17.

An Input-Output Analysis of Structure[1]

THE EMPIRICAL ANALYSIS of previous chapters revolved mainly around time series data extending back to 1926. Projections in Chapter 18 are for 1980 and stem from trends and certain assumptions on variable and parameter magnitudes as these relate to agricultural structure and its change. Many of these projections rest on observations over the period 1950-60, since the structure of this period is considered, for many categories of inputs, to depart greatly from that of previous decades. By 1950, U.S. agriculture was heavily mechanized. The additions to stocks of productive assets through this source, as well as its effect on demand for operating and similar inputs, had shifted from the 1930's when widespread mechanization was only beginning to gain momentum. Similarly, biological innovations such as hybrid corn were generally adopted by 1950, but provided a different input demand framework as compared to earlier decades. Of course, changes in structure are not discrete, but tend to be continuous over time. Some categories of inputs projected in Chapter 18 consider this fact and relate to observations prior to 1950 where it is obvious that change has been gradual and highly continuous.

However, since many of the projections relate back to time series observations of the 1950-59 decade when a different and "fairly mature" structure is assumed to exist, we present an alternative interpretation of resource demand and agricultural structure for 1954, a period near the midpoint of the 1950-59 decade. These interpretations or estimates are based on an input-output model emphasizing regional and commodity sectors of agriculture. Because of time limitations and inadequate data for aggregation and stratification of time series data by these sectors, it was not possible to derive comparable regression models for individual commodities and regions. Hence, we select 1954 for this analysis since it is midpoint in the decade to which many projections in Chapter 18 relate. Also, census data were not available for computing a parallel input-output model for 1959.

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INPUT-OUTPUT ANALYSIS AND LIMITATIONS

An input-output model represents a particular set of assumptions about inter-sector resource structure and demand. The model itself imposes certain restrictions for the impact of economic growth on the outputs and inputs of the various sectors of the economy. An input-output model generally refers to a particular point in time and, as we have mentioned elsewhere in applications particularly to agriculture, serves more usefully for descriptive purposes than in defining changes in interrelationships among resource furnishing and using sectors over time. More particularly, it provides requirements coefficients, indicating output induced or required from the i-th sector or industry for a one-unit increase in output by the j-th sector. Because of the particular mathematical characteristics of input-output models, certain constraints are forced on the intersectoral relationships expressing interdependence in supply and demand among commodities ranging from primary inputs to consumer goods and services. Mainly, these characteristics specify that an increment of output in one sector, or in final demand, reflects demand back to input supplying sectors in the manner of a fixed mix. Substitution is not allowed between inputs drawn from different sectors in a "pure" input-output model, although substitution can be considered to take place within the aggregation of inputs used to specify or define a sector or industry.

In contrast to most of the behavioral equations and the stability conditions outlined in Chapter 3, an input-output model necessarily assumes constant marginal productivities and total production elasticities equal to unity. While input-output models computed for data at different points in time can reflect economic and technical changes, one referring to a particular period or point in time does not do so. Other limitations of input-output models in general, and those applied to agriculture particularly, could be mentioned. However, since these have been discussed elsewhere, they need not be detailed here.[2] The

[2] For discussion of these limitations, see the following: Heady, Earl O., and Carter, Harold O. Input-output models as techniques of analysis for interregional competition. Journal of Farm Economics. Vol. 41. Dec. 1959; Heady, Earl O., and Schnittker, John A. Application of input-output models to agriculture. Journal of Farm Economics. Vol. 39. Dec. 1958; National Bureau of Economic Research. Input-Output Analysis, An Appraisal. Princeton University Press. Princeton, 1955; Carter, Harold O., and Heady, Earl O. An input-output analysis emphasizing regional and commodity sectors of agriculture. Iowa Agr. Exp. Sta. Bul. No. 469. 1959; Schnittker, John A., and Heady, Earl O. Application of input-output analysis to a regional model emphasizing agriculture. Iowa Agr. Exp. Sta. Bul. No. 454. 1959; Leontief, W., et al. Studies in the Structure of the American Economy, New York, Oxford Press, 1953; Barna, Tibor (Ed.). The Structural Interdependence of the Economy. John Wiley & Sons, Inc. New York, 1954; Morgenstern, Oskar (Ed.). Economic Activity Analysis. John Wiley & Sons, Inc. New York, N. Y. 1954; Morgenstern, Oskar. On the Accuracy of Economic Observation. Princeton University Press. 1950; Moses, L. N. Interregional input-output analysis. American Economic Review. Vol. 45. May, 1951; Peterson, G. A., and Heady, Earl O. Application of input-output analysis to a simple model emphasizing agriculture. Iowa Agr. Exp. Sta. Res. Bul. No. 427. 1955; Cameron, Burgess. The production function in Leontief models. Review Economic Studies, Vol. 20. Aug. 1952; Hurwicz, Leonid. Input-output analysis and economic structure. American Economic Review, Vol. 45. May, 1951.

empirical model presented in this chapter does, within the recognized limitations of such models, illustrate the interdependence in certain supply-demand relationships of different regional and commodity sectors of agriculture. It shows, in the restricted sense mentioned above and within the limitations of the model specification used, the "demand" or requirements for resources produced by these individual sectors as output of agricultural sectors or the final bill of goods is increased. Or, conversely, it shows the "demand" or requirements for inputs placed on other sectors as a particular commodity and regional sector of agriculture changes its output. Measured at different points over time, we would expect the technical and interdependency coefficients reflecting these parameters to change in the manner suggested by the projections of Chapter 18.

MODEL

The mathematical nature of the input-output model is summarized below. The empirical quantities presented later are based on an open model of the type in (17.1). In application of input-output models, the total economy is divided into a relevant number of sectors or subindustries, with each (a) requiring or purchasing resource inputs from other sectors and (b) producing intermediate resources or finished goods which are required by other sectors. If all sectors serve as both producers and consumers, the system is a "closed" model; here all sectors are assumed to be interdependent, and inputs and outputs are functionally related. In a closed model, households represent an industry with labor services as the output and consumption goods such as food, shelter, medicine, recreation, etc. as the inputs. Under the necessary input-output assumptions of constant technical ratios, this procedure implies that a man-hour of labor requires a fixed mix of consumption goods. For models where some sectors are related to other sectors but are not functionally dependent upon them, the system is open. Final demand (exports, government, service and household consumer goods) is autonomously determined by factors outside the system. Labor and managerial services then are considered as inputs but not as products functionally related to the household sector.

The open model used can be illustrated as:

$$
\begin{aligned}
X_1 - x_{11} - x_{12} - \dots - x_{1n} &= Y_1 \\
X_2 - x_{21} - x_{22} - \dots - x_{2n} &= Y_2 \\
\vdots \qquad\qquad & \quad \vdots \\
X_n - x_{n1} - x_{n2} - \dots - x_{nn} &= Y_n
\end{aligned}
\qquad (17.1)
$$

where $X_1, X_2, \dots, X_n$ represent gross output of the various economic sectors; x_{ij} $(i, j=1, \dots, n)$ represents actual flows of resource inputs and services from sector i to sector j; and Y_i (i=1, . . . , n) are the flows to final demand sectors (household consumption, investment, government, foreign trade, inventory).

The constraining assumptions made in input-output analysis are reflected in the relations between purchases or input demand of an endogenous sector (i.e., x_{ij}) and the level of output of this sector (i.e., X_j). Assuming a linear relationship (an assumption not too relevant for agriculture) the equation below follows:

$$x_{ij} = a_{ij}X_j + c_{ij} \tag{17.2}$$

where a_{ij} and c_{ij} are parameters.

In the empirical work following, the assumption is made that $c_{ij} = 0$. The a_{ij} (the input-output, technological or requirements coefficient) is derived as the ratio between x_{ij} and X_j:

$$a_{ij} = x_{ij}X_j^{-1}. \tag{17.3}$$

The input-output coefficient represents the direct requirement of sector j upon sector i per unit (dollar) of output of sector j. In this sense, it serves somewhat as a "technological reflection of demand" by sector j, per unit of its output. The x_{ij} similarly reflect the "total demand" of sector j for input from sector i in this same "technological manner." Thus, if output of an agricultural sector (j) requires \$2 million of materials from the chemical sector (i), and if total output of the agricultural sector is \$200 million, the related technical coefficient is 2/200 = .01. The agricultural sector has direct requirement or "de-mand" for .01 dollar of inputs drawn from the chemical sector for each dollar of farm sector output, the total chemical "input demand" being \$2 million.

