8	557.52	.34
Construction	374,380	140.79	140.79	6.55
Manufacturing	2,255,763	4,585.87	54,113.27	38.16
Transportation	361,465	99.4	994.39	38.75
Communication	165,756	9.94	91.76	1.3
Utilities	321,131	6,137.8	435,782.63	109.67
Trade	880,578	403.31	4,035.63	11.98
Finance, insurance & real estate	1,561,650	50.17	501.82	4.79
Services	1,367,820	1,102.72	11,028.36	31.31
Total	7,617,477.8	15,017.23	509,593.14	244.16

Table 4.8. Attainable gross production of goods and services and resource utilization by Mississippi water supply area in 2020

General economic sector	Gross output (1000 $)	Total water consumption MGY	Total water withdrawal MGY	Energy utili-zation TBTUY
Agric., forestry & fisheries	634,911	4,629.12	4,629.12	2.59
Mining	63,264.55	1,164.99	4,645.96	2.82
Construction	656,546	2,469.02	2,469.02	11.48
Manufacturing	9,602,346	13,526.54	159,613.17	145.6
Transportation	398,027	109.46	1,095.0	42.67
Communication	140,341	8.41	77.69	11.04
Utilities	681,472	13,024.97	924,773.15	232.72
Trade	1,638,461	750.42	7,508.91	22.28
Finance, insurance & real estate	2,177,606	69.95	699.67	6.68
Services	2,618,313	2,110.86	21,110.76	59.93
Total	18,611,287.55	37,863.74	1,126,622.45	537.81

of water per year in order to support its 2020 feasible gross production of goods and services which totals at 18.6 billion dollars. But this quantity of water allocated for consumptive purposes forms only 11.4 percent of the yield from the alluvial aquifers of the region which equals an average of 330.9 billion gallons per year. The manufacturing sector makes the greatest contribution to the region's economy and requires over 13 billion gallons of consumptive water for its output in 2020. The massive water resources of the region, including the Mississippi border river, which equals 4.3 trillion gallons per year mean that any expansion of economic activities would have negligible impact on the region's water resources. But to make the output of goods and services possible in 2020, given the production techniques embodied in the Iowa input-output matrix, an amount of energy equivalent to 537.8 trillion British thermal units would have to be provided.

The Skunk water supply area does not have a high volume of economic activities as the Des Moines, Iowa-Cedar, and Mississippi water supply areas, but it has a comparatively high volume of groundwater resources, in relation to its water withdrawal and consumptive requirements. Table 4.9 presents the feasible output of goods and services in the Skunk water supply area as well as its water and energy requirements. The livestock products sector has the highest consumptive requirements. An amount of 5.7 billion gallons, out of the total of 15.4 billion gallons required for consumption in 2020, will have to be allocated to the livestock sector of the Skunk economy. But this total

Table 4.9. Attainable gross production of goods and services and resource utilization by Skunk water supply area in 2020

General economic sector	Gross output (1000 $)	Total water consumption MGY	Total water withdrawal MGY	Energy utili-zation TBTUY
Agric., forestry & fisheries	781,915	5,700.92	5,700.92	3.19
Mining	12,087.45	233.0	929.2	0.56
Construction	382,879	1,439.86	1,439.86	6.7
Manufacturing	2,346,905	3,452.91	40,744.34	39.61
Transportation	111,348	30.62	306.31	11.9
Communication	54,425.6	3.26	30.13	.43
Utilities	160,728	3,072.0	218,112.0	54.8
Trade	705,973	323.3	3,235.39	9.6
Finance, insurance & real estate	872,132	28.66	286.67	2.84
Services	1,376,731	1,109.9	11,100.36	31.51
Total	6,825,124	15,394.43	281,885.18	161.27

consumptive requirement can be made available from the groundwater resources of the region which equal 179.5 billion gallons or 11.7 times the industrial consumptive water requirements in 2020. The manufacturing sector, which forms the largest component of the economy of the Skunk water supply area, needs to be allocated 3.4 billion gallons of consumptive water in 2020.

Even though this region has enough water supplies from its groundwater sources to support its economic growth to the year 2020, it requires 161.27 trillion British thermal units of energy in order to support its 2020 gross production.

In general, just as was found out for the state of Iowa, the separate water supply areas of the state of Iowa have more than enough water supplies to support their final demands in the year 2020. Even the most water deficient region of the eight water supply areas, the Western water supply area, has an average of 214 billion gallons of groundwater supplies per year which is enough to supply almost 8 times its industrial consumptive water requirements. Hence, except in periods of very extreme drought, the reservoir water supplies may not be needed to support industrial activities in any of the water supply areas.

But the analysis has shown that even though water is not a binding constraint in industrial production, to make all the above industrial activities possible, the state needs to supply an equivalent of 2,697.7 trillion British thermal units of energy, which is equivalent to 2.78

times the energy consumption in 1977 (36, p. 6) by all sectors of the Iowa economy.

Consumptive Water Requirements Under Irrigation Scenarios I and II

As has been shown in Tables 4.1 to 4.9, water utilization by the non-crop agricultural sectors of the Iowa economy constitutes virtually no burden on the available water resources of the state. The biggest demands on water requirements come from the crop irrigation requirements. Tables 4.10 and 4.11 present information on consumptive water requirements by each water supply area in terms of both irrigation demands and the demands by all other sectors of the economies of each region.

Under irrigation scenario I, 2020 aggregate water consumption for non-crop irrigation purposes, namely water consumption for industrial production and residential water uses, add up to 307,005 million gallons, while the aggregate water consumption for all purposes totals 1.3 trillion gallons. Hence, the non-crop irrigation water consumption constitutes only 23.6 percent of the overall water consumption, while the remaining 77 percent is due to crop irrigation water requirements.

In Table 4.10, it can be observed that the bulk of the statewide irrigation water requirements originate from the Des Moines and Iowa-Cedar water supply areas, which consume 28.32 percent and 22.72 percent of the total water consumption respectively under irrigation scenario I.

Table 4.10. Consumption water requirements under irrigation scenario I by water supply areas in 2020

Area	Irrigated acreage (1000 acres)	Water consumption: For irrigation MGY[b]	Water consumption: Other sectors MGY	Water consumption: Total[a] MGY	Supply source
Western	487.59	147,757.99	32,144.01	179,902 (13.73)	GW1, SF
Southern	148.92	45,615.09	19,419.32	65,034.41 (4.97)	GW1, SF
Des Moines	921.08	297,132.84	73,775.71	370,908.56 (28.32)	GW1, SF
Iowa-Cedar	758.09	224,791.86	72,708.41	297,500.27 (22.72)	GW1, SF
Northeastern	219.55	73,687.39	17,107.29	90,794.68 (6.93)	GW1, SF
Skunk	198.69	60,858.35	20,854.8	81,713.15 (6.24)	GWL, SF
Missouri	263.29	90,083.84	21,181.71	111,265.55 (8.49)	GW1
Mississippi	196.40	62,716.68	49,813.95	112,530.63 (8.60)	GW1
Total	3,193.61	1,002,644.04	307,005.2	1,309,649.24(100.0)	

[a]Figures in parentheses represent the percentages of aggregate state water consumption allocated to each water supply area. Note also that the total is less than the more conservative water availability values presented in Table 3.10 (pp. 74-75), footnote c.

[b]MGY represents million gallons per year.

Table 4.10. Continued

Water supply area	Volume of water available from: Alluvial aquifers MGY	Rivers MGY	Total supply from all sources[c] MGY	Shadow price[d] $/1000 gallons
Western	13,685.7	423,605	653,003.4	1.6 (GW1)
Southern	13,685.7	814,625	918,082.38	1.6 (GW1)
Des Moines	51,973.08	1,335,985	1,776,534.5	1.9 (GW1)
Iowa-Cedar	25,742.15	1,238,230	1,809,445.05	2.3 (GW1)
Northeastern	1,955.1	684,285	981,297.28	1.7 (GW1)
Skunk	18,247.6	619,115	802,731.48	1.6 (GW1)
Missouri	576,265.7	997,101	1,684,970.33	0
Mississippi	330,900.68	1,339,243.5	1,957,055.11	0
Total yield	1,032,455.7	7,452,189.5	10,583,119.53	

[c]The total water supply includes the sum of the supplies from alluvial aquifers, other shallow and bedrock aquifers, reservoirs, interior streams and 2 percent of the flow from Missouri and Mississippi border rivers which can be available for consumptive uses.

[d]The symbols in parentheses indicate the source of water supply to which the positive shadow price is associated.

This is because these two water supply areas have 29.6 percent and 23.6 percent, respectively, of the state's total class I land (allocated to field crops in the 1967 land inventory report) suitable for irrigation. Under irrigation scenario I, it can be observed that only the Missouri and Mississippi water supply areas have enough water from their alluvial aquifers to support the irrigation water requirements. The yields from the alluvial aquifers of the Missouri water supply area which stand at 576.3 billion gallons is enough to support the aggregate water consumptive requirements of this region which equals 111.26 billion gallons.

The Mississippi water supply area is also endowed with sufficient water from the alluvial aquifers of the Mississippi River, which has an average yield of 330.9 billion gallons or 2.9 times the aggregate consumptive water requirements of this region. Also, the Mississippi water supply area has only 196.4 thousand acres of irrigated land under the irrigation scenario I, compared with 921 thousand acres of irrigated land in the Des Moines water supply area or the 758 thousand acres in the Iowa-Cedar water supply area.

The Western water supply area, for example, irrigates 487.59 thousand acres under irrigation scenario I, almost 2.5 times the irrigated land in the Mississippi water supply area, and 1.9 times the irrigated acreage in the Missouri water supply area. But, incidentally, the Western water supply area has only 0.65 trillion gallons out of the state's consumption water resources which is 10.58 trillion gallons per year as shown in Table 4.10. This inequity forces the Western water supply area to exhaust its alluvial aquifers under irrigation scenario I and to use some additional water from its stream flow. When this occurs, a positive shadow price is associated with the water from alluvial aquifers as shown in the last column of Table 4.10. The shadow price indicates the change in the value of aggregate income that accrues to the region when the water supply constraint is relaxed by one unit. The shadow prices associated with the water from stream flow, the other shallow and bedrock aquifers, and the reservoir water supply in the Western water supply area are zero each, since these resources are not limited in quantities in the Western water supply area under irrigation scenario I.

Positive shadow prices are associated with the water from the alluvial aquifers of all eight water supply areas except the Missouri and Mississippi water supply areas, which have more cheap water resources, i.e. the alluvial aquifers, to take care of all their irrigation and non-irrigation requirements under irrigation scenario I. The last column of Table 4.10 shows that the alluvial aquifers of the Iowa-Cedar water supply area have the highest shadow price of 2.3 dollars per 1000 gallons of water, followed by the alluvial aquifers of the Des Moines water supply area, which have shadow prices of 1.9 dollars per 1000 gallons.

The difference between the shadow prices of the alluvial aquifers of these two regions might be partly due to the fact that the

Iowa-Cedar water supply area has a smaller quantity of alluvial aquifers in relation to the volume of its economic activities, than the Des Moines water supply area. The Des Moines water supply area has almost two times the volume of alluvial aquifers as the Iowa-Cedar water supply area as shown in Table 4.10. But these two water supply areas have almost the same attainable gross production of goods and services in 2020 as shown in Table 4.4 and Table 4.5, so that the alluvial aquifers, being scarcer in the Iowa-Cedar water supply area, command higher value. The shadow price of the alluvial aquifers of Northeastern water supply area is 1.7 dollars per thousand gallons, while the shadow prices of the alluvial aquifers of the Skunk, Southern, and Western water supply areas are 1.6 dollars per thousand gallons each.

Table 4.11 presents the irrigation water requirements as well as the non-irrigation consumptive water requirements in each water supply area under irrigation scenario II. Irrigation scenario II forces all water supply areas to irrigate all available flood plain land, class 2S and class 2E crop lands suitable for irrigation. In all, an aggregate of 8.96 million acres of land are irrigated, about 2.8 times the acreage irrigated under the first scenario. This creates a statewide consumptive water requirement of 3.119 trillion gallons, with the Des Moines and Iowa-Cedar water supply areas contributing to 21.89 percent and 20.18 percent, respectively, as shown in Table 4.11.

Under irrigation scenario II, there will not be enough water in the alluvial aquifers and streams of the Western water supply area

Iowa-Cedar has a small quantity of alluvial aquifers in relation to the volume of its economic activities than the Des Moines water supply area. The Des Moines water supply area has almost two times the volume of alluvial aquifers as the Iowa-Cedar water supply area, as shown in Table 4.10. But these two water supply areas have almost the same attainable gross production of goods and services in 2020 as shown in Table 4.4 and Table 4.5; so that the alluvial aquifers, being scarcer in the Iowa-Cedar water supply area, command higher value. The shadow price of the alluvial aquifers of the Northeastern water supply area is 1.7 dollars per thousand gallons, while the shadow prices of the alluvial aquifers of the Skunk, Southern, and Western water supply areas are 1.6 dollars per thousand gallons each.

Table 4.11 presents the irrigation water requirements as well as the consumptive water requirements in each water supply area under irrigation scenario II. Irrigation scenario II forces all water supply areas to irrigate all available flood plain land, class 2S and class 2E crop lands suitable for irrigation. In all, an aggregate of 8.96 million acres of land are irrigated, about 2.8 times the acreage irrigated under the first scenario. This creates a statewide consumptive water requirement of 3.119 trillion gallons, with the Des Moines and Iowa-Cedar water supply areas contributing to 21.89 percent and 20.18 percent, respectively, as shown in Table 4.11.

Under irrigation scenario II, there will not be enough water in the alluvial aquifers and streams of the Western water supply area to support the consumptive requirements of the economic activities, because the Western water supply area has 11.2 percent of irrigable flood plain land and 19.8 percent of the aggregate class 2E crop land suitable for irrigation in the state as shown in Table 3.13. So this area is forced to utilize additional water from the other shallow and bedrock aquifers (GW2), thus leading to a positive shadow price for its cheap water supplies, namely the alluvial aquifers and stream flow. The shadow price of water from the alluvial aquifers of the Western water supply area is still 1.6 dollars per thousand gallons, while that of the stream flow is 1.4 dollars per thousand gallons.

The Southern water supply area is allocated 9.07 percent of the aggregate state consumptive water requirements under irrigation scenario II, 4.3 times the amount of consumptive water allocated to it under irrigation scenario I. The increase is explained by the fact that while it has the least amount of irrigated land under irrigation scenario I, as shown in Table 4.10, the Southern water supply area ranks fourth in the acreage of irrigated land under scenario II, because it has 16.6 percent of the state's flood plain land, as shown in Table 3.13. But it has enough water resources from its interior streams and alluvial aquifers to support its consumptive water requirements, thus driving the shadow prices associated with the stream flows, other shallow and bedrock aquifers, and reservoir water supplies to zero. The shadow price of alluvial aquifers in the Southern water supply area under irrigation scenario II is equivalent to that under the first scenario.

Table 4.11. Consumption water requirements under irrigation scenario II by water supply areas in 2020

Area	Irrigated acreage (1000 acres)	Water consumption: For irrigation MGY[b]	Water consumption: Other sectors MGY	Water consumption: Total[a] MGY	Supply source
Western	1,529.02	463,392.61	32,144.01	495,536.62 (15.89)	GW1, SF, GW2
Southern	860.07	263,476.82	19,419.32	282,896.14 (9.07)	GW1, SF
Des Moines	1,887.93	609,068.75	73,775.71	682,844.46 (21.89)	GW1, SF
Iowa-Cedar	1,877.91	556,881.49	72,708.41	629,589.9 (20.18)	GW1, SF
Northeastern	1,085.05	364,208.71	17,107.29	381,316 (12.22)	GW1, SF
Skunk	529.74	162,296.76	20,854.8	183,151.56 (5.87)	GW1, SF
Missouri	566.69	193,927.35	21,181.71	215,109.06 (6.90)	GW1
Mississippi	622.54	198,836.77	49,813.95	248,650.72 (7.97)	GW1
Total	8,958.95	2,812,089.26	307,005.2	3,119,094.46 (100.0)	

[a]Figures in parentheses represent the percentages of aggregate state water consumption allocated to each water supply area. Note that the total is greater than the more conservative water availability values presented in footnotes c and d of Table 3.10, but much less than the average values of water availability shown in column 8 of Table 4.11 (p. 137).