Substituting (17.2) into (17.1) yields:

$$\begin{aligned} X_1 - a_{11}X_1 - a_{12}X_2 - \dots - a_{1n}X_n &= Y_1 \\ X_2 - a_{21}X_1 - a_{22}X_2 - \dots - a_{2n}X_n &= Y_2 \\ \vdots \qquad\qquad\qquad\qquad &\quad \vdots \\ X_n - a_{n1}X_1 - a_{n2}X_2 - \dots - a_{nn}X_n &= Y_n \end{aligned} \tag{17.4}$$

or in matrix notation:

$$X - AX = Y \tag{17.5}$$

where X is the vector of sector outputs, A is the matrix of input-output coefficients and Y is the vector of final demand quantities. Hence, with specified final demands $Y_1, Y_2, \dots, Y_n$ and constant input-output or resource requirement coefficients, equations (17.4) can be solved for the outputs $X_1, X_2, \ldots, X_n$; the resulting equations are given in (17.6). The A_{ij}'s (commonly referred to as interdependence coefficients) are elements of the inverse matrix $(I - A)^{-1}$.

$$(17.6)\qquad \begin{aligned} X_1 &= A_{11} Y_1 + A_{12} Y_2 + \ldots + A_{1n} Y_n \\ X_2 &= A_{21} Y_1 + A_{22} Y_2 + \ldots + A_{2n} Y_n \\ &\vdots \\ X_n &= A_{n1} Y_1 + A_{n2} Y_2 + \ldots + A_{nn} Y_n \end{aligned}$$

or in matrix notation

$$(17.7)\qquad X = (I - A)^{-1} Y .$$

Equations (17.1) and (17.4) represent the descriptive component while equation (17.6) represents the analytical aspects of an input-output model. However, from the standpoint of direct resource "demand" and inter-sector structure of agriculture, the elements of matrix A are of as much interest as those of $(I - A)^{-1}$. Using the definitional equation:

$$(17.8)\qquad (I - A)^{-1} = B$$

to simplify later presentation, we have interest in A to indicate all direct demand of sector j for inputs drawn from (representing the outputs) of other sectors, and B to indicate the sum total of direct and indirect demand upon a particular sector for a one-unit change delivered to final (consumer or exogenous) demand by a particular sector.

The interdependence coefficients (A_{ij}'s) represent the direct and indirect requirement or resource input demands upon sector i for a one-unit change in the amount of goods delivered to final demand by industry j. This analytical feature makes the tool pertinent to interregional relationships since the indirect as well as the direct effect of change are reflected among regions.

REGIONAL AND COMMODITY COMPONENTS OF MODEL

The empirical model used designates 10 agricultural regions and nine commodities within each of these as separate sectors. Hence, there are 90 possible agricultural sectors. The 10 regions or groupings of states are the same as those used in Chapter 7 for application of regression models in estimating fertilizer demand from time series observations. For purposes of identification in the tables which follow, the agricultural regions for aggregation are shown in Figure 17.1.

Two types of aggregation are feasible for agricultural commodity

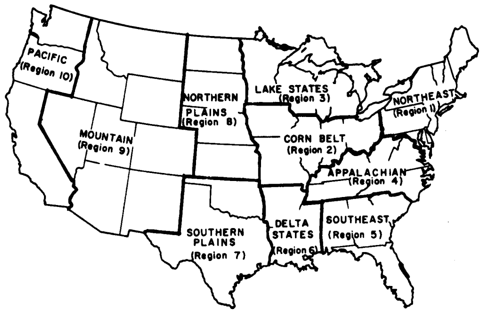

Figure 17.1. Regional sectors in input-output model.

sectors: (a) classification by products and (b) classification by enterprises. The product basis is used to conform with available data. Agricultural statistics are published, with few exceptions, on a commodity basis. Both classifications have disadvantages: for an enterprise classification, output and input composition varies to an extent that coefficients are not uniquely defined. For example, dairy farmers produce both cash and feed crops, while cash crop farmers raise some livestock. The proportions within each farm vary over time depending on relevant price relationships and individual preferences. In product groupings, large numbers of agricultural commodities are joint products. The distribution of resource inputs among commodity groups is difficult and sometimes arbitrary, since there is no given basis for allocating inputs such as machinery, building depreciation, petroleum products and similar items among individual commodities. For convenience, the commodity or product grouping is used in this study. The k-th regional sector (Figure 17.1) then has the following commodity sectors:

k.1 Livestock and livestock products — meat animals, dairy products, poultry and eggs and miscellaneous livestock products.

k.2 Feed grains — corn, oats, barley and grain sorghum.

k.3 Food grains — wheat, rice, rye and buckwheat.

k.4 Forage crops — hay, pasture, and grass and legume seeds.

k.5 Vegetables and fruit — vegetables, fruits and nuts.

k.6 Cotton — cotton lint and cottonseed.

k.7 Tobacco — unmanufactured tobacco.

k.8 Oil crops — soybeans, peanuts, flaxseed and tung nuts.

k.9 Miscellaneous agriculture — sugar crops, miscellaneous crops, forest, nursery and greenhouse products, horse and mule services, and other agricultural services.

Commodity groups are numbered 1 through 9, while k designates regions (k = 0, 1, 2, ... 10). Zero denotes a national group and 1, 2, ... 10 denote regional groups. For example, 1.1 denotes livestock (product 1) in the Northeast (region 1); livestock in the United States is denoted by 0.1. Although there are 90 possible sectors in the agricultural section of the model, cotton production is negligible in regions 1, 3 and 8, and tobacco is not produced in regions 6, 7, 8, 9 and 10. Hence, the agricultural economy is reduced to 82 sectors after deleting these 8 sectors.

Industry or nonfarm sectors have been aggregated on a national basis only. The major groupings of these sectors are: sectors 0.10 through 0.17 which include industries processing agricultural products; sectors 0.18 through 0.21 which are industries furnishing inputs directly to agriculture; and sector 0.22 which is an aggregation of all industries not mentioned above and furnishes inputs only indirectly to agriculture. It is obvious that the model gives greatest detail for resource requirements of one agricultural region on another agricultural sector and does not reflect requirements or "demand" for labor, either within or among agricultural sectors. The aggregations of sectors 0.10 through 0.22 can be summarized as follows:[3]

0.10 Meat and poultry processing — meat packing and prepared meats, products from poultry dressing plants and poultry products involving minor processing.

0.11 Dairy products — creamery butter, natural cheese, concentrated milk, ice cream and ices, special dairy products and fluid milk.

0.12 Grain processing — flour and meal, cereal preparations, rice cleaning and blended and prepared flours.

0.13 Prepared feeds — livestock feeds from mixers and manufacturers.

0.14 Miscellaneous food processing — miscellaneous food preparations, beverages, bakery and related products and confectionery and related products.

0.15 Vegetable and fruit processing — canned and frozen fruits and vegetables, and fruits and vegetables with minor processing.

0.16 Tobacco manufacturing — cigarettes, cigars, chewing and smoking tobacco and tobacco stemming and redrying.

0.17 Textile products — woolen and worsted manufacturing, cotton and rayon textiles, carpets, rugs and miscellaneous textile goods.

0.18 Fertilizers — fertilizer and fertilizer mixing.

0.19 Chemical products — chemicals, paints and varnishes, soap and related products, drugs and medicines and vegetables and animal oils.

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[3]Added detail on these and other points can be found in Carter and Heady, Iowa Agr. Exp. Sta. Bul. No. 469. 1959. op. cit.

0.20 Machinery and related services — tractors, farm machinery, motor vehicles and related services.

0.21 Petroleum products — gasoline, oil and grease.

0.22 All other industries — This sector includes all other products not listed above. The major products purchased by agriculture are wholesale and retail trade, transportation, veterinary services and miscellaneous supplies.

The over-all model outlined above and emphasizing regional and commodity sectors of agriculture, since previous chapters better relate agriculture to specific nonfarm sectors in terms of behavioral variables related to resource demand, gives rise to a transaction matrix with a possible order of 103. Matrices of resource requirements and interdependence coefficients of like order are possible. Because of lack of space not all data generated from the 103-order model will be presented. If we consider the flow or transactions matrix to be T and referring back to A, the matrix of input-output or per unit resource requirements, then the submatrices T^s_{gk} and A^s_{gk} can be formed where the rows in the submatrices define the requirements of the several commodity sectors in the k-th region for inputs from the commodity sectors in the g-th region. (g, k = 1, 2, ... 10.) Except for g = k and for "demands" of regional agricultural sectors for resources from industrial sectors, the greatest number of these submatrices are filled with zero elements. Hence, we summarize the total intersector flow of resources and their services in the manner of Table 17.1. In the limited sense of input-output analysis, the data show the total flow of resources from the input-supplying sectors to the commodity and regional sectors of agriculture. In contrast to earlier notation, however, the rows represent the commodity and regional "demanding" sectors (j) while the columns represent the regional "supplying" sectors (i) between which flows of resources take place. (Effectively, except for aggregation of commodity supplying sectors within regions, and the deletions mentioned below, Table 17.1 represents the transform of matrix A. The commodity "supplying" sectors of agriculture have been kept separate.) The elements which define flows of inputs from agricultural sectors to processing sectors are not shown, as also is true for all elements connecting columns of industrial sectors with agricultural supplying sectors.

The data of Table 17.1 show the estimated net flow of inputs from other regional sectors, as well as industrial sectors, to a particular commodity sector within a region. Hence, for the livestock sector (row 1.1) in the Northeast, a total of $692.4 million in inputs (largely feed) flows to this sector from other sectors within the region. The Northeast (row 1.1) has $12 million in inputs drawn from the Corn Belt. Similarly, the livestock sector in each "requiring" region is estimated to have the greatest (of all sectors within a "demanding" region) requirement for inputs of "supplying" regions (usually feed and livestock

Table 17.1. Inputs Drawn by Commodity Sectors (Rows) From Various Regions and Industries (Columns); Million Dollars, 1954

Sector (j)	1.N.E.	2.C.B.	3.Lake	4.Appal.	5.S.E.	6.Delta	7.S.P.	8.N.P.	9.Moun.	10.Pac.	0.18	0.19	0.20	0.21	0.22
1.1	692.4	12.0	3.4	6.1	--	--	--	12.9	--	--	--	8.4	53.2	12.0	269.5
1.2	24.0	--	--	--	--	--	--	--	--	--	24.7	.4	75.5	11.2	38.3
1.3	11.0	--	--	--	--	--	--	--	--	--	7.3	.3	17.2	3.7	13.5
1.4	48.7	--	--	--	--	--	--	--	--	--	15.4	.5	69.9	9.9	33.6
1.5	32.8	--	--	--	--	--	--	--	--	--	29.2	16.8	69.6	12.7	57.0
1.7	1.1	--	--	--	--	--	--	--	--	--	2.4	.3	6.4	1.0	5.5
1.8	1.6	--	--	--	--	--	--	--	--	--	1.6	--	2.0	.6	2.4
1.9	39.6	--	--	--	--	--	--	--	--	--	1.0	.7	21.6	5.6	19.1
2.1	--	2688.4	--	2.1	--	--	48.3	181.3	45.0	--	--	16.0	92.6	20.9	422.4
2.2	--	82.5	--	--	--	--	--	--	--	--	138.9	1.7	422.2	70.7	688.0
2.3	--	34.4	--	--	--	--	--	--	--	--	29.5	.6	42.2	8.8	113.6
2.4	--	80.5	--	--	--	--	--	--	--	--	16.1	1.3	84.2	13.0	159.0
2.5	--	10.4	--	--	--	--	--	--	--	--	4.2	4.1	15.4	5.4	19.9
2.6	--	5.8	--	--	--	--	--	--	--	--	2.5	.2	6.2	2.3	11.6
2.7	--	.1	--	--	--	--	--	--	--	--	.8	--	.7	.2	1.5
2.8	--	41.6	--	--	--	--	--	--	--	--	5.6	.1	78.8	14.0	152.4
2.9	--	36.3	--	--	--	--	--	--	--	--	.8	.6	9.0	3.6	14.2
3.1	--	.7	1122.0	--	--	--	--	19.8	11.0	--	--	7.4	55.1	12.6	196.0
3.2	--	--	45.5	--	--	--	--	--	--	--	37.5	1.5	203.6	31.7	174.4
3.3	--	--	10.9	--	--	--	--	--	--	--	5.6	.3	15.9	3.4	21.7
3.4	--	--	51.2	--	--	--	--	--	--	--	5.7	.4	68.2	9.7	64.5
3.5	--	--	12.0	--	--	--	--	--	--	--	7.6	5.9	30.3	6.6	29.9
3.8	--	--	11.8	--	--	--	--	--	--	--	1.3	--	28.9	4.9	26.4
3.9	--	--	20.5	--	--	--	--	--	--	--	1.1	.3	19.1	4.7	14.1
4.1	--	26.9	--	583.0	--	--	10.7	--	--	--	--	5.4	40.0	9.4	131.7
4.2	--	--	--	56.1	--	--	--	--	--	--	50.8	.5	74.1	13.9	92.5
4.3	--	--	--	10.9	--	--	--	--	--	--	5.2	.4	9.4	2.3	15.7
4.4	--	--	--	56.7	--	--	--	--	--	--	18.2	.4	41.6	7.6	49.4
4.5	--	--	--	16.7	--	--	--	--	--	--	12.0	4.8	19.3	4.8	20.7
4.6	--	--	--	22.2	--	--	--	--	--	--	9.8	2.0	20.0	4.5	23.9
4.7	--	--	--	8.9	--	--	--	--	--	--	22.9	4.3	47.1	10.3	63.9
4.8	--	--	--	14.3	--	--	--	--	--	--	3.2	--	16.1	3.5	16.7
4.9	--	--	--	94.9	--	--	--	--	--	--	.7	2.7	13.3	3.4	11.3
5.1	--	--	--	--	333.0	--	5.8	--	--	--	--	4.5	18.7	4.6	94.7
5.2	--	--	--	--	43.8	--	--	--	--	--	43.1	.4	48.5	10.5	56.9
5.3	--	--	--	--	2.3	--	--	--	--	--	1.2	.1	1.4	.6	2.6
5.4	--	--	--	--	17.5	--	--	--	--	--	20.0	.2	4.8	1.0	15.1
5.5	--	--	--	--	35.3	--	--	--	--	--	36.8	9.0	42.0	9.9	50.2
5.6	--	--	--	--	42.8	--	--	--	--	--	23.4	5.6	30.9	7.2	44.0
5.7	--	--	--	--	1.6	--	--	--	--	--	4.2	1.4	6.5	1.5	11.4