[b]MGY represents million gallons per year.

Table 4.11. Continued

Water supply area	Volume of water available from: Alluvial aquifers MGY	Volume of water available from: Rivers MGY	Total supply from all sources[c] MGY	Shadow price[d] $/1000 gallons
Western	13,685.7	423,605	653,003.4	1.6 (GW1)
				1.4 (SF)
Southern	13,685.7	814,625	918,082.38	1.6 (GW1)
Des Moines	51,973.08	1,335,985	1,776,534.5	1.9 (GW1
Iowa-Cedar	25,742.15	1,238,230	1,809,445.05	2.3 (GW1)
Northeastern	1,955.1	684,285	981,297.28	1.7 (GW1)
Skunk	18,247.6	619,115	802,731.48	1.6 (GW1)
Missouri	576,265.7	997,101	1,654,970.33	0
Mississippi	330,900.68	1,339,243.5	1,957,055.11	0
Total yield	1,032,455.7	7,452,189.5	10,583,119.53	

[c]The total water supply includes the sum of the supplies from alluvial aquifers, other shallow and bedrock aquifers, reservoirs and interior streams and 2 percent of the flow from Missouri and Mississippi border rivers which can be available for consumptive uses.

[d]The symbols in parentheses represent the source of the water supply to which the positive shadow price is associated.

The Des Moines water supply area, which has 18 percent of irrigable flood plain land, 20 percent of the irrigable class 2S land, and 22.5 percent of the class 2E crop land as shown in Table 3.13, has the biggest acreage of irrigated land under irrigation scenario II. It thus utilizes over 20 percent of the aggregate water allocated for consumptive purposes in 2020. But the shadow price associated with all other sources of water supply is zero in this region, since enough water is available from the alluvial aquifers and the rivers to take care of the consumptive water requirements as shown in Table 4.11.

Positive shadow prices are associated with the alluvial aquifers of the Iowa-Cedar, Northeastern, and Skunk water supply areas, but all other sources of water supply in these areas command zero shadow prices under irrigation scenario II, just as occurs under irrigation scenario I. Even though irrigation scenario II leads to large irrigation water requirements, the adequate stream flow water in these regions prevents the utilization of water from bedrock aquifers and reservoirs, thus setting their shadow prices at zero.

Table 4.11 also shows that water allocation for both irrigation and industrial production, including residential usages in the Missouri and Mississippi water supply areas, are taken care of by the alluvial aquifers of these two regions. The Missouri water supply area utilizes only 215.1 billion gallons of consumptive water in all its economic activities under irrigation scenario II. The volume of economic activities is not much in this area. This region contributes to only 7.6 billion dollars of goods and services in 2020, and only 566 thousand acres of irrigated land compared to other areas of smaller water supplies, such as the Western and Southern water supply areas. But the massive supply of water from the alluvial aquifers of the Missouri water supply area takes care of all economic activities under irrigation scenario II and leads to zero shadow price for water from all supply sources in the region.

Although the Mississippi water supply area contributes substantially to 2020 aggregate attainable state production of goods and services, as shown in Table 4.8, industrial and residential consumptive water requirements equal 49.8 billion gallons, only 15 percent of the yield from its alluvial aquifers. This water supply area has only 8 percent of the flood plain land irrigated, 4.1 percent of class 2S, and 6.6 percent of the aggregate class 2E crop land, as shown in Table 3.13. Table 4.11 shows that it has only 622.5 thousand acres of irrigated land under irrigation scenario II, compared to 1.53 million acres in the Western water supply area where the volume of available water is least in the state. Hence, all water requirements in the Mississippi water supply area are contributed from the alluvial aquifers, driving the shadow price of water from all sources of supply to zero in this region.

In a sensitivity analysis aimed at finding out the effects of changes in the priority sectors of the economy on aggregate production and resource utilization, ten sectors were selected based on the magnitudes of their type 2 employment multipliers. The agricultural sector and four other sectors, namely the electrical lighting and equipment (sector 55), medical (sector 77), apparel (sector 18), and trade (sector 69) sectors were included in both sets of priority choices. Hence, only four additional sectors were included under the employment multipliers priority sectors model which were not included in the output multipliers model. These four additional sectors were hotel (sector 77), amusement (sector 76), broad and narrow fabrics (sector 16), and miscellaneous textile goods and floor coverings (sector 17) sectors.

The inclusion of these four sectors in the model means that a unit increase in the final demand from these sectors will generate more employment than any other sectors which were not selected. The feasible state output of goods and services required to support the projected final demands in 2020 under the type 2 employment multipliers model was exactly equal to the result obtained under the output multipliers priority sectors model. This can be partly explained by the fact that even though these additional sectors had high employment generation capabilities, their water consumption coefficients are not big enough. And in a situation of excess water supplies, these sectors could not utilize enough water resources in order to create scarcity, which might cause the output levels and water employment by the other sectors to alter. Since the feasible output levels coincided with those reported in Table 4.1, it was decided to concentrate the discussions on the output multipliers model.

CHAPTER V. SUMMARY, CONCLUSION AND SUGGESTIONS FOR IMPROVEMENT OF THE MODEL

Summary and Conclusion

Interest in this work was generated by the work done by Rhee (53a) and Rossmiller (53b). Rhee utilized the 1967 input-output matrix of Iowa in order to allocate water resources between 13 economic sectors of northwestern Iowa, and Rossmiller utilized the technique of goal programming in the management of land and water resources in northwestern Iowa.

The input-output analysis allows the analyst to include the interdependence between the sectors of the economy in his or her model, while the technique of goal programming gives the analyst the flexibility of isolating certain segments of the economy as highest priority areas and to allocate scarce resources in order to satisfy these highest priority sectors before other sectors are considered. The Barnard (3) and Rhee (53a) input-output models have been based on what is called the basic input-output model, in which the income-consumption linkage in the economy is ignored. Hence, computations of aggregate productions and resource utilizations have been underestimations.

This study focuses on the development of a multi-objective model combining input-output analysis and goal programming for providing guidance in the allocation of the water resources of Iowa. The model was applied in the allocation of water between the economic sectors of the state of Iowa to satisfy the state's water needs for economic and demographic projections to 2020.

The 1972 input-output technical coefficients matrix of Iowa developed by Barnard in (59) was modified to include commodity-wise marginal properties to consume. This extension of the basic input-output model was aimed at capturing the income effect of consumption on production and resource utilization. It thus includes a comprehensive multiplier analysis of the effects of a shock in one sector of the economy throughout the entire economic system.

The 77 sectoral classifications (3) of the U.S. economy were adapted to the Iowa economy. In the application of the model to the various water supply areas of Iowa, the 77 sectors of the economy were categorized under ten general sectors. Based on the magnitudes of the type 2 output multipliers for each sector of the economy, ten specific sectors were selected as the highest priority sectors. Type 2 multipliers were used in selecting the highest priority sectors of the economy because these multipliers take into account the income-consumption linkage within the economy. The goal programming component of the model was formulated in a manner that allocated water resources to these ten sectors before other sectors were considered.

The aggregate sectoral output of goods and services and resource utilizations computed under the basic input-output model appear to be underestimations because the basic model does not include the income-consumption linkage within the economy. The extension of the model to include income-consumption linkages in the economy means that the computations of sectoral output levels and resource utilizations can be considered as the upper limits of gross output of goods and services and resource usages. The reason is that the indirect economic activities which take place as a result of increased production by any sector of the economy are captured by the modified model.

In the application of the model within the state of Iowa, eight water supply areas were identified. These areas are the Western, Southern, Des Moines, Iowa-Cedar, Northeastern, Skunk, Missouri, and Mississippi water supply areas. Four sources of water supply were identified for each area. These sources are the alluvial aquifers, other shallow and bedrock aquifers, stream flow, and reservoir storage. The average annual yields of water from these sources were estimated for each water supply area. These yields served as the major constraints in the specification of the model because the quantity of water in each water supply area was assumed to be the main constraint on economic growth.

Indicators of the intensity of economic activities in each water supply area were estimated, and it was found that the bulk of economic activities are expected to occur in the Des Moines and Iowa-Cedar water supply areas. These two water supply areas also have the largest share of irrigable lands in the state and provide the biggest share of total state earnings from all economic activities.

Based on projected growth rates of various sectors of the economy, output projects required to support specified levels of final demands were estimated for the year 2020. These output projections for each sector at the state level were scaled down to regional output projections for each water supply area. The goal programming input-output model was then used to investigate whether each water supply area could afford the growth projections under the constraint of regional water endowments. The coefficients utilized in the model were computed from the input-output tables for Iowa (3, 59). Water coefficients for industrial activities were taken from the 1967 water withdrawal and consumption coefficients computed by Barnard for the Iowa economy, while the water coefficients for crop irrigation were computed from the 1979 water permit data obtained from the Iowa water commissioner (42). Energy, employment, and income coefficients were computed from the revised 1972 input-output matrix of Iowa (59).

The energy coefficients were utilized to find out the amount of energy (in British thermal units) required to support the projected growth rates in economic activities for each water supply area. The income coefficients were used together with the sectoral marginal propensity to consume goods and services in modifying the basic input-output model to a closed input-output model. The employment coefficients were also used in computing employment multipliers which were later used in selecting ten sectors of the economy as top priority sectors in a sensitivity analysis.

Two irrigation scenarios were specified. Irrigation scenario I represented the irrigation of 3.19 million acres of class 1 and class

2S land suitable for irrigation in each water supply area. The second scenario expands irrigation to all flood plain land, class 2S and 2E crop lands.

The major part of the analysis was performed utilizing type 2 output multiplier priorities option, since the employment multiplier model produced no changes in the results due to the abundance of water resources in the state. At the state level, the value of goods and services feasible in the year 2020 under the constraint of the state's water resources is 101 billion dollars. This value coincides with the 2020 state projected output of goods and services required to satisfy the specified levels of final demands. The 101 billion dollars of goods and services could be regarded as near the upper limit of production, since the closed input-output component of the model includes the income effect of consumption on production and resource utilization. Thus, the associated water resources requirements can be regarded as the maximum amount of water that can be consumed or withdrawn to support the state's projected growth rates in the year 2020. The manufacturing sector forms the largest component of the economy of Iowa. Out of the attainable state output of 101 billion dollars in 2020, the manufacturing sector contributes 39.2 billion dollars.

Under the irrigation scenario I, aggregate water consumption in 2020 in Iowa is 1.31 trillion gallons, and a little over 1 trillion gallons will be consumed in crop irrigation while 65 billion gallons will be allocated to the livestock and livestock products sector. Hence, the agricultural sector in general consumes 81 percent of the aggregate water consumed in Iowa under irrigation scenario I. But the aggregate amount of water consumed constitutes only 8.4 percent of the aggregate water supply of the state (average to high estimates) which is 15.6 trillion gallons per year. Therefore, the water from stream flow which equals 12.5 trillion gallons per year would be sufficient to account for the total water consumed in all economic activities in the state in 2020.

Irrigation scenario II, which represents approximately 3 times the amount of acres irrigated under the first scenario, could be expected to place heavier burdens on the state's water supply. Under scenario II, 3.12 trillion gallons of water are consumed for all economic activities. Ninety percent of this amount is consumed in crop irrigation, and only ten percent of the consumptive water is allocated for non-irrigation economic activities. Although this represents an ambitious irrigation plan, there is enough water in the state's rivers (under average to high estimates) to meet this demand. However, under the low estimates presented in Table 3.10 (footnotes c and d), additional groundwater or reservoir sources would be needed to satisfy all economic activities.

Within the state of Iowa, the largest water using sector is the utilities sector which is allocated 62 billion gallons of consumptive water in satisfying its output of goods and services in 2020. The utilities sector also forms the largest water withdrawing sector in the state, withdrawing 4.4 trillion gallons of water in 2020.

Since this sector also has a large water multiplier, a unit increase in final demand for the output of this sector in 2020 is likely to place the heaviest burden on water resources of the state.

Analysis of areas within the state showed that even the Western water supply area, which has the least amount of water compared to the other areas of the state, has enough water resources to enable it to support its economic growth projections. Like all water supply areas of the state, the 2020 feasible output of goods and services of the Western water supply area coincides with the projected output. The yield from the interior streams of the Western water supply area is enough to satisfy its non-irrigation water requirements. Certain water supply areas have too much water in relation to the volume of their economic activities. The Missouri water supply area, for example, has a low volume of economic activities compared to the Des Moines and Iowa-Cedar areas; and it requires only 2.6 percent of the yield from the alluvial aquifers associated with the Missouri River in order to satisfy its non-irrigation water requirements. Thus, considering only the non-irrigation water requirements, water quantity is not a binding constraint on the economic performance of any of the eight water supply areas in the state under average yield conditions.

But even though the state and its various water supply areas have enough water to satisfy the economic and demographic projections to 2020, other resources might be limiting. The analysis showed that in order for all required industrial activities to be achieved in

2020, the state needs to utilize 2,698 trillion British thermal units of energy, an amount of energy which is almost equal to 3 times the energy consumed in 1977 for all economic activities in the state.

Crop irrigation makes the biggest demand on water consumption in the state, and hence, expansion of irrigation acreage is likely to lead to the exhaustion of water supply from some sources within the state. Under irrigation scenario I, only the Missouri and Mississippi water supply areas have enough water supply from their alluvial aquifers to support their irrigation water requirements. A water deficient area such as the Western water supply area is forced to irrigate about 2.5 times the amount of land irrigated by the Mississippi water supply area and 1.9 times the acreage irrigated by the Missouri water supply area, while it has only 6.2 percent of the state's consumptive water resources. Positive shadow prices are thus associated with the water from the alluvial aquifers of all the regions under irrigation scenario I, except the Missouri and Mississippi water supply areas. The highest shadow price is associated with the alluvial aquifers of the Iowa-Cedar water supply area which commands a value of 2.3 dollars per thousand gallons of water.

Under irrigation scenario II, the western water supply area is forced to utilize a third source of water supply, namely the water from other shallow and bedrock aquifers, thus leading to a positive shadow price of water from its other cheap sources. It is only in the Western water supply area that the water from the stream flow has a positive shadow price. All other supply areas have enough water to support such great expansion in irrigation as represented by the scenario II.

If any great increases in irrigation are contemplated for the future, the Western supply area should not be encouraged. Irrigation should be encouraged particularly in the Des Moines and Iowa-Cedar water supply areas which have enough irrigable lands and enough water resources from the alluvial aquifers and rivers to take care of their irrigation and non-irrigation economic activities. The Missouri and Mississippi water supply areas could be expected to shoulder a bigger share of the burden of irrigation water requirements, but these two areas do not have enough irrigable land.

Non-irrigation water requirements do not constitute any burden on the water resources of the water supply areas. But water withdrawal in the utilities sector is likely to affect the quality of water in most areas of the state, because the utilities sector withdraws over 4 trillion gallons per year in satisfying its share of the feasible output of goods and services in 2020.