5.8	--	--	--	--	18.1	--	--	--	--	--	4.2	--	14.0	3.2	12.4
5.9	--	--	--	--	63.4	--	--	--	--	--	.9	2.4	15.1	3.7	13.7
6.1	--	49.9	--	--	--	142.2	--	--	--	--	--	3.1	11.0	3.0	62.5
6.2	--	--	--	--	--	20.1	--	--	--	--	13.9	.4	25.4	6.8	33.8
6.3	--	--	--	--	--	11.2	--	--	--	--	4.6	.4	15.9	4.1	19.3
6.4	--	--	--	--	--	17.1	--	--	--	--	4.1	.2	8.5	2.3	11.9
6.5	--	--	--	--	--	5.8	--	--	--	--	3.1	1.1	4.6	1.9	8.1
6.6	--	--	--	--	--	81.5	--	--	--	--	28.6	12.2	63.6	16.6	85.6
6.8	--	--	--	--	--	11.1	--	--	--	--	.3	--	9.2	2.7	12.9
6.9	--	--	--	--	--	45.6	--	--	--	--	1.7	1.2	11.5	3.2	11.7
7.1	--	8.7	--	--	--	--	347.0	27.6	65.7	--	--	4.0	22.0	5.6	130.8
7.2	--	--	--	--	--	--	26.7	--	--	--	7.4	.5	87.5	17.4	79.1
7.3	--	--	--	--	--	--	41.1	--	--	--	4.9	.7	51.8	11.0	70.2
7.4	--	--	--	--	--	--	27.9	--	--	--	6.7	.3	19.1	3.7	18.9
7.5	--	--	--	--	--	--	6.4	--	--	--	2.5	.8	13.6	4.0	13.8
7.6	--	--	--	--	--	--	7.1	--	--	--	7.3	5.1	87.6	17.5	99.8
7.8	--	--	--	--	--	--	4.8	--	--	--	.9	--	5.3	2.0	3.5
7.9	--	--	--	--	--	--	17.2	--	--	--	1.1	1.4	4.9	1.7	8.9
8.1	--	--	--	--	--	--	24.8	1030.1	119.3	.5	--	5.4	33.2	8.1	137.5
8.2	--	--	--	--	--	--	--	58.3	--	--	16.6	1.4	215.6	36.2	237.2
8.3	--	--	--	--	--	--	--	103.8	--	--	8.3	2.1	116.4	21.3	195.9
8.4	--	--	--	--	--	--	--	91.3	--	--	3.0	.7	75.0	11.7	103.4
8.5	--	--	--	--	--	--	--	2.8	--	--	.5	.5	1.1	2.1	5.0
8.8	--	--	--	--	--	--	--	10.8	--	--	.2	.1	21.0	4.1	35.2
8.9	--	--	--	--	--	--	--	19.8	--	--	.7	.3	6.7	3.0	9.4
9.1	--	--	--	--	--	--	--	3.7	592.1	--	--	2.1	17.0	4.3	97.0
9.2	--	--	--	--	--	--	--	--	19.7	--	3.7	.9	44.6	8.1	47.7
9.3	--	--	--	--	--	--	--	--	39.8	--	1.6	2.0	47.8	9.6	82.7
9.4	--	--	--	--	--	--	--	--	46.1	--	3.9	1.6	70.2	12.2	57.7
9.5	--	--	--	--	--	--	--	--	13.4	--	3.1	2.1	22.5	5.2	23.9
9.6	--	--	--	--	--	--	--	--	19.3	--	4.5	2.9	12.7	3.0	20.6
9.8	--	--	--	--	--	--	--	--	.3	--	--	--	.5	.4	1.3
9.9	--	--	--	--	--	--	--	--	23.7	--	3.8	.8	20.4	4.4	17.0
10.1	--	--	--	--	--	--	30.8	27.7	80.1	464.8	--	3.4	17.9	4.4	149.7
10.2	--	--	--	--	--	--	--	--	--	15.2	7.3	2.3	37.9	6.6	76.5
10.3	--	--	--	--	--	--	--	--	--	20.6	7.5	2.3	23.5	4.7	71.2
10.4	--	--	--	--	--	--	--	--	--	22.3	8.7	2.4	38.4	6.1	58.5
10.5	--	--	--	--	--	--	--	--	--	65.0	20.8	19.0	123.3	22.3	131.1
10.6	--	--	--	--	--	--	--	--	--	24.5	7.9	3.1	15.1	3.2	30.5
10.8	--	--	--	--	--	--	--	--	--	.2	.4	--	.2	.4	1.2
10.9	--	--	--	--	--	--	--	--	--	14.5	5.8	3.1	22.0	4.7	25.5

for breeding and feeding purposes). Some seed inputs also flow among regions but the quantities were either too small to be presented, were impossible to estimate or were included with feed grains. The major intersector flows of inputs within agriculture are those among regions within a particular sector.

Aside from livestock, the major agricultural sectors drawing inputs from other sectors within the same region are feed grains, food grains, forage crops and cotton. Aside from livestock, and its heavier draw on inputs from other sectors within the same region and from other regions, Table 17.1 suggests the heavy dependence of agriculture on inputs from nonfarm sectors in an economy at a high stage of economic growth. The magnitude of farm inputs drawn from the industrial sectors (columns 0.18 through 0.22) completely overshadows the interregional and intraregional flow of inputs among sectors — except for feed and feeding stock for the livestock sectors. Development of policy which extends the demand for products of one region has, aside from livestock products, no important "spill over" to other regions in the sense of requiring large resource inputs drawn from farms of "outside" regions. The absolute "spill over" is much greater to the industrial sectors which furnish capital inputs to agriculture, in comparison with other sectors in the same region.

INPUT REQUIREMENT COEFFICIENTS

The number of possible technical coefficients in matrix A is 10,609; the number for the agricultural sectors on each other (the agricultural section of A) is 6,724. Hence, rather than present all of these, we present only aggregate input-output or requirements coefficients for the regional agricultural sectors. These are formed by adding the several commodity flows (the individual commodity sectors) from the g-th region to the k-th region and dividing them by the sum of commodity outputs in the k-th region. The result is a requirement or technical coefficient which shows the composite resource input flowing from the g-th region to produce a unit of output (one dollar) in the k-th region. The resource requirements of the k-th agricultural sector for inputs from two aggregate industrial sectors is repeated for comparison purposes. For identification, industrial sector I includes prepared feed, fertilizers, chemical products, machinery and related products and petroleum products. Industrial sector II includes all other resource services used by agriculture including "pure durables," operating expense items and transportation service. For purposes of clarity, and with columns added for the three aggregate industrial sectors, the matrix corresponding to Table 17.2 can be indicated as $\overline{A}$ to distinguish it from the larger and more detailed input-output matrix A from which Table 17.1 is drawn. Hence, the inverse of $\overline{A}$ is $\overline{B}$.

The elements in Table 17.1, showing estimates of the direct resource requirements of (a) the k-th region on (b) the g-th region and

Table 17.2. Matrix $\overline{A}$: Requirements Coefficients for the k-th Agricultural Region on the g-th Region and on Aggregates of Industrial Sectors, 1954*

Agricultural Regions (g) and Industrial Sectors	Agricultural Region (k)									
	1 North-east	2 Corn Belt	3 Lake States	4 Appal. States	5 South-east	6 Delta States	7 S. Plains	8 N. Plains	9 Moun. States	10 Pacific States
1	.22612	--	--	--	--	--	--	--	--	--
2	.00319	.29053	.00018	.00725	--	.02396	.00276	--	--	--
3	.00090	.00033	.30210	--	--	--	--	--	--	--
4	.00162	.00021	--	.23295	--	--	--	--	--	--
5	--	--	--	--	.20487	--	--	--	--	--
6	--	--	--	--	--	.16074	--	--	--	--
7	--	.00471	--	.00287	.00213	--	.17270	.00579	--	.00765
8	.00342	.01768	.00470	--	--	--	.00878	.30698	.00141	.00688
9	--	.00439	.00261	--	--	--	.02092	.02782	.28990	.01986
10	--	--	--	--	--	--	--	.00012	--	.15559
I†	.30137	.15573	.17937	.19690	.20392	.18759	.19868	.16707	.15950	.17423
II‡	.11664	.15432	.12506	.11483	.11053	.11815	.13538	.16874	.13370	.13502

*Elements in matrix show direct purchases from the region and nonfarm sector indicated at the left by the agricultural region indicated at the top.

†Includes sectors 0.13, 0.18, 0.19, 0.20 and 0.21 explained in the text.

‡Includes sector 0.22 explained in the text.

the two aggregate industrial sectors for 1954, indicate the magnitude of inputs which are drawn from (g) to produce a unit (dollar) of product in (k). The large direct resource requirements are for one region on itself (g = k). Even then, the requirements of agriculture on at least one of the two industrial sectors is greater than the requirements of the agricultural region on itself for the Northeast, Delta, Southern Plains and Pacific regions. When the requirements of one agricultural region on all other agricultural regions are summed, they are smaller than the sum of requirements by each agricultural region on the two aggregate industrial sectors — as expected from the discussion in Chapter 2. Even in the Corn Belt, with large "demand" for livestock and feed inputs from agricultural sectors, the sum of these requirements is only .3178, as compared to direct requirements of .3100 for the Corn Belt on aggregate industrial sectors I and II. In the Northern Plains where crop production rests less on chemicals such as fertilizer, and livestock production largely is from forage within the region, the sum of direct requirements against agricultural regions is .3407 of farm inputs per $1 of product produced while the corresponding direct input requirement on the two industrial sectors is .3358. The two figures are nearly equal for the Lake States and the Mountain States. The corresponding requirements of an agricultural region on (a) all agricultural regions and (b) the aggregate on industrial sectors are, respectively, .2353 and .4180 for the Northeast; .2052 and .3341 for the Southern Plains; .2060 and .3144 for the Southeast; .1910 and .3092 for the Pacific; and .1847 and .3057 for the Delta States.

TOTAL AND INDIRECT REQUIREMENTS

The requirement or technical coefficients serve only as estimates to indicate the direct requirements on the g-th farm region or industrial sector as output of the k-th region is increased. An indirect or circular "demand" for output of a particular sector also arises as output of another sector or region increases. The total of direct (Table 17.2) and indirect effects, representing the sum of "demand" for the product of a sector as output of another sector increases, can be illustrated by use of a simple two-sector model where Y_1 and Y_2 are the quantities delivered to final or consumer demand by sectors 1 and 2, X_1 and X_2 are the outputs of these two sectors and a_{ij} is the technical coefficient explained above. In addition to the direct output drawn from sector 1 as Y_1 is increased, sector 1 also needs to produce output to serve as inputs for both sectors 1 and 2, to an extent that X_1 requires some of X_2 as an input and X_2 requires some of X_1. Similarly, sector 2 must not only produce a quantity to be represented in Y_2, but also to serve as input in X_2 and X_1. Hence, sector 2 must produce, in addition to Y_2, an indirect amount equal to $a_{21} Y_1 + a_{22} Y_2$ for these "circular purposes." These additions, the indirect additions explained above, are considered to be first-round requirements or effects. Total circular or indirect requirements are derived as the sum of the second-round, third-round, fourth-round, etc., requirements. Second-round requirements for X_1 and X_2 are additional gross output generated from first-round requirements. Algebraically, second-round requirements for X_1 and X_2 are given in equations (17.9) and (17.10) respectively.

$$X_1^{(2)} = a_{11} X_1^{(1)} + a_{12} X_2^{(1)} = a_{11}(a_{11} Y_1 + a_{12} Y_2) + a_{12}(a_{21} Y_1 + a_{22} Y_2) \tag{17.9}$$

$$X_2^{(2)} = a_{21} X_1^{(1)} + a_{22} X_2^{(1)} = a_{21}(a_{11} Y_1 + a_{12} Y_2) + a_{22}(a_{21} Y_1 + a_{22} Y_2) \tag{17.10}$$

where the exponent in parentheses denotes the "round" of input requirements.

The third-round requirements (i.e., the additional gross output generated from second-round requirements) are:

$$X_1^{(3)} = a_{11} X_1^{(2)} = a_{12} X_2^{(2)} = a_{11}\Big[(a_{11} Y_1 + a_{12} Y_2) + a_{12}(a_{21} Y_1 + a_{22} Y_2)\Big] + a_{12}\Big[a_{21}(a_{11} Y_1 + a_{12} Y_2) + a_{22}(a_{21} Y_1 + a_{22} Y_2)\Big] \tag{17.11}$$

$$(17.12)\quad X_2^{(3)} = a_{21}X_1^{(2)} + a_{22}X_2^{(2)} = a_{21}\Big[a_{11}(a_{11}Y_1 + a_{12}Y_2) + a_{12}(a_{21}Y_1 + a_{22}Y_2)\Big] + a_{22}\Big[a_{21}(a_{11}Y_1 + a_{12}Y_2) + a_{22}(a_{21}Y_1 + a_{22}Y_2)\Big]$$

Continuing with this procedure, the r-th round is derived from the r-1 round as follows:

$$(17.13)\quad X_1^{(r)} = a_{11}X_1^{(r-1)} + a_{12}X_2^{(r-1)}$$

$$(17.14)\quad X_2^{(r)} = a_{21}X_1^{(r-1)} + a_{22}X_2^{(r-1)}$$

Summing rounds 1 to infinity and factoring out Y yields the final mangitudes (17.15) and (17.16),

$$(17.15)\quad X_1^r = (1 + a_{11} + a^2_{11} + a_{12}a_{21} + a^3_{11} + 2a_{11}a_{12}a_{21} + a_{12}a_{22}a_{21} + \ldots)\,Y_1 + (a_{12} + a_{11}a_{12} + a_{12}a_{22} + a^2_{11}a_{12} + a_{11}a_{12}a_{22} + a^2_{12}a_{21} + a^2_{22}a_{12} + \ldots)\,Y_2 = A_{11}Y_1 + A_{12}Y_2$$

$$(17.16)\quad X_2^r = (a_{21} + a_{21}a_{11} + a_{22}a_{21} + a_{21}a^2_{11} + a^2_{21}a_{12} + a_{22}a_{21}a_{11} + a^2_{22}a_{21})\,Y_1 + (1 + a_{22} + a_{21}a_{12} + a^2_{22} + a_{21}a_{11}a_{12} + 2a_{21}a_{12}a_{22} + a^3_{22} + \ldots)\,Y_2 = A_{21}Y_1 + A_{22}Y_2$$

of the X_i, including the proportions represented both in the final or consumer demand, Y_i, and as inputs, x_{ij}, for the X_j. We are interested especially in the latter as part of the resource "demand" structure of agriculture. Hence, the matrix of relevant interdependency coefficients $\overline{B}$ to correspond with $\overline{A}$ for Table 17.2 is (except for two columns) provided in Table 17.3. With the direct requirements shown in Table 17.2, the sums of direct and circular requirements are shown in Table 17.3 and include the various "stages of indirect" requirements illustrated above. The elements in Table 17.3 show the gross output required in each agricultural region or industrial sector named at the left for a \$1 increase in final demand for the region or sector indicated in the column and expresses both the direct and indirect effects. The services of resources used in agriculture were valued at 1954 market prices. (Since some resources in agriculture receive less than market prices, the sum of requirements exceeds the value of the unit of product.) Hence, a \$1 increase in output for final demand from the agricultural processing sector (through which most of agricultural products

Table 17.3. Matrix $\bar{B}$: Interdependence Coefficients Expressing Direct and Indirect "Demands" Among Regional Agricultural Sectors, 1954

Region (g) or Sector	Agricultural Regions (k)										Agricultural Processing Sector
	1 North-east	2 Corn Belt	3 Lake States	4 Appal. States	5 South-east	6 Delta States	7 S. Plains	8 N. Plains	9 Moun. States	10 Pacific States	III ‡
1	1.29475	.00196	.00204	.00184	.00173	.00164	.00188	.00225	.00191	.00172	.06269
2	.01928	1.41862	.01014	.02263	.00897	.04851	.01390	.01025	.00886	.00825	.15302
3	.00567	.00351	1.43589	.00281	.00267	.00251	.00281	.00322	.00277	.00253	.06762
4	.00551	.00240	.00213	1.30567	.00186	.00176	.00198	.00230	.00197	.00179	.05281
5	.00230	.00165	.00174	.00162	1.25920	.00144	.00162	.00187	.00160	.00147	.03778
6	.00207	.00140	.00151	.00143	.00138	1.19280	.00142	.00158	.00137	.00127	.02317
7	.00301	.01030	.00223	.00664	.00519	.00204	1.21092	.01239	.00199	.01284	.04018
8	.01091	.03910	.01297	.00344	.00296	.00374	.01855	1.44661	.00580	.01469	.06020
9	.00267	.01208	.00746	.00190	.00168	.00178	.03793	.05879	1.41003	.03544	.04319
10	.00277	.00208	.00217	.00198	.00186	.00176	.00201	.00258	.00203	1.18609	.06265
I*	.55243	.33461	.37292	.37022	.36519	.32879	.35760	.36909	.32627	.31155	.23448
II †	.56233	.54855	.50184	.45425	.43073	.42168	.47719	.61010	.48577	.44431	.46126

*Same as sector I in Table 17.2.