Further Extensions of the Model

The analysis has confirmed that the state of Iowa, as well as its eight major water supply areas, have enough water resources to satisfy the long term growth projections to the year 2020. This conclusion embraces only quantity of water regardless of quality demanded or quality supplied. The next research on water allocation must be extended to include the lowest estimates of water quantity availability as well as the quality aspect. Water is not a homogeneous resource (56), and the productivity of a given quality of water is likely to vary between industries. Thus, the aggregate water supply should be differentiated on quality basis. Instead of using general water consumption coefficients, consumption coefficients should be defined on quality basis. In this case, it could be found out that, even though the state might have abundant water resources in terms of quantity, quality constraints might be binding on economic activities. A model could be developed which identifies areas of scarce water resources for certain qualitatively oriented demands and areas of over supply for certain other economic activities.

The model should also be modified to include energy constraints for all sectors and all water supply areas of the economy. Instead of utilizing water as the sole constraint on regional economic growth, energy constraints could be imposed which would enable the state to find out to what extent the growth projections are compromised by factors other than water.

The marginal propensity to consume commodities and resources are the main coefficients which form the difference between the basic input-output model and the closed input-output model. In any future work, attempts should be made to improve the procedure utilized in this analysis for computing the marginal propensity coefficients. Commodity-wise consumption functions could be estimated for each category of commodities in order to obtain more accurate estimates of marginal propensities to consume goods and services and natural resources.

Lastly, a more flexible version of the goal programming model, for example, lexicographic linear goal programming which does not require any cardinal weights to be placed on any priority sector, could be employed. Then, sectors of high priorities can be ranked in an ordinal way, rather than being assigned cardinal weights. In this study, this ordinal ranking may not make much difference because of the way the model was specified. Aggregate water quantity was assumed to be the main constraint on economic growth. But the results showed that the aggregate water supply was not a binding constraint in any of the eight water supply areas. If water is differentiated into non-homogeneous quality categories, scarcities may show up in certain uses of water, and hence, the water resources will have to be allocated, on the basis of quality, to satisfy those sectors of the economy where they contribute most in terms of either employment or output of goods and services.

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DEDICATION

This work is dedicated to my mother, Mrs. Afua Sam, and my senior brother, Oscar Kofi Sammy.

APPENDIX A. MATHEMATICAL FOOTNOTE

A1: When there is an initial increase in final demand, the induced increase in income consumption and the production of goods and services converge in the limit.

Assume an increase in final demand by Δf. The initial production of intermediate inputs required to satisfy the increase in final demand is $A\Delta f$, where A is the technical coefficient (intermediate input) matrix. To produce $A\Delta f$ of intermediate inputs, industries have to produce $A^2\Delta f$ of intermediate inputs, etc. Hence, the production of goods and services required to satisfy the initial increase in final demand

$$= x = (I + A + A^2 + A^3 + \ldots)\Delta f = (I - A)^{-1}\Delta f,$$

assuming that $(I - A)^{-1}$ exists. This leads to an initial increase in income of Δy_1, where

$$\Delta y_1 = v'(I - A)^{-1}\Delta f = k'\Delta f,$$

and v is the income coefficient vector of x. The initial increase in income, Δy_1, leads to a first round commodity consumption expenditure of $ck'\Delta f$, where c is the vector of marginal propensity to consume goods and services. The initial increase in consumption of natural resources is $\hat{c}k'\Delta f$, where $\hat{c}$ is the aggregate marginal propensity to consume resources.

The second round increase income associated with the initial increase in final demand (Δf) is

$$\Delta y_2 = k'ck'\Delta f + \hat{c}k'\Delta f = (k'c + \hat{c})k'\Delta f.$$

Consumption expenditures on goods and services and natural resources rise by

$$c(k'c + \hat{c})k'\Delta f + \hat{c}(k'c + \hat{c})k'\Delta f.$$

In the third round, income increases by Δy_3, where

$$\Delta y_3 = k'c(k'c + \hat{c})k'\Delta f + \hat{c}(k'c + \hat{c})k'\Delta f = (k'c + \hat{c})(k'c + \hat{c})k'\Delta f$$

$$= (k'c + \hat{c})^2\Delta f.$$

Assume the process continues to infinity. Then the successive income increases add up to Δy, where

$$\Delta y = (1 + (k'c + \hat{c}) + (k'c + \hat{c})^2 + (k'c + \hat{c})^3 + (k'c + \hat{c})^4$$
$$+ \ldots)\Delta f,$$

where $(k'c + \hat{c})^{j-1}k'\Delta f$ is the induced increase in income at the jth stage of the process. Since $0 \leq (k'c + \hat{c}) \leq 1$ (53, pp. 100-103), the aggregate income series converges.

A2: The procedure for scaling down the output of goods and services at the state level to regional (water supply areas) output levels.

The assumption of constant income coefficients in input-output analysis implies the following relationship between gross production of sector i, x_i, and the income which accrues to sector i, y_i:

$$y_i = v_i x_i,$$

where v_i is the income coefficient of sector i. Let

x_i^j = gross production of sector i in water supply area j,

x_i^s = gross production of sector i at the state level,

y_i^j = aggregate income which accrues to sector i in water supply area j, and

y_i^s = aggregate income which accrues to sector i at the state level.

Then,

$$x_i^j = y_i^j v_i^{-1},$$

and

$$x_i^s = y_i^s v_i^{-1}.$$

Therefore,

$$(x_i^j)(x_i^s)^{-1} = (y_i^j)(y_i^s)^{-1},$$

which means that

$$x_i^j = (y_i^j)(y_i^s)^{-1} x_i^s.$$

Hence, knowing the output of sector i at the state level and the sectoral income ratios, the output of goods and services in each water supply area can be computed.

APPENDIX B. DATA UTILIZED IN MODEL APPLICATION

Table B.1. Standard industrial classification of the U.S. economy[a]

	Industry number and title	
Agriculture, Forestry and Fisheries		
1	Livestock and livestock products	
		Dairy farm products
		Poultry and eggs
		Meat animals and miscellaneous livestock products
2	Other agricultural products	
		Cotton
		Food feed grains and grass seeds
		Tobacco
		Fruits and tree nuts
		Vegetables, sugar and miscellaneous crops
		Oil bearing crops
		Forest, greenhouse and nursery products
3	Forestry and fishering products	
		Forestry and fishery products
4	Agricultural, forestry and fishering services	
		Agricultural, forestry and fishery services
Mining		
5	Iron and ferroalloy ores mining	
		Iron and ferroalloy ores mining
6	Nonferrous metal ores mining	
		Copper ore mining
		Nonferrous metal ores mining, except copper
7	Coal mining	
		Coal mining
8	Crude petroleum and natural gas	
		Crude petroleum and natural gas
9	Stone and clay mining and quarrying	
		Stone and clay mining and quarrying
10	Chemicals and fertilizer mineral mining	
		Chemicals and fertilizer mineral mining

[a]Source: (3).

Table B.1. Continued

Industry number and title
Construction
11 New construction
New construction, residential buildings (nonfarm)
New construction, nonresidential buildings
New construction, public utilities
New construction, highways
New construction, all other
12 Maintenance and repair construction
Maintenance and repair construction, residential buildings (nonfarm)
Maintenance and repair construction, all other
Manufacturing
13 Ordnance and accessories
Complete guided missiles
Ammunition, except for small arms, n.e.e.
Tanks and tank components
Sighting and fire control equipment
Small arms
Small arms ammunition
Other ordnance and accessories
14 Food and kindred products
Meat products
Creamery butter
Cheese, natural and processed
Condensed and evaporated milk
Ice cream and frozen desserts
Fluid milk
Canned and cured sea foods
Canned specialties
Canned fruits and vegetables
Dehydrated food products
Pickles, sauces and salad dressings
Fresh or frozen packaged fish
Frozen fruits and vegetables
Flour and cereal preparations
Prepared feeds for animals and fowls
Rice milling
Wet corn milling

Table B.1. Continued

Industry number and title	
	Bakery products
	Sugar
	Confectionary and related products
	Alcoholic beverages
	Bottled and canned soft drinks
	Flavoring extracts and sirups, n.e.e.
	Cottonseed oil mills
	Soybean oil mills
	Vegetable oil mills, n.e.e.
	Animal and marine fats and oils
	Roasted coffee
	Shortening and cooking oils
	Manufactured ice
	Macaroni and spaghetti
	Food preparations, n.e.e.
15	Tobacco manufactures
	Cigarettes, cigars, etc.
	Tobacco stemming and redrying
16	Broad and narrow fabrics, yarn and thread mills
	Broadwoven fabric mills and fabric finishing plants
	Narrow fabric mills
	Yarn mills and finishing of textiles, n.e.e.
	Thread mills
17	Miscellaneous textile goods and floor coverings
	Floor coverings
	Felt goods, n.e.e.
	Lace goods
	Paddings and upholstery fillings
	Processed textile waste
	Coated fabrics, not rubberized
	Tire cord and fabric
	Scouring and combing plants
	Cordage and twine
	Textile goods, n.e.e.
18	Apparel
	Hosiery
	Knit apparel mills
	Knit fabric mills
	Apparel made from purchased materials

Table B.1. Continued

Industry number and title	
19	Miscellaneous fabricated textile products
	Curtains and draperies
	Housefurnishings, n.e.e.
	Fabricated textile products, n.e.e.
20	Lumber and wood products, except containers
	Logging camps and logging contractors
	Sawmills and planing mills, general
	Hardwood dimensions and flooring
	Special product sawmills, n.e.e.
	Millwork
	Veneer and plywood
	Prefabricated wood structures
	Wood preserving
	Wood products, n.e.e.
21	Wooden containers
	Wooden containers
22	Household furniture
	Wood household furniture
	Upholstered household furniture
	Metal household furniture
	Mattresses and bedsprings
23	Other furniture and fixtures
	Wood office furniture
	Metal office furniture
	Public building furniture
	Wood partitions and fixtures
	Metal partitions and fixtures
	Venetian blinds and shades
	Furniture and fixtures, n.e.e.
24	Paper and allied products except containers and boxes
	Pulp mills
	Paper mills, except building paper
	Paperboard mills
	Envelopes
	Sanitary paper products
	Wallpaper and building paper and board mills
	Converted paper, products, n.e.e., except containers and boxes

Table B.1. Continued

Industry number and title	
25	Paperboard containers and boxes
	Paperboard containers and boxes
26	Printing and publishing
	Newspapers
	Periodicals
	Book printing and publishing
	Miscellaneous publishing
	Commerical printing
	Manifold business forms, blankbooks and binders
	Greeting card publishing
	Miscellaneous printing services
27	Chemicals and selected chemical products
	Industrial inorganic and organic chemicals
	Fertilizers
	Agricultural chemicals, n.e.e.
	Miscellaneous chemical products
28	Plastics and synthetic materials
	Plastics materials and resins
	Synthetic rubber
	Cellulosic man-made fibers
	Organic fibers, noncellulosic
29	Drugs, cleaning and toilet preparations
	Drugs
	Cleaning preparations
	Toilet preparations
30	Paints and allied products
	Paints and allied products
31	Petroleum refining and related industries
	Petroleum refining and related products
	Paving mixtures and blocks
	Asphalt felts and coatings
32	Rubber and miscellaneous plastics products
	Tires and inner tubes
	Rubber footwear
	Reclaimed rubber and miscellaneous rubber products, n.e.e.
	Miscellaneous plastics products

Table B.1. Continued

Industry number and title	
33	Leather tanning and industrial leather products
	Leather tanning and industrial leather products
34	Footwear and other leather products
	Footwear cut stock
	Footwear except rubber
	Other leather products
35	Glass and glass products
	Glass and glass products except containers
	Glass containers
36	Stone and clay products
	Cement, hydraulic
	Brick and structural clay tile
	Ceramic wall and floor tile
	Clay refractories
	Structural clay products, n.e.e.
	Vitreous plumbing fixtures
	Food utensils, pottery
	Porcelain electrical supplies
	Pottery products, n.e.e.
	Concrete block and brick
	Concrete products, n.e.e.
	Ready-mixed concrete
	Lime
	Gypsum products
	Cut stone and stone products
	Abrasive products
	Asbestos products
	Gaskets and insulations
	Minerals, ground or treated
	Mineral wool
	Nonclay refractories
	Nonmetallic mineral products, n.e.e.
37	Primary iron and steel manufacturing
	Blast furnaces and basic steel products
	Iron and steel foundries
	Iron and steel forgings
	Primary metal products, n.e.e.
38	Primary nonferrous metals manufacturing
	Primary copper
	Primary lead

Table B.1. Continued

Industry number and title	
39	Metal containers
	Metal cans
	Metal barrels, drums and pails
40	Heating. plumbing and fabricated structural metal products
	Metal sanitary ware
	Plumbing fittings and brass goods
	Heating equipment, except electric
	Fabricated structural steel
	Metal doors, sash and trim
	Fabricated plate work (boiler shops)
	Sheet metal work
	Architectural metal work
	Miscellaneous metal work
41	Screw machine products, bolts, nuts, etc. and metal stampings
	Screw machine products and bolts, nuts, rivets and washers
	Metal stampings
42	Other fabricated metal products
	Cutlery
	Hand and edge tools including saws
	Hardware, n.e.e.
	Coating, engraving and allied services
	Miscellaneous fabricated wire products
	Safes and vaults
	Steel springs
	Pipe, valves and pipe fittings
	Collapsible tubes
	Metal foil and leaf
	Fabricated metal products, n.e.e.
43	Engines and turbines
	Steam engines and turbines
	Internal combustion engines, n.e.e.
44	Farm machinery
	Farm machinery
45	Construction, mining, oil field machinery equipment
	Construction machinery
	Mining machinery
	Oil field machinery

Table B.1. Continued

Industry number and title	
46	Materials handling machinery and equipment
	Elevators and moving stairways
	Conveyors and conveying equipment
	Hoists, cranes and monorails
	Industrial trucks and tractors
47	Metalworking machinery and equipment
	Machine tools, metal cutting types
	Machine tools, metal forming types
	Special dies and tools and machine tool accessories
	Metalworking machinery n.e.e.
48	Special industry machinery and equipment
	Food products machinery
	Textile machinery
	Woodworking machinery
	Paper industries machinery
	Printing trades machinery
	Special industry machinery, n.e.e.
49	General industrial machinery and equipment
	Pumps and compressors
	Ball and roller bearings
	Blowers and fans
	Industrial patterns
	Power transmission equipment
	Industrial furnaces and ovens
	General industrial machinery, n.e.e.
50	Machine shop products
	Machine shop products
51	Office, computing and accounting machines
	Computing and related machines
	Typewriters
	Scales and balances
	Office machines, n.e.e.
52	Service industry machines
	Automatic merchandising machines
	Commercial laundry equipment
	Refrigeration machinery
	Measuring and dispensing pumps
	Service industry machines, n.e.e.

Table B.1. Continued

Industry number and title	
53	Electric transmission and distribution equipment and electrical industrial apparatus
	Electric measuring instruments
	Transformers
	Switchgear and switchboard apparatus
	Motors and generators
	Industrial controls
	Welding apparatus
	Carlson and graphite products
	Electrical industrial apparatus, n.e.e.
54	Household appliances
	Household cooking equipment
	Household refrigerators and freezers
	Household laundry equipment
	Electric housewares and fans
	Household vacuum cleaners
	Sewing machines
	Household appliances, n.e.e.
55	Electric lighting and wiring equipment
	Electric lamps
	Lighting fixtures
	Wiring devices
56	Radio, television and communication equipment
	Radio and television receiving sets
	Phonograph records
	Telephone and telegraph apparatus
	Radio and television communication equipment
57	Electronic components and accessories
	Electronic tubes
	Semiconductors
	Electronic components, n.e.e.
58	Miscellaneous electrical machinery, equipment and supplies
	Storage batteries
	Primary batteries, wet and dry
	X-ray apparatus and tubes
	Engine electrical equipment
	Electrical equipment, n.e.e.