† Same as sector II in Table 17.2.

‡ Includes sectors 0.10, 0.11, 0.12, 0.14, 0.15, 0.16 and 0.17 explained in text.

flow to final consuming sectors) is estimated to require (in direct, indirect and circular effects) .6033 of $1 of outputs from the 10 agricultural regions and .6957 of $1 from the two aggregate industrial sectors which supply inputs to agriculture. These figures again emphasize the structural nature of agriculture in a developed economy, with value of inputs from industrial sectors exceeding the sum of all inputs from agricultural sectors to produce $1 of processed products for final demand (with the agricultural product itself included in the latter). Over 25 percent, or $.15 of outputs induced from agricultural regions as a result of a flow of $1 of product from the agricultural processing sector to final demand comes from the Corn Belt. The corresponding figure hardly exceeds 10 percent from other individual regions.

Including the indirect effects in expressing requirements on regions and sectors for inputs further emphasizes the lack of "economic tie" between regions, with the interrelationship of an agricultural region being much more with itself and with the industrial sectors which furnish resource inputs to agriculture. In a more "universal sense" relative to all other regions, the Mountain region tends to be second to the industrial sectors in providing inputs to other regions. The inputs required from the Mountain region, with $1 of product moving to final demand from other regions, is .04 for the Southern Plains, .06 for the Northern Plains, .04 for the Pacific States. However, the Corn Belt, with movement of $1 in products to final demand, has a requirement of .04 on the Northern Plains (mainly for feeder stock), and the Delta region has a requirement of .05 on the Corn Belt (mainly for feed). Other coefficients, comparing regions with product flowing to final demand against other agricultural regions furnishing farm products as inputs for the former, equal to or exceeding .01, are almost entirely for grain as livestock feed. These are small interregional dependence coefficients and are dwarfed entirely by the magnitude of the interdependence coefficients of the k-th agricultural regions on industrial sectors in aggregate.

For the complete model, the interdependence coefficients (based on matrices A and B) are even smaller for the j-th agricultural commodity sector (in reflecting "demand" for inputs, from the i-th agricultural commodity sector) as compared to "demand" for inputs of an agricultural sector against the several industrial sectors defined earlier in the text. (Of course, comparable coefficients perhaps would require disaggregating an industrial sector such as chemicals into plant insecticides, animal medicines, etc.) On the detailed basis of agricultural commodity sectors, the requirements of a livestock sector on feed grain and forage sectors within the same region are much higher than the interdependence coefficients connecting the k-th "demanding" and the g-th "supplying" regions ($g \neq k$) in Table 17.3. Also, the coefficient of livestock of the k-th region against grain or feeder stock of the g-th region ($g \neq k$) also tends to be relatively large. The interdependence coefficients, based on the complete 103-order matrix B, are provided in Table 17.4 for the livestock sector in the k-th region against the

Table 17.4. Interdependence Coefficients of Regional (k) Livestock Sectors With Livestock and Feed Grain Sectors of Other Regions (g); From Matrix B, 1954

Region (g) and Sector	Livestock Sector by Regions (k)									
	1.N.E.	2.C.B.	3.Lake	4.Appal.	5.S.E.	6.Delta	7.S.P.	8.N.P.	9.Moun.	10.Pac.
1. l. stock	1.0618	.0008	.0007	.0011	.0011	.0011	.0011	.0007	.0008	.0011
1. f. grain	.1297	.0012	.0010	.0023	.0026	.0027	.0025	.0010	.0013	.0026
2. l. stock	.0034	1.0583	.0021	.0028	.0028	.0028	.0027	.0020	.0020	.0027
2. f. grain	.0336	.3808	.0083	.0387	.0201	.1143	.0270	.0077	.0010	.0206
3. l. stock	.0031	.0015	1.0422	.0012	.0012	.0012	.0011	.0008	.0008	.0012
3. f. grain	.0056	.0020	.3254	.0033	.0037	.0038	.0035	.0015	.0019	.0037
4. l. stock	.0037	.0008	.0004	1.0473	.0006	.0006	.0006	.0004	.0004	.0006
4. f. grain	.0012	.0003	.0002	.2561	.0003	.0003	.0003	.0002	.0002	.0003
5. l. stock	.0004	.0003	.0002	.0004	1.0640	.0004	.0004	.0003	.0003	.0004
5. f. grain	.0010	.0004	.0003	.0067	.2557	.0007	.0007	.0003	.0004	.0003
6. l. stock	.0003	.0002	.0002	.0003	.0003	1.0552	.0002	.0001	.0002	.0002
6. f. grain	.0009	.0003	.0003	.0006	.0007	.1288	.0006	.0003	.0003	.0007
7. l. stock	.0010	.0110	.0007	.0094	.0079	.0007	1.0550	.0152	.0006	.0252
7. f. grain	.0033	.0027	.0010	.0034	.0035	.0025	.1620	.0031	.0012	.0061
8. l. stock	.0075	.0383	.0100	.0010	.0010	.0010	.0009	1.0657	.0007	.0063
8. f. grain	.0096	.0142	.0051	.0050	.0057	.0057	.0310	.3225	.0067	.0243
9. l. stock	.0014	.0142	.0069	.0014	.0012	.0008	.0689	.0787	1.1588	.0723
9. f. grain	.0009	.0017	.0009	.0006	.0007	.0006	.0075	.0081	.1172	.0078
10. l. stock	.0015	.0005	.0005	.0008	.0008	.0008	.0007	.0008	.0005	1.0594
10. f. grain	.0013	.0005	.0004	.0001	.0011	.0011	.0010	.0004	.0005	.0657

livestock and feed grain sectors in the g-th region. (The coefficients along the diagonal exceed unity because $1 in sales not only requires this amount of livestock, but also requires inputs of breeding and feeder stock from the same area.) Again, however, the interdependence coefficient of the j-th agricultural commodity sector against the i-th sector is, except for the two sectors in Table 17.4, much smaller when the latter is an agricultural sector than when it is an industrial sector, even with the degree of aggregation considerably smaller than in 0.13 through 0.22.

SUMMARY OF SOME INPUT INTERDEPENDENCE AMONG REGIONS

In terms of the magnitude of interregional interdependence coefficients, the Northern Plains was most dependent upon other agricultural regions (Table 17.3) for inputs to service its outputs. A $1 increase in agricultural products of this region delivered to final demand generated 9.5 cents of agricultural output in other regions to serve as inputs in the former. Of this, the Mountain States accounted for 5.9 cents or 62 percent of the increase in inputs so generated. Each $1 of Northern Plains livestock products delivered outside the system generated in the Mountain States: 7.9 cents of livestock output and .8 cents of grain output (Table 17.4). Likewise, 1.5 cents of livestock in the Southern Plains was associated with each $1 of Northern Plains livestock products. A strong two-way dependence is shown between the Northern and Southern Plains. The Southern Plains required feed grains from the Northern Plains, while the Northern Plains purchased feeder animals from the Southern Plains.

Also, agriculture in the Southern Plains showed a high dependency upon other regions. A $1 delivery to final demand of livestock products in the Southern Plains required 3.1 cents from feed grains in the Northern Plains, 6.9 cents and .8 cents from livestock and grain, respectively, in the Mountain States. These individual flows, traced back through the model, indicate that an increase in output of feed grains (2.0 cents) in the Corn Belt (sector 2.1) consisted primarily of direct flows to livestock in the Southern Plains and indirect flows to prepared feeds (sector 0.13) eventually purchased in region 7. Similarly, feed grains requirement in the Northern Plains (sector 8.2) is divided into direct and indirect flows. Purchases by the Southern Plains from the Mountain States (sector 9.1) were mainly feeder cattle and sheep. Increases in forage output in the Mountain States, as reflected in aggregations and specifications of the particular model, resulted from the increased requirements of feeder animals subsequently shipped to the Southern Plains.