Table B.1. Continued

Industry number and title	
59	Motor vehicles and equipment
	Truck and bus bodies
	Truck trailers
	Motor vehicles and parts
60	Aircraft and parts
	Aircraft
	Aircraft engines and parts
	Aircraft propellers and parts
	Aircraft equipment, n.e.e.
61	Other transportation equipment
	Shipbuilding and repairing
	Boatbuilding and repairing
	Locomotives and parts
	Railroad and street cars
	Motorcycles, bicycles and parts
	Trailer coaches
	Transportation equipment, n.e.e.
62	Professional, scientific and controlling instruments and supplies
	Engineering and scientific instruments
	Mechanical measuring devices
	Automatic temperature controls
	Surgical and medical instruments
	Surgical appliances and supplies
	Dental equipment and supplies
	Watches, clocks and parts
63	Optical, ophthalmic and photographic equipment and supplies
	Optical instruments and lenses
	Ophthalmic goods
	Photographic equipment and supplies
64	Miscellaneous manufacturing
	Jewelry, including costume, and silverware
	Musical instruments and parts
	Games, toys, etc.
	Sporting and athletic goods, n.e.e.
	Pens, pencils, etc.
	Artificial flowers
	Buttons, needles, pins and fasteners
	Brooms and brushes

Table B.1. Continued

Industry number and title
Hard surface floor covering
Mortician's goods
Signs and advertising displays
Miscellaneous manufactures, n.e.e.
Transportation, Communication, Electric, Gas, and Sanitary Facilities
65 Transportation and warehousing
Railroads and related services
Local, suburban and interurban highway passenger transportation
Motor freight transportation and warehousing
Water transportation
Air transportation
Pipeline transportation
Transportation services
66 Communications, except radio and television broadcasting
Communications, except radio and television
67 Radio and television broadcasting
Radio and television broadcasting
68 Electric, gas, water and sanitary services
Electric utilities
Gas utilities
Water and sanitary services
Wholesale and Retail Trade
69 Wholesale and retail trade
Wholesale trade
Retail trade
Finance, Insurance and Real Estate
70 Finance and insurance
Banking
Credit agencies
Security and commodity brokers
Insurance carriers
Insurance agents and brokers

Table B.1. Continued

Industry number and title
71 Real estate and rental
Owner-occupied dwellings
Real estate
Services
72 Hotels and lodging places; personal and repair services, except automobile repair
Hotels and lodging places
Personal and repair services except auto repair and barber and beauty shops
73 Business service
Miscellaneous business services
Advertising
Miscellaneous professional services
74 Eating and drinking places
75 Automobile repair and services
Automobile repair and services
76 Amusements
Motion pictures
Amusement and services
77 Medical, educational services and nonprofit organizations
Hospitals
Other medical and health services
Educational services
Nonprofit organizations

Table B.2. Estimated total output of goods and services in the Iowa economy in 1972.[a]

Industry number	Sector	Total output ($1,000)
1	Livestock and livestock products	2,633,986
2	Other agricultural products	2,379,412
3	Forestry and fishery products	10,004
4	Agric., forestry, & fisheries serv.	95,245
5	Iron and ferroalloy ores mining	0
6	Nonferrous metal ores mining	0
7	Coal mining	6,400
8	Crude petroleum and natural gas	0
9	Stone and clay mining and quarrying	64,000
10	Chem. and fertilizer mineral mining	0
11	New construction	1,031,703
12	Maintenance and repair construction	170,646
13	Ordnance and accessories	243,773
14	Food and kindred products	5,458,925
15	Tobacco manufactures	0
16	Broad & narrow fabrics, yarn & thrd mills	15,153
17	Misc textile goods and floor coverings	19,097
18	Apparel	28,527
19	Misc fabricated textile products	45,387
20	Lumber & wood products except containers	103,784
21	Wood containers	8,600
22	Household furniture	49,393
23	Other furniture and fixtures	40,357
24	Paper & allied products except containers	86,006
25	Paperboard containers and boxes	106,800
26	Printing & publishing	403,856
27	Chemical and select chemical products	45,332
28	Plastics and synthetic materials	30,645
29	Drugs, cleaning and toilet preparation	105,665
30	Paints and allied products	52,700
31	Petroleum refining & related industries	23,059
32	Rubber and misc. plastics products	378,671
33	Leather tanning and finishing	14,426
34	Footwear and other leather products	76,998
35	Glass and glass products	0

[a]Source: (59).

Table B.2. Continued

Industry number	Sector	Total output ($1,000)
36	Stone and clay products	219,730
37	Primary iron and steel manufacturing	117,866
38	Primary nonferrous metals manufacturing	111,312
39	Metal containers	13,829
40	Heating, plumbing & str. mtl. products	220,661
41	Screw machine products and stampings	25,667
42	Other fabricated material products	229,024
43	Engines and turbines	83,079
44	Farm and garden machinery	709,027
45	Construction and mining machinery	607,903
46	Materials handling machinery & equipment	23,256
47	Metalworking machinery & equipment	23,599
48	Special industrial machines & equipment	70,186
49	General industrial machines & equipment	47,164
50	Misc. machinery except electrical	39,600
51	Office, computing & accounting machinery	0
52	Service industry machines	0
53	Electrical industrial equip. & apparatus	92,834
54	Household appliances	332,140
55	Electrical lighting & wiring equipment	4,715
56	Radio, tv & communication equipment	168,839
57	Electronic components & accessories	62,931
58	Misc. electrical machinery & supplies	41,900
59	Motor vehicles and equipment	358,190
60	Aircraft and parts	17,772
61	Other transportation equipment	19,895
62	Scientific & controlling instruments	44,225
63	Optical, ophthalmic & photographic equip.	7,458
64	Misc. manufacturing	168,023
65	Transportation & warehousing	641,591
66	Communications, except radio & tv	155,565
67	Radio & tv broadcasting	66,072
68	Electric, gas, water & sanitary serv.	579,311
69	Wholesale and retail trade	2,489,157
70	Finance and insurance	772,223

Table B.2. Continued

Industry number	Sector	Total output ($1,000)
71	Real estate and rental	1,508,470
72	Hotels; per. & repair serv. except auto	241,766
73	Business services	129,843
74	Eating and drinking places	450,670
75	Auto repair and services	81,814
76	Amusements	72,715
77	Medical, educ. serv. & nonprofit org.	934,787

Table B.3. Projected output of goods and services for the state of Iowa (1975-2020) in 1972 prices

Industry number[a]	1975 output ($1000)	Estimated 2020 output ($1000)
1	2,747,247	4,555,210
2	2,478,552	4,277,431
3	10,427	17,678
4	99,274	168,309
5	0	0
6	0	0
7	7,413	22,619
8	0	0
9	74,595	227,612
10	0	0
11	1,195,022	3,646,371
12	197,659	603,117
13	280,826	136,133
14	5,703,220	9,842,493
15	0	0
16	17,456	84,620
17	22,000	106,647
18	32,863	159,307
19	52,286	253,462
20	119,559	579,574
21	9,907	48,025
22	56,901	275,833
23	46,491	225,370
24	99,079	480,295
25	123,034	596,420
26	465,242	2,255,307
27	52,222	253,151
28	35,303	171,135
29	121,726	590,079
30	60,710	294,298

[a]Refer to Table B.1 for names of specific industries.

Table B.3. Continued

Industry number	1975 output ($1000)	Estimated 2020 output ($1000)
31	26,564	128,772
32	436,229	2,114,664
33	16,619	80,562
34	88,702	429,992
35	0	0
36	25,312	1,227,068
37	135,782	658,217
38	128,231	621,613
39	15,931	77,227
40	254,201	1,232,265
41	29,568	143,334
42	263,836	1,278,971
43	95,707	463,949
44	74,844	1,268,886
45	700,304	3,394,794
46	26,791	129,872
47	27,140	131,564
48	80,854	391,948
49	54,333	263,385
50	45,619	221,143
51	0	0
52	0	0
53	106,945	518,427
54	382,625	1,854,813
55	5,432	26,332
56	194,503	942,873
57	72,497	351,436
58	48,269	233,989
59	412,635	2,000,289
60	20,473	99,245
61	22,919	111,102
62	50,947	246,971
63	8,592	41,651
64	193,562	938,311
65	726,083	2,769,847

Table B.3. Continued

Industry number	1975 output ($1000)	Estimated 2020 output ($1000)
66	175,648	870,178
67	74,602	369,586
68	654,100	3,240,477
69	2,723,932	9,438,140
70	863,394	5,667,318
71	1,686,566	11,070,619
72	286,154	1,878,315
73	153,682	1,008,769
74	533,413	3,501,323
75	96,835	635,625
76	86,065	564,931
77	1,106,414	7,262,502

Table B.4. Industrial water use (consumption and withdrawal) coefficients[a]

Industry number	Water withdrawal coefficient (gallons/$ output)	Water consumption coefficient (gallons/$ output)
1	14.435	14.435
2	4.423[b]	4.423[b]
3	0	0
4	0	0
5	0	0
6	0	0
7	8.49	11.886
8	0	0
9	80.797	19.292
10	0	0
11	3.769	3.769
12	3.71	3.71
13	20.1[c]	2.07[c]
14	15.072	1.273
15	0	0
16	22.989	2.368
17	15.464	5.155
18	20.1[c]	2.07[c]
19	20.1[c]	2.07[c]
20	46.963	7.692
21	85.571	18.303
22	4.927	1.279
23	3.647	0.075
24	53.437	5.534
25	13.827	4.133

[a]Source: (4).

[b]This figure was replaced by the irrigation water requirements computed in Table 3.13.

[c]Water use coefficients for sectors 13, 18, 19, 26 and 33 were not provided in the original data. These missing coefficients were replaced by the average water use coefficients for the manufacturing sector. The water use coefficients for sector 74 (eating and drinking places) were assumed to be equivalent to the coefficients for sector 72 (hotels and lodging places).

Table B.4. Continued

Industry number	Water withdrawal coefficient (gallons/$ output)	Water consumption coefficient (gallons/$ output)
26	20.1[c]	2.07[c]
27	158.94	17.893
28	86.545	11.935
29	6.787	0.506
30	13.297	0.587
31	13.787	3.393
32	20.434	0.793
33	20.1[c]	2.07[c]
34	18.42	1.016
35	11.279	0.00
36	69.446	10.133
37	156.23	3.554
38	14.37	0.331
39	9.709	0.00
40	5.401	0.127
41	5.055	0.181
42	7.862	0.405
43	13.069	0.372
44	13.927	0.781
45	6.119	0.04
46	8.55	0.015
47	7.087	0.685
48	5.96	2.935
49	4.753	0.124
50	7.84	1.176
51	0	0
52	0	0
53	5.875	0.383
54	8.919	0.288
55	2.97	0.601
56	2.972	0.222
57	4.012	0.247
58	4.548	0.13
59	7.025	0.934
60	24.758	1.265

Table B.4. Continued

Industry number	Water withdrawal coefficient (gallons/$ output)	Water consumption coefficient (gallons/$ output
61	6.13	0.365
62	7.223	0.048
63	22.402	0.314
64	9.973	0.554
65	2.751	0.275
66	0.657	0.068
67	0.31	0.041
68	1364.3	19.113
69	4.583	0.458
70	0.49	0.048
71	0.235	0.024
72	5.578	0.558
73	3.81	0.382
74	5.578[c]	.558[c]
75	4.426	0.439
76	4.802	0.486
77	11.066	1.106

Table B.5. Energy, employment and income coefficients and sectoral marginal propensities to consume[a]

Industry number	Energy coefficients (MBTU/ $ output)[b]	Employment coefficients (jobs/ $10,000 output)	Income coefficients ($ of participation income/ $ output)	Marginal propensity to consume[c]
1	0.0073	.308	0.344	0.005
2	0.0181	.196	0.224	0.007
3	0.0097	.2	0.173	0.001
4	0.0203	.472	0.408	0
5	0	0	0	0
6	0	0	0	0
7	0.0451	.313	0.233	0.001
8	0	0	0	0
9	0.0451	.373	0.411	0
10	0	0	0	0
11	0.0175	.455	0.352	0
12	0.0175	.444	0.347	0
13	0.0252	.315	0.14	0.0005
14	0.0115	.077	0.097	0.119
15	0	0	0	0.011
16	0.0061	.667	0.252	0.002
17	0.0031	.472	0.192	0.003
18	0.0022	.980	0.558	0.033
19	0.001	.198	0.113	0.003
20	0.0109	.309	0.392	0
21	0.0058	.348	0.231	0
22	0.0058	.405	0.399	0.007
23	0.011	.446	0.547	0
24	0.0324	.233	0.195	0.003
25	0.0119	.196	0.18	0

[a]Energy, employment and income coefficients were computed from (59) while the sectoral marginal propensities to consume goods and services were computed from (3).

[b]MBTU represents million British thermal units.

[c]Values less than 0.0001 were arbitrarily set to zero.

Table B.5. Continued

Industry number	Energy coefficients (MBTU/ $ output)	Employment coefficients (jobs/ $10,000 output)	Income coefficients ($ of participation income/ $ output)	Marginal propensity to consume
26	0.0044	.347	0.288	0.009
27	0.2523	.508	0.34	0.001
28	0.0505	.521	0.291	0
29	0.0065	.170	0.325	0.012
30	0.0078	.114	0.209	0
31	0.063	.130	0.092	0.023
32	0.0189	.261	0.246	0.004
33	0.0238	.277	0.157	0
34	0.001	.649	0.367	0.008
35	0	0	0	0
36	0.143	.255	0.287	0.001
37	0.0523	.306	0.451	0
38	0.0197	.225	0.303	0
39	0.0095	.145	0.17	0
40	0.0094	.295	0.254	0
41	0.0026	.400	0.361	0.001
42	0.0121	.314	0.291	0.001
43	0.0025	.216	0.2	0
44	0.0089	.303	0.394	0
45	0.0089	.207	0.273	0
46	0.0236	.344	0.476	0
47	0.011	.382	0.516	0
48	0.0144	.299	0.394	0
49	0.0136	.297	0.398	0
50	0.0136	.403	0.545	0
51	0	0	0	0
52	0	0	0	0.001
53	0.005	.333	0.347	0
54	0.0034	.187	0.199	0.007
55	0.0084	.424	0.332	0.001

Table B.5. Continued

Industry number	Energy coefficients (MBTU/ $ output)	Employment coefficients (jobs/ $10,000 output)	Income coefficients ($ of participation income/ $ output)	Marginal propensity to consume
56	0.0041	.332	0.41	0.005
57	0.0127	.333	0.326	0.001
58	0.0067	.262	0.293	0.001
59	0.0062	.179	0.173	0.03
60	0.0076	.282	0.272	0
61	0.0073	.352	0.339	0.003
62	0.0134	.385	0.407	0.001
63	0.0088	.134	0.233	0.002
64	0.006	.369	0.24	0.008
65	0.1072	.543	0.557	0.03
66	0.0093	.641	0.681	0.008
67	0.0045	.317	0.332	0
68	0.3415	.236	0.213	0.03
69	0.0136	.935	0.537	0.18
70	0.0077	.529	0.497	0.047
71	0.0007	.048	0.045	0.123
72	0.0168	1.149	0.533	0.03
73	0.0113	.775	0.358	0.008
74	0.0138	.943	0.543	0.021
75	0.0133	.917	0.49	0.014
76	0.0139	.952	0.425	0.011
77	0.032	2.174	0.81	0.071

Table B.6. Iowa inter-industry transaction matrix (1972) (thousands of dollars) (59)