Each $1 of agricultural products delivered to final demand from the Pacific States generated 8 cents of agricultural output in other regions to serve as inputs in region 10. The largest tie-up is with agriculture in the Mountain States. Each $1 of livestock products (sector 10.1), delivered to final demand, directly and indirectly required 2.1 cents of feed grain from the Corn Belt (sector 2.2), 2.5 cents of livestock from the Southern Plains (sector 7.1), 7.2 cents of livestock from the Mountain States (sector 9.1) and 2.0 cents of forage crops from the Mountain States (sector 9.4). The induced output of 2.1 cents from feed grains in the Corn Belt consisted chiefly of direct feed grain shipments to prepared feeds (sector 0.13) which, in turn, were purchased for (a) livestock in region 10 and (b) feeder livestock raised in other regions and purchased in region 10.

Agriculture in the southeastern section of the United States (regions 4, 5 and 6) also is dependent upon feed grain production in the Corn Belt. A $1 delivery of livestock products from the Appalachian region to final demand requires an increase in output of 3.9 cents of feed grains in the Corn Belt (sector 2.2). A $1 delivery of livestock products in the Southeast (sector 5.1) to final demand requires 2.0 cents of feed grains in the Corn Belt (sector 2.2), as reflected in both direct and indirect or induced flows of inputs. A $1 delivery of livestock in the Delta States (sector 6.1) similarly requires 11.4 cents of feed grains in the Corn Belt (sector 2.2).

The Corn Belt again, in both direct and indirect flows of inputs, has a relatively large dependence on livestock production in the Great Plains (regions 7 and 8) and Mountain States (region 9). One dollar of livestock products in the Corn Belt delivered to final demand required livestock output of 1.1 cents in the Southern Plains (sector 7.1), 3.8 cents from livestock in the Northern Plains (sector 8.1) and 1.4 cents from livestock in the Mountain States (sector 9.1).

We also can summarize the indirect or induced outputs from agricultural regions and sectors as a result of changes in demand for the products of agricultural processing sectors (e.g., "finished" products from farms moving to consumers).[4] A $1 increase in the demand for meat and poultry products (sector 0.10) generates, under the restrictions and model limitations mentioned above, $1.09 of total gross output in agriculture and 73 cents in industries furnishing inputs to agriculture. Of this $1.09, 39.5 cents, or 35 percent of the total, is generated in the Corn Belt. In contrast, only 2.8 cents is generated in the Delta States. The majority of the increase in gross output in each region, to serve as inputs for the agricultural processing and other agricultural sectors, resulting from a $1 increase in consumption of meat and poultry products, is in livestock and feed crop sectors. Output generated in livestock and feed grain sectors of the Corn Belt (sectors 2.1 and 2.2) was 25.9 and 10.3 cents, respectively, as demand for meat and poultry products is increased by $1. Gross output of feed grains generated in the Corn Belt, required to produce the livestock generated in other regions, is greater than the total increase in livestock generated

[4]Not all details are shown here but can be found in Carter and Heady, Iowa Agr. Exp. Sta. Bul. No. 469. 1959. op. cit.

in all regions. Most Corn Belt feed grains are consumed by livestock within the region. However, the prepared feeds industry (sector 0.13) purchases large quantities of corn from the Corn Belt that subsequently flow to livestock in other regions. Too, the Corn Belt, a surplus feed grain region, makes direct shipments of corn to deficit feed grain regions.

Gross output generated in the Northern Plains, for each $1 of meat and poultry products delivered to final demand, was 14.7 cents, second only to the Corn Belt. Correspondingly, gross output induced was 11.4 cents in the Lake States and 8.8 cents in the Northeast. As a group, the Southeast regions of the United States (regions 4, 5 and 6) generated gross output of 14.6 cents for each additional dollar of meat and poultry products delivered to final demand. The parallel increase in agricultural output was 60 cents in the Northeastern regions (regions 1, 2 and 3), 21 cents in the Great Plains (regions 7 and 8) and 13 cents in the Western States (regions 9 and 10).

The $1 change in final demand for meat and poultry products has the effect of inducing 11.0 cents of output from the machinery sector to flow as inputs to agricultural sectors. The induced output in the prepared feed industry (sector 0.13) is 9.8 cents. Output induced in the fertilizer industry, per $1 of meat and poultry products delivered to final demand, is estimated at 1.8 cents. Fertilizer use is associated with crop production, an indirect effect following from the need of livestock for grains and forages. Hence, fertilizer production is indirectly related to demand for processed meat products.

A $1 increase in final demand for dairy products (sector 0.11) generates a total of 91.6 cents of gross output in agriculture and 67.7 cents of gross output in industries providing agricultural inputs. The largest increase, or the greatest proportion of the 67.7 cents total, is generated in the dairy areas of the Lake States, Northeast and Corn Belt. The required increases in output, per $1 of dairy products delivered to final demand, are 19.3 cents in the Lake States, 18.7 cents in the Northeast and 18.3 cents in the Corn Belt. In the Northeast, 14.4 cents of the output is from the livestock sector and 1.8 cents from the feed grain sector. In contrast, 11.1 cents is from the feed grain sector and 5.1 is from the livestock sector in the Corn Belt. The increase of feed grains in the Corn Belt is entirely an indirect transaction. Feed grain flows to livestock sectors within and outside the regions and also to prepared feeds (sector 0.13). However, the majority of the increase in the livestock sectors of the Corn Belt is a direct transaction. The Pacific States show the largest increase in gross output, of the Plains and Western States, associated with a $1 increase in final demand for dairy products. Most of the required increase (6.1 cents out of 8.3 cents) is in the livestock sector rather than in feed grains. This large proportion of the total in the region results because the region is a deficit producer of feed grains.

Gross output generated in industrial sectors, from a $1 change in final demand for dairy products, was similar in magnitude to those required for changes in demand for meat and poultry products.

A $1 increase in the demand for processed grain products generated an increase in agricultural output totaling 57 cents and an increase in industry output totaling 98.2 cents.[5] These magnitudes are in contrast to the effect on agricultural and industrial output when the changes in final demand were for meat, poultry and dairy products. A $1 increase in final demand for meat and poultry products requires an increase of $1.09 of agricultural output. The corresponding increase in final demand for grain products is only about one-half that generated by meat products. The differential is related primarily to the relative degree of processing that grain products undergo before reaching the final consumer.

The product mix of the vegetables and fruit sector includes highly processed products (e.g., canned and frozen foods) and vegetables and fruit with only minor processing. The linear constraints of the model cause this mix to remain in a constant proportion for changes in demand. A $1 increase in final demand for vegetable and fruit products required an increase in gross output of 54 cents from agriculture and a total of 70 cents from industry. The largest regional increase in gross output was in the Pacific States with 19.6 cents, or approximately 40 percent, of the total increase in agricultural output. A $1 change in final demand for tobacco products generates about a 50-cent increase in total agricultural output. The Appalachian region, the primary source of raw tobacco, accounts for 38.3 cents, or about 75 percent, of the induced output.

Changes in final demand for industrial sectors which furnish inputs to agriculture have small effects on agricultural output. Approximately 10 percent of output from the agricultural input supplying industry was purchased by agriculture, while more than 40 percent was purchased by final demand sectors in the form of motor vehicles, fuel and oil, paints and varnishes, etc.

PROJECTIONS BY INPUT-OUTPUT MODELS

Projections relating economic growth to output from various sectors to serve for final demand and inputs of various sectors have been and can be made from input-output models. They serve "best" for models with "highly aggregated sectors" where the broad composition of the sector allows a decline in one input used in production to be offset or "covered up" by an increase in another. For this reason, they serve with very limited utility for models emphasizing agriculture where great change is taking place in the relative commodity making up "food" in its composition from different regions and in the relative mix of labor and the various capital resources going into it within all regions. Given the magnitude of technical change and resource

[5]Excluding agricultural processing sectors, as in the case of other quantities mentioned for this section.

substitutions indicated in Chapters 2 and 4 and with divergent changes in demand for various categories of inputs predicted in Chapters 7 through 16, it is obvious that interdependence or resource requirements coefficients based on an input-output model at one point in time cannot serve efficiently for projecting resource demand and structure at a distant point in time.