Producing sector	Purchasing sector 1	2	3	4	5	6	7
1	687734.500	59038.207	0.0	5027.098	0.0	0.0	0.0
2	613101.063	76571.813	0.0	1375.640	0.0	0.0	0.0
3	0.0	0.0	46.710	280.470	0.0	0.0	0.0
4	74293.125	87404.125	250.290	2818.060	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	1.880
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	54.250	0.0	0.0	0.0	0.0	771.420
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	30.290	5975.656	0.0	32.050	0.0	0.0	0.0
10	0.0	3093.000	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	13620.978	20640.207	0.0	1461.120	0.0	0.0	53.150
13	0.0	0.0	0.0	2.670	0.0	0.0	0.0
14	323568.000	61.150	235.570	694.500	0.0	0.0	0.350
15	24.230	13.560	0.510	10.690	0.0	0.0	0.120
16	0.0	651.250	0.0	0.0	0.0	0.0	13.290
17	796.250	3662.870	265.010	1137.910	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	4.590
19	0.0	1302.250	114.230	349.920	0	0.0	0.0
20	340.310	210.340	0.0	0.0	0.0	0.0	44.100
21	48.730	8207.309	0.0	446.080	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	4144.840	1227.780	0.510	96.160	0.0	0.0	15.520
25	60.850	332.400	0.0	3098.530	0.0	0.0	0.0

Table B.6. Continued

Pro-ducing sector	Purchasing sector 1	2	3	4	5	6	7
26	522.580	495.160	21.320	261.770	0.0	0.0	0.940
27	5524.520	204503.500	119.810	2895.520	0.0	0.0	65.380
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	4558.109	0.0	1.020	0.0	0.0	0.0	0.0
30	0.0	0.0	43.150	0.0	0.0	0.0	0.0
31	11079.598	59499.340	249.270	1909.870	0.0	0.0	92.190
32	8229.098	14610.297	17.260	106.850	0.0	0.0	55.620
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	948.230	0.0	0.0	90.820	0.0	0.0	0.0
35	182.270	0.0	1.520	37.390	0.0	0.0	0.230
36	0.0	678.370	0.0	253.760	0.0	0.0	30.930
37	376.920	311.940	0.0	2.670	0.0	0.0	62.910
38	0.0	0.0	0.0	0.0	0.0	0.0	17.170
39	0.0	0.0	198.510	0.0	0.0	0.0	0.0
40	279.470	244.130	0.0	0.0	0.0	0.0	0.120
41	796.250	0.0	0.0	0.0	0.0	0.0	78.790
42	2674.290	3581.250	211.200	814.700	0.0	0.0	23.170
43	0.0	0.0	90.880	478.140	0.0	0.0	10.000
44	10599.418	19127.617	0.0	507.510	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	303.400
46	0.0	0.0	0.0	0.0	0.0	0.0	17.760
47	0.0	0.0	0.0	0.0	0.0	0.0	1.180
48	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49	237.060	725.720	87.320	5.340	0.0	0.0	6.590
50	431.450	454.470	0.0	0.0	0.0	0.0	4.120

Table B.6. Continued

Producing sector	Purchasing sector 1	2	3	4	5	6	7
51	0.0	0.0	0.0	2.670	0.0	0.0	0.0
52	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	0.0	0.0	0.0	0.0	0.0	0.0	3.530
54	0.0	0.0	0.0	0.0	0.0	0.0	0.0
55	133.810	74.710	12.690	0.0	0.0	0.0	13.640
56	12.120	6.900	0.510	5.340	0.0	0.0	0.120
57	0.0	0.0	0.0	0.0	0.0	0.0	0.0
58	680.620	2041.540	1.020	232.390	0.0	0.0	0.470
59	1185.030	1105.710	0.510	427.380	0.0	0.0	1.410
60	0.0	0.0	0.510	152.260	0.0	0.0	0.0
61	0.0	0.0	325.940	88.150	0.0	0.0	0.0
62	6.060	0.0	41.120	2.670	0.0	0.0	0.820
63	24.230	6.900	0.510	48.080	0.0	0.0	0.120
64	218.880	210.340	36.050	146.920	0.0	0.0	4.700
65	39997.078	33236.098	197.490	3472.490	0.0	0.0	61.970
66	7068.297	6301.398	20.820	590.320	0.0	0.0	6.000
67	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	21703.250	16801.270	4.570	1047.090	0.0	0.0	129.240
69	88016.438	95869.125	337.610	3573.990	0.0	0.0	196.150
70	34539.199	33853.316	125.910	1399.680	0.0	0.0	42.450
71	61244.387	244807.438	81.230	2866.140	0.0	0.0	263.060
72	36.350	40.690	33.000	595.660	0.0	0.0	4.700
73	11243.699	33568.508	245.720	6969.020	0.0	0.0	168.870
74	1051.490	936.060	21.320	753.260	0.0	0.0	8.350
75	7250.566	7155.840	106.610	1733.570	0.0	0.0	22.930

Table B.6. Continued

Producing sector	Purchasing sector						
	1	2	3	4	5	6	7
76	30.290	13.560	0.510	16.030	0.0	0.0	0.230
77	13674.598	841.120	6.090	400.670	0.0	0.0	7.740

Table B.6. Continued

Producing sector	Purchasing sector 8	9	10	11	12	13	14
1	0.0	0.0	0.0	0.0	0.0	0.0	1200209.000
2	0.040	0.0	0.0	1244.440	22.490	20.550	399874.438
3	0.0	0.0	0.0	0.830	0.0	0.0	35835.656
4	0.0	0.0	0.0	780.280	19.680	3.440	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.030	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	45.240	0.0	0.0	0.0	222.690	1633.310
8	53.540	0.0	0.0	0.0	0.0	0.0	0.0
9	0.050	1354.910	0.0	8203.898	1765.640	0.0	350.460
10	0.0	0.0	0.0	0.0	0.0	0.0	267.490
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	65.970	438.820	0.0	260.400	67.010	1116.870	10613.238
13	0.010	0.0	0.0	78.000	5.150	9897.699	9.280
14	0.360	6.790	0.0	220.580	53.410	253.520	986256.313
15	0.080	2.260	0.0	58.080	15.000	65.090	180.140
16	0.0	0.0	0.0	0.0	0.0	0.0	165.950
17	0.0	0.0	0.0	5641.758	257.730	30.840	618.500
18	0.200	47.500	0.0	72.430	20.150	541.300	1194.960
19	0.0	0.0	0.0	30.230	104.490	185.000	2459.250
20	0.0	0.0	0.0	70827.188	3860.220	322.050	913.820
21	0.0	0.0	0.0	0.0	0.0	1192.240	3299.370
22	0.0	0.0	0.0	713.420	44.520	0.0	0.0
23	0.0	0.0	0.0	2319.270	153.700	0.0	0.0
24	0.170	275.960	0.0	2785.080	411.430	116.470	46518.227
25	0.0	0.0	0.0	36.630	0.460	811.960	111185.188

Table B.6. Continued

Pro-ducing sector	Purchasing sector						
	8	9	10	11	12	13	14
26	0.190	24.880	0.0	192.720	52.470	147.310	30325.969
27	10.130	891.210	0.0	2611.450	543.100	1301.870	19223.598
28	0.0	0.0	0.0	0.0	0.0	222.690	0.0
29	0.0	0.0	0.0	0.0	0.0	85.660	16828.770
30	0.310	0.0	0.0	4478.520	4970.777	106.210	4.370
31	5.880	1936.230	0.0	15881.520	5328.297	692.050	12966.578
32	0.400	635.610	0.0	9145.020	1702.840	829.100	50634.258
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	0.050	0.0	0.0	23.940	6.550	27.400	32.210
35	0.380	9.050	0.0	1297.780	264.280	54.820	77753.625
36	0.340	36.190	0.0	74147.250	5499.816	277.510	2731.650
37	10.530	1479.310	0.0	19654.656	1335.480	14327.488	2178.110
38	0.0	246.560	0.0	20031.238	599.790	8318.309	0.0
39	0.0	0.0	0.0	0.0	0.0	0.0	159632.563
40	1.540	110.830	0.0	86660.938	4895.340	0.0	0.0
41	0.0	122.150	0.0	445.900	111.060	2281.720	10779.188
42	7.290	497.630	0.0	24919.859	1875.280	2429.030	10908.566
43	4.090	762.280	0.0	0.0	0.0	147.310	0.0
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	10.560	2420.290	0.0	2188.760	394.550	0.0	0.0
46	0.0	588.110	0.0	3769.120	1076.350	0.0	9.280
47	0.270	4.520	0.0	115.450	33.280	1586.230	433.980
48	0.0	0.0	0.0	0.0	0.0	0.0	2985.490
49	6.520	339.290	0.0	3290.620	209.930	849.650	2838.100
50	6.630	52.020	0.0	85.220	36.550	1020.950	1674.800

Table B.6. Continued

Producing sector	Purchasing sector						
	8	9	10	11	12	13	14
51	0.0	0.0	0.0	1.550	0.460	0.0	0.0
52	0.0	0.0	0.0	10505.727	3383.670	0.0	1435.150
53	10.900	104.050	0.0	6611.566	671.950	328.900	0.0
54	0.010	0.0	0.0	1873.470	1096.030	6.850	0.0
55	0.540	22.620	0.0	14150.629	2979.750	10.290	105.900
56	0.310	2.260	0.0	831.970	285.830	4279.066	105.900
57	0.0	0.0	0.0	0.0	0.0	4306.469	0.0
58	0.050	11.310	0.0	426.710	84.350	3.440	129.380
59	0.170	409.410	0.0	296.200	81.070	431.670	599.940
60	0.310	0.0	0.0	0.0	0.0	13214.059	27.840
61	0.0	0.0	0.0	7.940	1.880	0.0	0.0
62	0.770	0.0	0.0	3323.320	587.600	1010.660	387.580
63	0.040	6.790	0.0	113.070	9.370	34.250	230.910
64	0.480	76.910	0.0	1383.820	646.190	123.320	461.280
65	9.680	778.110	0.0	26445.328	4377.547	2953.210	145489.063
66	4.170	70.120	0.0	2652.920	679.440	1500.590	8536.668
67	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	21.130	2399.930	0.0	1227.730	305.520	2737.380	40801.098
69	8.290	1954.330	0.0	80135.438	12802.270	3494.510	234811.250
70	10.170	943.230	0.0	5955.508	1374.370	1130.570	25393.277
71	243.550	2447.430	0.0	5644.957	1435.750	1658.170	25541.219
72	1.450	128.930	0.0	221.300	57.640	859.930	12408.137
73	35.340	2318.500	0.0	61057.219	2839.170	9592.777	154524.125
74	9.060	63.340	0.0	4115.457	1052.920	5019.066	8565.758
75	2.300	651.440	0.0	3476.940	747.870	551.590	14734.180

Table B.6. Continued

Producing sector	Purchasing sector						
	8	9	10	12	13	14	15
76	0.160	2.260	0.0	91.510	24.370	106.210	595.020
77	0.600	85.950	0.0	480.880	123.240	431.670	3387.260

Table B.6. Continued

Pro-ducing sector	Purchasing sector						
	15	16	17	18	19	20	21
1	0.0	51.410	186.210	0.0	0.0	0.0	0.0
2	0.0	907.320	58.010	13.980	0.0	0.970	0.0
3	0.0	0.0	0.0	68.290	0.0	8337.387	0.0
4	0.0	0.0	0.0	3.970	0.0	59.820	3.690
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	9.000	5.770	1.320	14.750	188.640	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.430	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	37.190	30.130	19.830	34.090	373.900	22.160
13	0.0	0.090	0.0	0.090	0.0	0.0	0.0
14	0.0	29.820	26.600	10.770	115.190	19.290	1.850
15	0.0	0.680	0.640	1.230	3.690	4.340	1.850
16	0.0	4546.199	4894.758	6189.988	14339.566	0.0	0.0
17	0.0	118.840	1853.800	89.440	4989.957	47.760	0.0
18	0.0	10.710	215.380	7237.348	361.230	52.110	0.0
19	0.0	1.280	104.160	365.430	1515.880	32.810	0.0
20	0.0	46.270	30.130	17.660	108.740	30556.148	3475.460
21	0.0	0.0	0.0	0.0	0.0	6.270	97.870
22	0.0	0.0	0.0	0.0	0.0	7.720	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	19.110	58.330	79.900	456.140	143.770	3.690
25	0.0	101.540	167.300	245.290	498.540	327.590	0.0

Table B.6. Continued

Pro-ducing sector	Purchasing sector						
	15	16	17	18	19	20	21
26	0.0	4.370	7.370	27.010	94.910	20.260	3.690
27	0.0	404.690	474.990	105.310	53.450	1018.950	0.0
28	0.0	2042.910	2268.540	491.990	233.140	158.730	0.0
29	0.0	53.550	23.720	46.190	0.0	0.0	0.0
30	0.0	4.280	21.470	0.0	0.0	460.270	0.0
31	0.0	37.870	61.860	53.080	65.430	1302.160	36.930
32	0.0	75.570	533.640	95.210	1071.710	628.160	3.690
33	0.0	0.0	0.0	131.570	292.120	0.0	0.0
34	0.0	0.260	0.0	0.570	0.0	15.440	0.0
35	0.0	53.900	74.680	0.190	0.0	227.240	0.0
36	0.0	11.140	11.540	9.450	16.590	962.990	3.690
37	0.0	4.200	8.330	6.230	129.900	328.070	358.260
38	0.0	0.0	0.0	0.0	0.0	55.480	0.0
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0	195.390	0.0
41	0.0	0.0	0.0	0.0	0.0	436.140	16.620
42	0.0	13.450	0.0	18.420	0.0	3474.680	14.770
43	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	14.960	0.0
46	0.0	18.510	7.690	5.010	0.0	121.580	0.0
47	0.0	0.0	0.0	0.0	0.0	50.660	0.0
48	0.0	106.250	99.360	26.260	8.290	238.820	16.620
49	0.0	3.690	42.950	8.880	1.840	140.400	1.850
50	0.0	19.450	18.270	11.150	23.960	166.930	16.620

Table B.6. Continued

Pro-ducing sector	Purchasing sector						
	15	16	17	18	19	20	21
51	0.0	0.0	0.0	0.090	0.0	0.0	0.0
52	0.0	1.890	0.0	0.0	0.0	35.700	0.0
53	0.0	0.0	0.0	0.0	0.0	35.220	0.0
54	0.0	0.680	0.0	17.470	44.230	2.900	0.0
55	0.0	0.600	1.280	0.190	0.0	48.250	0.0
56	0.0	0.430	0.640	0.850	0.920	3.370	0.0
57	0.0	7.030	0.0	0.0	0.0	0.0	0.0
58	0.0	0.170	0.0	0.570	0.0	21.710	0.0
59	0.0	0.600	0.320	1.320	0.920	180.930	1.850
60	0.0	0.340	0.0	0.0	0.0	0.970	0.0
61	0.0	0.0	0.0	0.0	0.0	9.160	0.0
62	0.0	9.170	0.0	0.090	0.0	44.870	5.540
63	0.0	12.850	25.960	2.460	4.610	9.160	0.0
64	0.0	1.710	7.050	437.490	292.120	80.570	9.230
65	0.0	277.450	508.320	362.600	1026.560	3399.900	391.500
66	0.0	40.790	77.560	106.450	199.040	197.320	29.550
67	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	0.0	229.040	241.020	155.940	262.630	1101.460	92.330
69	0.0	621.820	854.790	1043.490	1924.110	4359.508	515.220
70	0.0	57.240	64.740	179.640	288.430	839.970	162.510
71	0.0	102.140	267.940	276.930	774.990	750.710	60.940
72	0.0	29.560	104.490	101.060	268.160	164.520	12.930
73	0.0	247.970	439.410	566.610	792.500	1574.750	123.730
74	0.0	45.330	43.590	93.130	124.400	262.460	33.240
75	0.0	15.250	25.960	29.560	58.050	826.940	24.010

Table B.6. Continued

Pro-ducing sector	Purchasing sector						
	15	16	17	18	19	20	21
76	0.0	0.940	0.960	3.870	12.900	15.920	1.850
77	0.0	26.910	13.140	49.300	174.160	127.370	12.930

Table B.6. Continued

Producing sector	Purchasing sector						
	22	23	24	25	26	27	28
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.360	0.0	66.710	2.680	24.430	56.380	0.950
3	0.0	0.0	17.330	0.0	0.0	16.220	0.0
4	22.380	0.0	13.000	6.700	54.280	9.810	5.060
5	0.0	0.0	0.0	0.0	0.0	77.690	0.0
6	0.0	0.0	12.570	0.0	0.0	279.640	3.480
7	13.570	31.400	470.920	16.070	4.080	207.800	135.120
8	0.0	0.0	0.0	0.0	0.0	107.670	31.640
9	0.0	0.0	337.050	0.0	0.0	250.040	0.0
10	0.0	0.0	25.990	0.0	0.0	556.830	1.580
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	102.430	96.360	845.650	601.280	1424.800	386.180	268.980
13	0.0	0.0	0.430	1.340	5.410	0.570	0.320
14	221.130	16.240	708.750	18.740	229.310	409.380	109.180
15	3.390	6.500	6.930	5.360	58.360	4.340	2.850
16	2876.100	217.620	739.940	0.0	165.540	0.0	60.760
17	1087.360	804.430	455.320	0.0	422.030	0.0	0.0
18	187.220	238.190	40.720	61.600	252.410	6.790	7.910
19	99.040	285.830	1.300	1.340	28.510	22.060	0.630
20	7050.520	2763.010	7048.109	10.710	0.0	100.320	12.980
21	12.890	5.410	5.630	0.0	0.0	0.0	0.0
22	235.380	18.410	0.0	0.0	0.0	0.0	0.0
23	0.0	462.310	0.0	0.0	0.0	0.0	0.0
24	67.150	16.240	14973.047	42740.887	58511.750	297.180	587.960
25	878.430	475.300	1542.710	1949.830	914.570	214.210	323.730

Table B.6. Continued

Producing sector	Purchasing sector						
	22	23	24	25	26	27	28
26	49.520	58.470	91.850	46.870	40012.438	30.360	16.460
27	78.010	94.190	2987.500	2035.530	5811.809	9292.066	9860.578
28	0.0	19.490	1164.500	949.470	25.770	386.750	1163.270
29	0.0	0.0	107.440	0.0	0.0	38.090	168.350
30	508.070	326.970	39.430	0.0	141.110	80.700	54.110
31	139.730	98.520	967.390	660.210	758.520	526.100	254.110
32	2678.710	2214.090	1742.850	154.010	2480.520	314.710	526.570
33	97.680	38.980	0.0	0.0	43.410	0.0	0.0
34	0.0	0.0	3.470	2.680	25.770	9.810	1.270
35	305.250	320.470	5.190	2.680	12.200	19.610	16.140
36	315.420	167.820	196.690	56.240	325.670	84.290	11.710
37	862.150	3619.410	34.220	440.580	128.910	235.700	8.540
38	331.700	339.960	92.280	155.340	730.050	432.760	32.590
39	0.0	0.0	0.0	0.0	0.0	400.510	64.240
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	333.740	742.720	0.0	0.0	1.370	6.220	0.0
42	2933.080	1948.830	568.820	144.630	636.400	85.230	33.230
43	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	8.230	0.0	46.120	0.0	0.0
47	4.750	51.970	12.130	237.030	58.360	0.0	14.240
48	52.230	0.0	266.430	365.600	1112.700	382.600	141.140
49	5.750	75.790	84.910	29.470	12.200	282.470	67.090
50	49.520	35.730	88.380	135.250	128.910	33.190	28.800

Table B.6. Continued

Producing sector	Purchasing sector						
	22	23	24	25	26	27	28
51	0.0	0.0	0.0	0.0	4.080	0.0	0.0
52	0.0	0.0	0.0	0.0	0.0	37.530	0.0
53	0.0	79.040	0.0	0.0	0.0	19.610	0.0
54	0.0	0.0	0.0	0.0	4.080	0.380	0.0
55	26.450	7.580	6.060	4.020	13.570	2.830	2.220
56	2.710	4.330	3.040	2.680	44.790	3.580	1.270
57	0.0	0.0	0.0	0.0	0.0	0.0	0.0
58	1.360	0.0	0.0	2.680	10.860	0.380	0.0
59	6.780	3.250	1.300	5.360	38.000	1.320	0.320
60	0.0	0.0	2.600	0.0	2.710	0.570	0.630
61	0.0	0.0	0.0	0.0	0.0	0.0	0.0
62	23.060	0.0	89.240	1.340	8.160	46.010	26.270
63	26.450	4.330	7.800	0.380	3076.210	8.860	2.850
64	140.410	102.850	22.520	117.840	995.990	6.790	3.800
65	1393.280	1384.750	4126.449	5593.699	13482.688	2146.430	908.530
66	171.620	124.510	187.150	451.300	4374.809	148.400	111.390
67	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	343.230	427.660	2510.090	930.720	2445.230	2232.030	658.530
69	2663.110	1671.660	3871.710	2976.980	10680.578	1194.560	873.400
70	422.600	450.400	424.990	437.910	3745.200	338.850	230.380
71	607.780	741.640	1330.000	1467.730	16898.098	966.960	427.840
72	95.640	194.880	391.640	653.510	3823.870	151.040	123.730
73	1352.580	931.110	2053.480	2300.690	21245.809	1748.750	1070.870
74	191.970	224.110	319.290	373.630	4632.629	342.060	165.190
75	145.160	194.880	118.710	250.420	1499.440	74.100	52.530

Table B.6. Continued

Producing sector	Purchasing sector						
	22	23	24	25	26	27	28
76	4.750	6.500	8.230	8.030	156.050	7.350	3.170
77	106.500	120.180	74.080	111.150	1097.760	51.290	41.140

Table B.6. Continued

Producing sector	Purchasing sector 29	30	31	32	33	34	35
1	26.990	0.0	0.0	0.0	0.0	0.0	0.0
2	118.990	300.720	0.290	9.160	0.0	0.0	0.0
3	16.560	199.990	0.0	0.0	0.0	0.0	0.0
4	24.540	4.380	1.250	102.660	0.0	1.700	0.0
5	0.0	23.360	0.0	0.0	0.0	0.0	0.0
6	0.0	103.650	0.0	9.160	0.0	0.0	0.0
7	20.250	1.460	25.960	183.350	9.510	3.400	0.0
8	0.0	24.820	10987.430	0.0	0.0	0.0	0.0
9	65.020	110.940	64.100	240.150	0.0	0.0	0.0
10	0.0	0.0	0.290	337.320	13.580	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	544.650	144.520	398.390	1897.520	31.230	95.200	0.0
13	1.230	1.460	0.070	5.490	0.0	0.0	0.0
14	1364.070	1213.090	31.390	117.350	6017.277	163.200	0.0
15	15.940	5.840	0.660	25.670	1.360	10.200	0.0
16	0.0	0.0	0.0	7250.938	0.0	2674.160	0.0
17	3.680	0.0	7.630	11440.137	0.0	3519.070	0.0
18	8.590	1.460	1.250	308.010	0.0	256.700	0.0
19	39.870	1.460	0.070	76.980	0.0	156.410	0.0
20	15.940	0.0	4.330	1316.340	0.0	681.720	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	792.450	105.100	70.700	3351.390	4.070	651.110	0.0
25	2545.370	440.860	77.080	5421.238	6.790	1060.820	0.0

Table B.6. Continued

Pro-ducing sector	Purchasing sector						
	29	30	31	32	33	34	35
26	442.220	453.990	2.420	229.170	2.720	45.900	0.0
27	6860.250	10907.578	607.050	16947.566	949.240	647.710	0.0
28	88.330	5023.148	0.660	52782.379	0.0	39.100	0.0
29	5745.797	113.860	76.350	80.660	513.320	134.300	0.0
30	126.970	537.200	2.050	436.340	0.0	54.400	0.0
31	614.570	766.390	1710.100	1131.170	66.540	166.600	0.0
32	4742.367	129.920	39.460	16320.566	1.360	5227.609	0.0
33	0.0	0.0	0.0	18.330	1224.910	13343.578	0.0
34	7.360	2.920	0.660	18.330	0.0	1851.340	0.0
35	1710.000	49.630	1.760	1626.200	1.360	0.0	0.0
36	71.760	277.360	66.150	808.500	48.890	20.400	0.0
37	3.680	83.210	9.530	2757.370	2.720	56.100	0.0
38	41.090	572.240	34.030	348.340	0.0	297.500	0.0
39	2537.410	3013.010	206.240	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	472.270	17.520	0.0	2788.530	0.0	482.810	0.0
42	598.010	188.310	37.040	3793.220	0.0	921.420	0.0
43	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.370	36.660	0.0	88.400	0.0
47	15.330	0.0	0.440	1472.200	0.0	0.0	0.0
48	0.0	0.0	0.0	1006.510	0.0	295.800	0.0
49	80.350	2.920	31.460	256.660	1.360	3.400	0.0
50	36.190	11.680	5.350	878.180	10.860	90.100	0.0

Table B.6. Continued

Pro-ducing sector	Purchasing sector						
	29	30	31	32	33	34	35
51	0.0	0.0	0.0	1.820	0.0	0.0	0.0
52	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	0.0	0.0	0.0	0.0	0.0	0.0	0.0
54	1.840	0.0	0.070	1.820	0.0	64.600	0.0
55	4.290	2.920	1.760	383.180	0.0	0.0	0.0
56	12.880	2.920	0.440	16.510	0.0	3.400	0.0
57	0.0	0.0	0.0	0.0	0.0	0.0	0.0
58	1.230	0.0	0.290	3.670	0.0	0.0	0.0
59	3.060	2.920	1.320	390.520	0.0	3.400	0.0
60	1.230	0.0	0.220	7.350	0.0	0.0	0.0
61	0.0	0.0	0.0	0.0	0.0	0.0	0.0
62	126.340	21.900	10.190	425.320	0.0	0.0	0.0
63	15.330	8.760	4.250	62.330	1.360	8.500	0.0
64	85.860	115.320	2.930	597.660	9.510	1105.020	0.0
65	2676.020	1979.480	1299.540	13708.000	392.460	1327.730	0.0
66	425.050	291.960	42.170	1505.180	21.730	278.800	0.0
67	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	679.580	344.510	468.070	5817.258	137.160	372.310	0.0
69	3063.040	1788.250	218.260	10121.988	745.540	2886.660	0.0
70	692.470	290.500	148.590	2420.050	69.260	511.710	0.0
71	3136.640	1567.820	213.060	4103.047	100.490	1008.120	0.0
72	1035.940	468.590	6.240	2225.710	13.580	154.700	0.0
73	18770.148	1769.270	494.540	11759.168	100.490	2407.250	0.0
74	1454.850	408.740	50.460	1974.540	28.520	346.810	0.0
75	144.750	113.860	17.820	650.860	12.220	107.100	0.0

Table B.6. Continued

Pro-ducing sector	Purchasing sector						
	29	30	31	32	33	34	35
76	49.070	7.300	2.640	36.660	1.360	10.200	0.0
77	382.120	65.690	7.990	936.830	10.860	132.610	0.0

Table B.6. Continued

Producing sector	Purchasing sector						
	36	37	38	39	40	41	42
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	4.330	1.600	0.920	0.0	5.760	0.680	4.830
3	18.720	0.0	0.0	0.0	0.0	0.0	0.0
4	57.570	13.500	45.940	6.810	145.220	9.350	64.560
5	243.240	5563.316	42.230	0.0	0.0	0.0	0.0
6	410.210	87.070	8698.508	0.0	238.690	0.0	0.0
7	1332.820	2451.530	49.190	0.280	156.740	6.840	29.040
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	13483.578	328.370	12.530	0.0	14.390	0.0	69.390
10	381.430	101.850	0.920	0.0	0.0	0.0	1.600
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1653.780	1498.230	404.210	28.960	487.440	94.820	858.590
13	1.450	0.650	0.0	0.0	2.870	0.0	0.0
14	136.740	20.570	19.960	0.850	71.890	5.020	62.940
15	23.030	4.820	5.110	0.280	23.010	0.680	16.150
16	744.140	0.0	103.950	0.0	0.0	0.0	0.0
17	105.070	0.0	44.550	0.0	0.0	0.0	187.200
18	28.780	45.940	17.630	3.980	103.530	16.410	132.330
19	1.450	12.850	31.090	8.230	70.460	47.410	62.940
20	1721.430	480.340	459.900	21.010	661.410	60.400	1951.190
21	44.630	42.740	96.530	0.0	76.220	42.170	80.690
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	51.410	0.0	0.0	0.0	0.0	0.0
24	3588.230	60.090	101.170	24.420	465.860	93.230	88.770
25	1004.650	116.630	197.230	101.080	1243.760	149.080	2296.560

Table B.6. Continued

Producing sector	Purchasing sector						
	36	37	38	39	40	41	42
26	92.110	107.950	41.760	635.470	84.840	8.890	108.120
27	5598.957	2189.670	1572.260	33.790	392.530	132.660	3440.810
28	945.630	0.0	829.290	17.890	0.0	24.620	284.040
29	115.140	4.170	0.920	14.770	199.850	20.520	159.770
30	426.030	54.620	151.750	259.810	1997.180	47.870	1767.220
31	2114.370	557.140	517.900	23.280	703.110	76.590	797.260
32	1247.890	128.520	808.400	14.770	1081.260	191.470	5869.719
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	5.760	5.460	1.390	0.0	5.760	0.0	0.0
35	149.680	12.530	46.410	0.280	1748.430	22.340	311.470
36	24226.680	810.650	286.800	15.620	661.410	72.490	1179.750
37	1341.450	22745.527	856.670	4722.578	51676.637	6587.367	30555.789
38	495.120	2533.780	44908.859	1213.010	16474.988	1166.160	14721.906
39	21.600	50.760	0.0	18.740	0.0	43.540	82.310
40	14.390	129.810	0.0	0.0	3147.460	0.0	54.870
41	70.530	775.950	207.440	7.670	4859.969	775.010	4089.590
42	2514.500	1364.570	815.830	155.320	7882.340	373.600	8779.566
43	59.020	12.210	0.0	0.0	12.930	0.0	388.950
44	0.0	0.0	0.0	0.0	0.0	7.750	40.350
45	420.280	0.0	0.0	0.0	0.0	0.0	0.0
46	37.420	94.790	58.940	0.0	0.0	6.380	0.0
47	38.870	855.310	941.600	77.800	1401.900	352.860	1789.800
48	41.750	97.990	0.0	0.0	0.0	2.740	69.390
49	200.060	2059.540	722.560	21.010	1312.760	20.740	485.780
50	355.520	579.950	329.480	36.350	1537.080	428.080	1946.360

Table B.6. Continued

Producing sector	Purchasing sector 36	37	38	39	40	41	42
51	0.0	137.830	0.0	0.0	0.0	0.0	0.0
52	0.0	11.560	0.0	0.0	473.050	0.0	51.640
53	182.790	947.510	365.230	0.0	2025.930	33.280	900.550
54	0.0	0.320	0.0	0.0	0.0	2.960	0.0
55	351.190	318.730	82.600	0.570	79.080	16.640	11.290
56	14.390	3.850	3.250	0.280	12.930	0.680	12.920
57	0.0	0.0	0.0	0.0	0.0	0.0	54.870
58	5.760	12.210	0.0	0.0	50.330	6.150	3.230
59	71.960	2.570	1.390	0.570	126.530	62.680	22.600
60	2.880	1.600	0.920	0.0	0.0	9.570	0.0
61	0.0	80.960	0.0	0.0	33.080	0.0	0.0
62	86.350	186.360	25.060	3.120	751.990	11.620	146.870
63	60.450	24.090	8.820	1.140	100.640	3.650	33.900
64	505.200	82.260	46.410	0.850	186.920	3.880	225.960
65	20503.156	6666.027	2762.140	681.750	6310.770	507.860	5621.188
66	777.230	256.080	215.330	22.430	901.530	65.650	798.880
67	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	7202.379	3929.830	2869.330	132.320	1945.410	272.620	3000.210
69	5545.719	4470.258	4417.469	442.670	8082.188	732.840	6707.328
70	1941.640	692.400	713.280	91.150	1342.960	180.300	2020.590
71	2900.240	225.230	581.020	143.960	3627.710	225.440	2748.450
72	485.050	308.770	157.320	51.390	941.800	52.660	724.630
73	5335.566	2195.120	2007.560	444.370	4737.750	461.360	5743.828
74	1034.880	318.730	231.570	42.310	1449.370	70.890	1036.130
75	1101.090	125.950	151.750	19.590	609.640	28.260	535.800