Recognizing this point, we provide conditional projections in Chapter 18 which recognize the great change in the structural parameters of agriculture over time. We believe these to be the more relevant types of projections for guidance of public policy, individual decisions and research and educational programming relating to the farm industry. Those from input-output models necessarily cause a "fixed structure" to prevail because of the conditions cited earlier; namely, linear homogeneous production functions, fixed mix requirements on inputs, etc. However, for individuals who (a) do not wish to accept the projections of Chapter 18, based on expected continuous change in the structural parameters of agriculture and in its behavioral interrelations with the industrial economy and (b) insist that structure of the past will be extended into the future, we have derived some projections for 1975 based on the above input-output model. These conditional projections (see Chapter 18) are compared with 1954 outputs.

The assumptions made for the projections to 1975 for the above input-output model, but not for the projections of Chapter 18, and aside from population, are those of Daly.[6] The basic assumptions for projections in this chapter are: (a) a population of 230 million (b) farm commodity exports at 1954 levels (c) price at 1953 levels and (d) final demand for sectors other than agricultural processing sectors at the 1954 level. (The latter assumption, for purposes of computational convenience, does not recognize the very small quantity of farm products flowing directly to final demand or the small indirect effect of growth in final demand for industrial nonfood products on output of agriculture which serve as inputs for industry.)

To conform with the model, to avoid confusion with the more realistic projections of Chapter 18 and to conserve space, we present only a summary of the projections and emphasize industrial sectors producing inputs for agricultural sectors.

The projected "demands" for agricultural processed goods (sectors 0.10 through 0.17) for 1975 suggest a required increase of 28 percent, over 1954, in farm output. The associated increase in outputs from industrial sectors, to serve as inputs for farm sectors, would be 6.5 percent. The latter percentage is small since industrial sectors producing inputs for agriculture distributed the very major part of their output to nonfarm sectors in 1954. (See summary in Table 17.5.)

Industries whose outputs serve directly as inputs to agriculture would be required to increase their output by 5.5 percent. Other

[6]Daly, R. F. The long-run demand for farm products. Agricultural Economics Research. Vol. 7. Feb. 1956.

Table 17.5. Changes in Gross Output (With 1954 Conditions) Needed To Meet Projected Deliveries to Final Demand for Processing Industries in 1960 and 1975, U.S. Economy (Aggregation of Commodity Groups and Subdivisions of Industry)

National Processing Sectors	1954 to 1975	
	Absolute change	Percentage change
	(million dollars)	
0.1 Livestock and livestock products	6,145.2	33.2
0.2 Feed grains	1,817.0	28.8
0.3 Food grains	301.9	12.8
0.4 Forage crops	798.6	32.0
0.5 Vegetable and fruit	1,135.9	32.7
0.6 Cotton	272.0	8.0
0.7 Tobacco	606.0	52.9
0.8 Oil crops	94.2	8.6
0.9 Miscellaneous agriculture	363.5	17.9
Total farm output	11,534.3	28.2
I Agr. furnishing ind.*	3,991.4	5.5
II All other ind.†	9,138.5	2.4
III Agr. proc. ind.‡	20,494.2	32.2
Total ind. output	33,624.1	6.5

*Agricultural furnishing industries include sectors 0.13, 0.18, 0.19, 0.20 and 0.21.
†All other industries include sector 0.22.
‡Agricultural processing industries include sectors 0.10, 0.11, 0.12, 0.14, 0.15, 0.16 and 0.17.

industries, with only an indirect relationship to agriculture, would be required to increase output by 2.4 percent (as a result of 28 percent growth in demand for "finished or processed" agricultural commodities alone, without considering increase in final demand for the many non-farm sectors of the economy). For the agricultural input-furnishing industries (sectors 0.13 through 0.17), the largest percentage increase in output, about 30 percent, would be required in the prepared feeds industry (sector 0.13). Most of this increase would be associated with projections in demand for livestock products (sectors 0.10 and 0.11). The second largest percentage increase in output, about 26 percent, indicated by the input-output model would be in the fertilizer industry. Practically all of the fertilizer increases are indirect demands of livestock (sectors 0.10 and 0.11) processing sectors which purchase livestock, but which in turn require crops that are fertilized. However, with the present rate at which new fertilizer practices are adopted, needed production increases in the fertilizer industry likely will be much greater than 26 percent. (See Chapter 18.)

The third largest projected increase among the agricultural furnishing industries to meet 1975 demands on the agricultural processing industries, about 6 percent, would be in the chemical industry (sector 0.19). Half of this increase is related to projected demand for fruit and vegetable products (sector 0.15). "Indirect" inputs to farm fruit and vegetable sectors of fruit sprays and dust make up a large part of the increase.

The machinery and related services sector (0.20) would have a 3.7 percent increase in volume from 1954 to 1975; however, the projected absolute change is 1,368 million (1954) dollars, the largest of any agricultural furnishing sector. An increase of 1.8 percent, or almost one-half of the total increase in sector 0.20, is related to increases in demand for meat and poultry products (sector 0.10).

Required increases in the petroleum industry (sector 0.21), i.e., gasoline, grease and oil, to meet projected 1975 final demand for agricultural processing products were 2.6 percent, or 323 million (1954) dollars. The large part of the increase in production again is related to projected changes in demand for meat and poultry products (sector 0.10).

APPLICATION OF PROJECTIONS

We have not compared interregional flows under the above projections. One limitation, in change in interregional "demand" relationships, revolves around the "fixed mix" assumption. Without examining the direct and indirect effects of changes in final demand on output in a particular sector, we can illustrate the effect of a proposed change in output in the j-th producing sector on outputs in the i-th sector (i.e., on the amount of output in the i-th sector necessary to serve as an input in the j-th sector). Suppose that j refers to livestock production in one region and i refers to feed grain production in another. Then a_{ij} indicates the additional amount of grain needed to be produced in the i-th region, to allow a unit increase in output by the j-th region. This interpretation would be entirely correct if j obtained grain inputs only from i. However, at the time for which data apply, j may have obtained part of its requirement from i and part from other regions. If sector j is to increase livestock output, input-output models suppose that its incremental feed imports are met by flows of grain from crop regions in proportion to the a_{ij}'s. If region j has been importing feed grain from regions g and k, the model assumes increase in livestock production in j to be forthcoming from incremental imports in the ratio $a_{gj}a_{kj}^{-1}$ from the two grain-producing regions, regardless of the level to which livestock production and feed imports in j are increased. "Fixed mix" projections might approach reality for small regional changes. But for larger regional shifts, the allocation of grain imports from deficit regions to surplus regions could not be expected to correspond to the pattern of the past.

These projections for other sectors can serve the person who wishes to concentrate on a nostalgic structure of agriculture, who imagines that the relative share of farming in the national economy and that the relative labor and capital employment of agriculture will remain unchanged so that educational and policy programs can retain their historic pattern. We prefer a "heads out of the sand approach," however, and turn to the conditional projections in Chapter 18 where we try, although imperfectly, to account better for changes in structural variables and parameters. The reader is welcome to accept either set or type of projections, or others lying between them. Other input-output models can be computed at later dates and can serve, in comparison with the one above, to indicate direction and magnitude of change in agricultural structure. Because of economic development and technological change, shifts in factor prices and consumer expenditure patterns, low aggregate supply elasticities for some agricultural resources (especially land) and production functions which do not impose conditions of constant returns and technical complementarity among resources, models computed for the future will show a continuous shift in interdependence coefficients. This direction is expected, given the momentum of change in magnitudes in variables and parameters summarized in Chapters 1 through 4. Hence, we now turn to projections which are more realistic in allowing this change in structure.