Table B.6. Continued

Producing sector	Purchasing sector						
	36	37	38	39	40	41	42
76	25.910	13.810	6.030	0.280	27.320	1.370	20.980
77	283.540	141.050	110.910	16.470	381.040	59.270	408.300

Table B.6. Continued

Producing sector	Purchasing sector						
	43	44	45	46	47	48	49
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	3.070	12.690	23.100	0.0	0.990	2.390	1.740
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	9.210	114.510	38.480	0.0	0.990	3.590	3.470
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	13.820	178.110	153.920	1.650	2.310	3.590	5.210
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	153.470	1386.570	3017.200	49.610	78.500	186.630	130.220
13	0.0	12.690	7.720	0.0	0.0	1.190	0.580
14	27.620	1017.670	153.920	9.100	12.530	29.910	22.570
15	3.070	50.910	46.200	3.310	3.630	9.570	5.210
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	237.880
18	35.300	267.160	200.120	1.650	15.170	21.530	21.900
19	1.540	12.690	15.380	0.0	0.0	0.0	0.580
20	0.0	1831.840	1485.530	38.860	22.760	361.300	140.060
21	0.0	572.470	269.420	17.370	13.520	25.130	31.830
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	12.400	0.0	0.0	0.0
24	46.040	203.560	184.740	9.920	10.230	28.710	97.230
25	217.920	2022.640	0.0	10.750	17.810	67.000	152.800

Table B.6. Continued

Producing sector	Purchasing sector						
	43	44	45	46	47	48	49
26	29.160	343.450	323.280	14.880	15.830	32.300	21.410
27	6.140	101.750	354.040	4.960	51.780	1282.500	5.210
28	0.0	0.0	0.0	0.0	0.0	0.0	19.680
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	32.230	1755.550	1069.850	15.710	18.470	47.850	5.790
31	248.620	1819.150	1754.890	81.030	165.240	470.170	359.420
32	296.190	23394.199	10829.547	479.590	79.160	837.460	392.980
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	0.0	25.450	23.100	0.0	0.990	7.180	1.160
35	6.140	25.450	15.380	0.0	1.320	105.280	2.320
36	610.810	1704.640	4510.398	40.520	189.980	183.050	239.610
37	10943.887	91961.250	87437.000	3214.080	2153.730	6329.969	6122.227
38	4023.960	6029.848	3671.430	605.280	558.390	2122.350	1434.190
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	1778.700	0.0	3132.650	134.780	114.120	997.770	299.800
41	1810.940	17733.328	7073.500	230.700	151.720	434.280	556.200
42	994.480	8217.906	6288.387	362.170	146.770	1196.360	499.480
43	9389.238	43315.590	19303.898	353.910	0.0	671.160	262.760
44	53.710	30759.789	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	37122.270	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	883.930	0.0	39.480	0.0
47	853.290	5431.930	7542.977	188.530	1349.630	951.110	632.020
48	0.0	0.0	0.0	0.0	0.0	2599.700	0.0
49	1611.430	40605.977	31880.680	1288.280	521.780	2951.430	3062.850
50	2905.170	9477.438	10429.309	551.530	565.640	1193.980	750.090

Table B.6. Continued

Producing sector	Purchasing sector						
	43	44	45	46	47	48	49
51	0.0	0.0	0.0	0.0	0.0	20.340	0.0
52	0.0	0.0	0.0	0.0	0.0	33.500	0.0
53	672.190	5482.828	7011.918	831.010	587.080	1902.220	1587.570
54	0.0	0.0	0.0	0.0	0.0	0.0	0.0
55	1.540	1043.120	23.100	0.0	21.770	1.190	1.160
56	3.070	38.150	30.760	3.310	2.640	8.370	4.630
57	0.0	0.0	0.0	0.0	0.0	128.010	88.550
58	1005.220	5482.828	654.230	53.750	0.660	0.0	4.630
59	379.070	13433.578	7989.430	0.0	1.320	38.290	2.320
60	0.0	0.0	69.300	0.0	0.0	0.0	0.0
61	0.0	0.0	0.0	0.0	0.0	0.0	0.0
62	26.090	241.710	207.840	9.100	40.240	34.690	92.030
63	9.210	89.050	76.960	4.960	4.620	16.750	8.680
64	16.880	915.920	484.920	13.230	16.490	10.770	10.420
65	1123.390	10367.750	7396.719	442.380	191.960	1222.690	636.650
66	205.650	2315.260	3186.510	91.780	118.740	467.780	239.030
67	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	538.680	4554.148	4564.258	152.150	224.610	528.800	439.290
69	2193.080	30734.340	24329.977	764.860	595.990	2066.120	1777.400
70	412.840	5253.816	4464.199	124.030	142.480	484.530	306.750
71	297.730	1806.390	3763.770	332.400	202.510	1667.730	486.750
72	127.380	1641.040	939.030	33.070	36.280	148.350	64.820
73	1238.500	18712.848	14824.258	577.990	501.000	1292.080	1009.380
74	296.190	3065.830	2763.220	172.820	203.500	556.310	358.260
75	328.430	941.380	1362.370	131.470	28.040	119.640	111.120

Table B.6. Continued

Producing sector	Purchasing sector						
	43	44	45	46	47	48	49
76	6.140	63.600	292.460	4.130	8.250	13.160	19.680
77	81.340	661.520	646.570	30.600	36.940	98.100	63.090

Table B.6. Continued

Producing sector	Purchasing sector						
	50	51	52	53	54	55	56
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.890	0.0	0.0	4.460	4.980	0.090	11.280
3	0.0	0.0	0.0	0.0	0.0	0.0	0.950
4	4.450	0.0	0.0	10.690	0.0	0.600	15.970
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	23.130	0.0	0.0	24.050	59.750	0.850	5.640
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	77.420	0.0	0.0	245.900	726.990	8.100	364.520
13	0.890	0.0	0.0	0.890	0.0	0.0	2.820
14	10.680	0.0	0.0	45.440	109.540	2.220	107.110
15	3.560	0.0	0.0	14.260	29.890	0.600	25.360
16	0.0	0.0	0.0	0.0	1339.450	11.680	0.0
17	88.090	0.0	0.0	16.920	607.480	0.0	0.0
18	57.840	0.0	0.0	53.450	74.700	2.470	83.610
19	0.890	0.0	0.0	0.0	0.0	3.070	1.870
20	26.690	0.0	0.0	227.190	1145.250	11.680	153.140
21	6.230	0.0	0.0	83.750	497.940	0.0	144.680
22	0.0	0.0	0.0	0.0	0.0	0.0	2956.640
23	0.0	0.0	0.0	0.0	129.470	0.0	0.0
24	18.690	0.0	0.0	357.260	343.570	1.530	322.250
25	299.880	0.0	0.0	407.160	5656.578	81.830	472.580

Table B.6. Continued

Producing sector	Purchasing sector						
	50	51	52	53	54	55	56
26	25.810	0.0	0.0	67.710	313.710	2.470	840.870
27	117.460	0.0	0.0	508.730	2016.650	41.680	137.160
28	0.0	0.0	0.0	355.480	2564.390	44.660	587.190
29	9.790	0.0	0.0	0.0	0.0	0.0	0.0
30	23.130	0.0	0.0	274.410	2922.900	13.300	94.890
31	477.850	0.0	0.0	439.230	517.870	9.630	221.720
32	213.560	0.0	0.0	1053.090	13937.289	120.180	1270.230
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	1.780	0.0	0.0	7.130	0.0	0.0	11.280
35	1.780	0.0	0.0	49.890	1429.100	141.920	401.180
36	257.170	0.0	0.0	901.630	2703.820	17.050	118.370
37	3640.370	0.0	0.0	6109.156	28009.027	266.700	1506.040
38	1731.640	0.0	0.0	6766.680	15271.758	288.100	4025.810
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	425.870	0.0	0.0	123.080
41	557.050	0.0	0.0	1487.870	9211.867	140.980	2678.550
42	768.830	0.0	0.0	861.540	10133.059	70.060	1958.890
43	66.740	0.0	0.0	277.080	0.0	0.0	0.0
44	0.0	0.0	0.0	0.0	84.660	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47	833.790	0.0	0.0	643.260	1683.020	30.090	644.510
48	0.0	0.0	0.0	0.0	79.680	0.0	46.040
49	388.860	0.0	0.0	446.360	2390.110	0.430	55.430
50	2459.540	0.0	0.0	542.580	1090.480	13.130	466.000

Table B.6. Continued

Pro-ducing sector	Purchasing sector						
	50	51	52	53	54	55	56
51	0.0	0.0	0.0	162.150	0.0	0.0	167.240
52	0.0	0.0	0.0	0.0	4556.129	0.0	21.610
53	257.170	0.0	0.0	6958.227	15963.906	115.320	1085.150
54	0.0	0.0	0.0	0.0	3913.800	0.0	30.070
55	0.890	0.0	0.0	960.430	4476.477	179.420	1764.400
56	2.670	0.0	0.0	9.800	24.910	0.600	13214.250
57	0.0	0.0	0.0	1947.590	0.0	16.540	29539.238
58	171.740	0.0	0.0	4.460	1055.640	111.320	143.750
59	80.090	0.0	0.0	1.780	0.0	0.170	5.640
60	0.0	0.0	0.0	2.670	0.0	0.0	3.770
61	0.0	0.0	0.0	0.0	0.0	0.0	0.0
62	24.920	0.0	0.0	162.150	10934.750	2.050	197.310
63	8.010	0.0	0.0	17.810	49.790	0.940	50.740
64	41.820	0.0	0.0	127.410	1533.660	0.680	77.990
65	779.510	0.0	0.0	1740.900	5377.750	83.110	1992.710
66	194.880	0.0	0.0	604.050	796.700	20.970	1022.190
67	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	437.810	0.0	0.0	908.760	2574.350	39.720	929.170
69	845.360	0.0	0.0	2496.410	13190.406	159.560	4345.258
70	269.620	0.0	0.0	544.360	1503.760	24.120	1112.380
71	777.730	0.0	0.0	1348.880	4874.816	62.140	2548.890
72	112.120	0.0	0.0	1585.870	836.530	21.740	2286.770
73	740.350	0.0	0.0	2606.890	12667.547	112.170	6456.340
74	256.280	0.0	0.0	845.500	1354.400	29.320	2242.620
75	76.530	0.0	0.0	162.150	169.290	17.810	464.120

Table B.6. Continued

Producing sector	Purchasing sector						
	50	51	52	53	54	55	56
76	4.450	0.0	0.0	18.710	84.660	0.680	94.890
77	64.960	0.0	0.0	155.910	448.160	10.060	360.780

Table B.6. Continued

Pro-ducing sector	Purchasing sector						
	57	58	59	60	61	62	63
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2.990	0.980	4.410	2.090	0.780	7.590	0.230
3	0.0	0.0	0.0	0.100	0.0	0.0	0.0
4	11.210	2.930	12.640	1.670	1.870	3.790	0.570
5	0.0	24.410	0.0	0.0	0.0	0.0	0.0
6	0.0	21.480	0.0	0.0	0.0	2.530	0.0
7	2.990	9.760	152.700	1.770	2.020	1.900	6.510
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.470	3.790	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	173.430	102.500	593.160	60.710	28.780	96.780	39.620
13	1.500	0.0	1.110	3.020	0.160	0.0	0.110
14	36.630	17.570	35.140	23.160	5.760	136.000	2.170
15	10.470	4.880	8.240	5.420	1.400	6.960	0.690
16	0.0	0.0	135.650	17.320	6.070	392.190	0.0
17	0.0	18.550	1081.950	5.530	290.150	289.710	3.310
18	48.590	46.860	98.320	8.350	30.650	46.180	1.830
19	2.240	0.0	5984.848	0.310	47.920	0.0	0.110
20	0.0	73.220	635.430	3.960	1187.660	189.770	2.400
21	0.0	0.0	99.970	7.510	0.310	0.0	0.0
22	57.560	0.0	0.0	0.0	195.560	0.0	0.0
23	0.0	0.0	1054.510	23.050	62.390	0.0	0.0
24	153.990	19.530	330.070	10.740	27.380	309.960	154.270
25	298.260	274.320	479.470	12.620	2.490	294.770	49.900

Table B.6. Continued

Pro- ducing sector	Purchasing sector 57	 58	 59	 60	 61	 62	 63
26	38.870	66.380	116.980	42.770	10.740	69.580	3.650
27	897.770	857.110	633.780	12.210	15.560	45.540	296.100
28	338.630	400.250	315.240	38.810	60.670	313.120	17.130
29	0.0	0.0	8.780	0.0	3.730	41.750	0.0
30	2.990	13.670	1063.820	27.330	142.200	41.750	0.110
31	158.470	82.000	583.280	62.380	66.740	187.240	23.070
32	1533.170	1341.320	10121.547	35.570	293.570	988.690	144.800
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	2.990	0.0	6.050	2.710	0.310	27.830	0.230
35	1474.110	12.690	3955.460	2.290	100.660	252.390	34.830
36	373.020	157.170	1347.800	12.830	117.770	103.110	2.630
37	763.220	1186.100	26588.770	434.910	1688.770	862.180	130.060
38	2527.380	5075.328	5189.559	602.030	621.370	1770.540	219.360
39	0.0	0.0	0.0	0.0	0.0	61.360	0.0
40	0.0	0.0	50.540	0.0	744.900	108.170	0.570
41	1332.830	317.270	26867.797	146.150	146.400	1020.320	47.160
42	1284.250	897.140	10261.066	218.550	387.850	859.020	45.910
43	0.0	0.0	2848.790	10.010	512.930	0.0	0.0
44	0.0	0.0	23.600	0.0	12.290	0.0	0.0
45	0.0	0.0	0.0	0.0	51.960	0.0	0.0
46	0.0	0.0	37.360	0.0	25.520	0.0	0.0
47	245.930	348.510	1141.260	167.220	62.070	208.750	0.0
48	0.0	0.0	0.0	0.0	15.250	0.0	0.0
49	16.440	515.440	1363.160	108.490	388.940	56.930	20.550
50	223.510	84.930	3484.790	358.130	73.740	296.670	11.650

Table B.6. Continued

Producing sector	Purchasing sector						
	57	58	59	60	61	62	63
51	20.930	0.0	8.240	57.170	0.780	20.240	0.0
52	0.0	0.0	1825.590	0.0	489.130	0.0	0.0
53	200.330	233.320	366.890	25.660	209.400	917.220	21.010
54	0.0	0.0	48.890	0.520	349.580	0.0	0.0
55	85.210	427.580	1670.170	1.040	86.030	232.150	11.190
56	8.230	3.910	1713.010	793.140	115.750	5.060	0.570
57	9845.629	485.180	340.530	455.250	7.000	908.990	174.490
58	51.580	2291.170	6374.777	62.700	22.710	155.610	1.260
59	2.990	8.790	80063.438	0.100	496.130	12.650	1.140
60	0.0	0.980	8.780	2986.980	0.0	0.630	0.340
61	0.0	0.0	134.000	0.0	899.850	0.0	0.0
62	94.190	23.430	612.360	144.270	74.830	2327.830	11.190
63	12.710	5.860	63.720	65.510	4.670	91.090	337.320
64	19.430	6.830	96.100	8.970	48.380	246.700	40.770
65	1020.370	814.160	6311.059	284.480	389.720	900.140	105.290
66	349.090	164.980	441.040	90.030	51.960	305.530	34.710
67	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	640.620	382.680	1722.360	128.830	102.210	313.750	37.570
69	1622.130	1140.220	18505.918	326.830	991.480	1386.580	213.770
70	596.520	490.060	1264.300	98.480	118.860	325.140	90.210
71	831.990	781.950	565.690	109.640	117.930	538.310	59.610
72	657.820	328.010	528.370	177.030	33.920	288.450	37.110
73	1988.410	1571.700	6151.227	619.240	353.310	1914.130	312.090
74	696.690	228.430	702.980	508.660	99.720	408.630	47.390
75	198.090	282.130	2927.880	31.300	17.890	170.790	15.300

Table B.6. Continued

Producing sector	Purchasing sector						
	57	58	59	60	61	62	63
76	15.690	5.860	31.310	10.640	2.330	22.140	2.170
77	164.460	82.000	215.310	34.740	23.490	116.390	41.000

Table B.6. Continued

Producing sector	Purchasing sector						
	64	65	66	67	68	69	70
1	0.0	30.030	0.0	0.0	0.0	0.0	0.0
2	276.040	82.380	2.960	1.470	54.280	169.010	57.530
3	23.830	17.130	0.0	0.0	0.0	10.450	3.940
4	14.010	0.0	434.680	5.850	955.340	1203.260	17.840
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	15.410	7.700	0.0	0.0	26665.738	0.0	0.0
8	0.0	271.140	0.0	0.0	42579.938	0.0	0.0
9	176.560	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	504.440	19405.816	4649.898	238.630	20684.066	9929.750	2951.590
13	0.0	3.400	0.500	1.470	2.320	20.660	10.890
14	395.140	1446.530	31.550	14.640	67.030	1409.110	606.810
15	23.830	37.730	7.390	4.390	15.000	205.850	142.780
16	2565.610	30.030	0.0	0.0	0.0	0.0	0.0
17	850.530	302.900	0.0	0.0	0.0	180.710	0.0
18	142.920	411.000	69.990	0.0	115.510	444.070	2.010
19	371.310	417.870	0.0	0.0	0.0	1028.520	443.180
20	5561.387	60.890	0.0	0.0	0.0	405.980	3.010
21	124.710	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	2331.600	622.020	118.770	27.820	301.530	13172.617	3220.320
25	3899.560	289.170	0.0	0.0	0.0	4212.648	0.0

Table B.6. Continued

Producing sector	Purchasing sector						
	64	65	66	67	68	69	70
26	151.340	1180.590	517.970	64.410	800.550	4616.387	12400.359
27	1052.310	652.950	3.940	1.470	1362.020	165.530	51.580
28	4141.969	0.0	0.0	0.0	0.0	0.0	0.0
29	67.260	133.840	0.0	0.0	0.0	1166.420	43.630
30	917.790	138.130	0.0	0.0	0.0	0.0	0.0
31	1028.490	22389.020	65.540	61.490	15827.527	17745.199	1559.580
32	7402.566	4042.790	38.940	27.820	570.680	5400.969	394.610
33	297.050	0.0	0.0	0.0	0.0	0.0	0.0
34	483.420	15.460	4.430	4.390	9.270	168.020	77.300
35	109.300	153.600	2.460	4.390	13.850	740.770	31.740
36	1031.290	139.870	0.980	0.0	45.070	88.610	11.890
37	5220.887	1845.540	0.980	0.0	61.230	57.500	8.960
38	9630.508	229.950	91.670	0.0	117.830	0.0	0.0
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	1509.100	252.270	0.0	0.0	0.0	0.0	0.0
42	2428.290	1418.240	0.500	0.0	63.550	701.690	10.890
43	14.010	896.560	0.0	0.0	1098.610	0.0	0.0
44	0.0	0.0	0.0	0.0	0.0	86.370	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	33.620	23.160	0.0	0.0	0.0	88.610	0.0
47	96.680	163.030	0.0	0.0	0.0	262.360	0.0
48	15.410	0.0	0.0	0.0	0.0	13.690	0.0
49	184.960	1302.430	0.0	0.0	296.900	22.900	6.950
50	316.670	291.730	0.0	0.0	0.0	585.450	0.0

Table B.6. Continued

Producing sector	Purchasing sector						
	64	65	66	67	68	69	70
51	0.0	4.300	17.730	1.470	79.710	155.320	307.340
52	50.440	49.790	0.0	0.0	0.0	983.470	0.0
53	732.830	566.270	0.0	0.0	293.420	0.0	0.0
54	0.0	5.130	0.500	0.0	1.160	95.580	15.830
55	242.410	157.900	73.920	10.250	877.950	255.390	73.360
56	151.340	146.730	2996.450	150.790	10.370	64.470	106.100
57	699.210	364.620	210.930	537.290	23.110	67.950	140.780
58	63.060	815.910	19.230	2.930	17.320	456.760	63.480
59	14.010	2751.530	6.910	4.390	91.240	803.000	79.310
60	0.0	4090.010	0.0	0.0	0.0	0.0	0.0
61	89.670	5487.656	53.720	27.820	48.550	135.660	122.940
62	176.560	286.530	0.980	1.470	69.290	48.290	22.780
63	37.840	74.620	34.010	136.150	142.100	493.600	368.810
64	9140.078	333.760	71.950	16.100	181.380	1116.880	740.640
65	4639.398	75584.750	473.120	651.480	5453.750	31717.340	3394.850
66	975.240	7525.348	2071.880	1800.730	2486.000	35191.199	17836.648
67	0.0	0.0	0.0	61.490	0.0	0.0	0.0
68	1333.950	4974.578	1021.640	857.910	131482.688	37732.379	6640.887
69	7587.527	15667.590	319.860	196.170	4908.500	34632.137	3889.530
70	2312.000	14968.316	1452.880	863.770	5997.840	34180.109	154290.500
71	3142.900	10481.988	3110.770	4236.828	6000.156	102871.625	24521.168
72	994.860	948.080	705.740	639.770	2886.880	10648.609	2980.390
73	9084.027	22963.887	4750.938	4438.859	8937.898	140132.313	59816.699
74	1220.450	4412.609	680.110	303.050	1479.850	28016.707	13663.559
75	406.350	13543.219	504.170	98.090	1593.050	32972.367	3173.680

Table B.6. Continued

Producing sector	Purchasing sector						
	64	65	66	67	68	69	70
76	32.230	233.350	46.330	15486.238	78.550	487.630	348.040
77	828.120	923.190	185.310	144.940	277.260	5462.949	5475.906

Table B.6. Continued

Producing sector	Purchasing sector						
	71	72	73	74	75	76	77
1	0.0	0.0	0.0	2309.500	0.0	245.330	885.240
2	1055.020	137.110	8.690	5279.957	1.340	1984.930	507.590
3	0.910	0.0	0.380	2908.260	0.0	0.570	59.450
4	5251.738	153.760	6.230	0.0	0.0	445.600	842.340
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	12.970	61.820	0.0	0.0	0.0	0.0	227.900
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	93200.188	2942.030	622.480	1645.800	484.020	1082.890	15629.449
13	2.560	2.370	40.250	0.0	0.340	1.710	12.150
14	123.540	420.070	69.350	142983.438	11.430	181.430	13651.906
15	29.420	17.430	15.880	0.0	2.360	15.980	112.270
16	0.0	669.720	0.0	0.0	0.0	0.0	101.330
17	0.0	120.470	16.810	0.0	0.0	46.220	22.060
18	19.910	3379.500	60.090	0.0	180.500	18.260	2306.680
19	0.0	1622.390	10.390	232.050	0.0	63.330	2166.840
20	0.910	251.240	48.180	0.0	0.0	0.570	156.390
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	254.930	1375.890	368.310	1579.910	111.930	53.060	1900.420
25	0.0	573.830	75.020	2838.640	0.0	0.0	703.610

Table B.6. Continued

Producing sector	Purchasing sector 71	72	73	74	75	76	77
26	486.480	758.490	1128.170	443.730	14.790	300.110	9718.977
27	533.090	973.280	390.610	165.220	8.070	114.680	3898.810
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	39.670	2866.720	252.280	1136.180	0.0	19.400	14944.527
30	0.0	90.350	36.650	0.0	350.580	0.0	117.780
31	3861.380	2573.480	746.260	96.530	608.730	157.470	4721.328
32	2001.140	2430.010	620.780	1424.880	1204.010	55.340	5697.898
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	18.100	1019.240	20.030	0.0	1.680	197.410	92.450
35	6.030	128.400	79.550	483.610	400.660	4.570	1042.660
36	2.560	618.990	66.140	370.360	577.800	1.140	148.630
37	2.560	49.150	33.640	0.0	0.0	0.0	97.970
38	0.0	55.490	0.0	108.610	0.0	0.0	0.0
39	0.0	0.0	17.010	0.0	0.0	0.0	0.0
40	112.380	0.0	0.0	0.0	0.0	0.0	0.0
41	0.0	416.100	234.510	464.150	1077.290	0.0	385.410
42	2.560	1337.060	360.760	41.780	690.740	7.980	586.860
43	0.0	369.350	166.480	0.0	150.250	0.0	0.0
44	207.410	0.0	325.790	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47	0.0	13.470	30.990	0.0	6.390	0.0	0.0
48	0.0	0.0	24.570	153.180	0.0	0.0	0.0
49	24.140	72.920	107.340	0.0	29.580	11.410	37.390
50	11.160	354.280	236.600	38.980	533.100	0.0	0.0

Table B.6. Continued

Producing sector	Purchasing sector						
	71	72	73	74	75	76	77
51	5.130	787.820	221.850	0.0	0.0	0.0	111.240
52	0.0	629.290	48.760	0.0	2859.100	44.500	137.600
53	0.0	369.350	377.000	0.0	38.320	0.0	0.0
54	2.560	1277.610	25.320	0.0	0.340	2.280	14.300
55	65.620	68.150	3.780	43.620	342.180	16.540	547.220
56	21.570	16.630	11.710	0.0	459.480	13.130	121.150
57	0.0	2575.850	372.270	0.0	0.0	0.0	265.390
58	81.160	61.820	22.490	0.0	212.770	5.710	39.630
59	34.540	108.580	28.720	0.0	19260.406	6.280	24.210
60	0.0	0.0	0.0	0.0	0.0	0.0	0.0
61	47.520	283.740	171.780	0.0	36.640	49.070	220.240
62	3.470	573.030	10.580	0.0	0.340	1.710	7127.098
63	83.870	1856.210	821.840	0.0	3.700	576.250	4115.770
64	184.940	4338.520	490.200	514.260	13.110	186.570	2896.900
65	2296.650	1963.190	2693.810	7052.039	1007.380	501.510	9028.637
66	2533.480	3507.110	2575.890	1386.850	507.880	472.410	8516.656
67	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	7794.566	5108.898	722.250	7161.547	504.190	840.990	19028.340
69	4404.129	5946.468	1452.830	27732.828	4909.129	1061.220	12862.477
70	28892.180	4039.720	1587.750	4777.777	959.650	1121.130	11463.008
71	101150.250	16908.648	5962.289	18915.250	3039.590	5045.340	54094.629
72	1708.190	7755.297	1454.330	5013.566	117.980	654.990	9298.418
73	21643.680	12996.539	10086.059	12292.066	1848.370	4251.137	38958.457
74	2702.730	1471.000	1633.670	0.0	231.930	1561.580	13114.590
75	2886.000	3268.560	1649.730	203.300	226.220	313.230	3130.320

Table B.6. Continued

Producing sector	Purchasing sector						
	71	72	73	74	75	76	77
76	57.020	30.920	320.880	3912.630	4.700	11291.688	1763.850
77	313.610	492.190	367.550	1543.730	50.760	210.530	14904.898

Table B.7. Type 1 and type 2 output and employment multipliers[a]

Industry number	Output multiplier ($ of output/ $ change in final demand)		Employment multiplier (jobs/$10,000 change in final demand)	
	Type I	Type II	Type I	Type II
1	2.719	3.480	.855	1.095
2	1.784	2.123	.508	.599
3	1.717	1.975	.509	.585
4	1.980	2.713	.9396	1.276
5	0	0	0	0
6	0	0	0	0
7	1.720	2.391	.5744	.8099
8	0	0	0	0
9	1.700	2.516	.6753	.9994
10	0	0	0	0
11	2.087	3.089	.9606	1.422
12	1.766	2.208	.7197	.8996
13	1.819	3.220	.6344	1.123
14	2.622	3.199	.6225	.7532
15	0	0	0	0
16	2.501	3.226	1.489	1.936
17	2.625	2.966	1.362	1.553
18	2.533	3.546	2.006	2.788
19	2.547	3.973	1.045	1.630
20	2.232	2.969	.7691	1.031
21	2.316	3.196	.8201	1.140
22	2.203	3.062	.927	1.289
23	2.078	3.075	.8526	1.270
24	2.190	2.957	.6650	.9044
25	2.268	2.971	.6559	.8592
26	1.930	2.644	.6833	.9225
27	2.034	2.644	.9407	1.195
28	2.185	2.644	1.044	1.305
29	2.056	2.591	.7044	.8805
30	2.281	2.783	.6505	.8001

[a]Source: (3, 59).

Table B.7. Continued

Industry number	Output multiplier ($ of output/ $ change in final demand)		Employment multiplier (jobs/$10,000 change in final demand)	
	Type I	Type II	Type I	Type II
31	2.267	2.652	.5277	.6174
32	2.017	2.562	.783	1.002
33	2.734	2.783	.8299	.9500
34	2.274	3.047	1.133	1.518
35	0	0	0	0
36	1.940	2.444	.6924	.9278
37	2.036	2.708	.6906	.9668
38	2.461	3.445	.6433	.9071
39	2.374	2.920	.6063	.7579
40	2.183	2.991	.7391	1.005
41	2.052	2.770	.7963	1.075
42	1.976	2.806	.6747	.9506
43	2.084	2.688	.5882	.7647
44	2.090	2.884	.7218	.9989
45	2.020	2.990	.5916	.8697
46	2.022	2.790	.6958	1.051
47	1.737	2.588	.6952	1.022
48	1.922	2.806	.6549	.9627
49	1.931	2.588	.6650	.8911
50	1.841	3.258	.7239	1.289
51	0	0	0	0
52	0	0	0	0
53	1.967	2.714	.6833	.9361
54	2.103	2.797	.6334	.8551
55	1.942	5.826	.7650	2.280
56	2.006	3.511	.7164	1.2537
57	1.918	2.724	.6704	.9520
58	2.030	2.944	.7013	1.01
59	2.379	2.150	.7105	.9805
60	2.039	2.895	.7241	1.043

Table B.7. Continued

Industry number	Output multiplier ($ of output/ $ change in final demand)		Employment multiplier (jobs/$10,000 change in final demand)	
	Type I	Type II	Type I	Type II
61	2.253	2.951	.8768	1.157
62	1.892	2.706	.7853	1.123
63	1.708	2.237	.4052	.5267
64	2.142	2.913	.8948	1.217
65	1.676	2.631	.8166	1.290
66	1.267	1.774	.7272	1.018
67	1.775	2.734	.8169	1.266
68	1.877	2.159	.4851	.5627
69	1.368	2.161	1.085	1.714
70	1.681	2.656	.8646	1.357
71	1.298	1.40	.2129	.2491
72	1.736	3.333	1.554	2.984
73	1.497	1.826	1.054	1.296
74	1.724	1.983	1.804	1.500
75	2.017	2.662	1.268	1.686
76	1.773	2.677	1.456	2.199
77	1.540	3.08	2.461	4.922