8-1972

AN ANALYSIS OF UNITED STATES COMMODITY FREIGHT SHIPMENTS

Karen R. Polenske

AN ANALYSIS OF UNITED STATES COMMODITY FREIGHT SHIPMENTS

by

Karen R. Polenske*

August 1972

*This paper will be published in Studies in Economic Planning Over Space and Time, a book edited by George G. Judge and Takashi Takayama and published by North-Holland Publishing Company.

AN ANALYSIS OF UNITED STATES COMMODITY FREIGHT SHIPMENTS

Karen R. Polenske*

As efforts are being made to understand and solve some of the current economic problems of the United States, the need for a comprehensive and systematic analysis of these problems at a regional level becomes increasingly evident. The impact of almost all changes in the economic conditions of the country varies significantly among different regions. A dock-workers' strike on the West Coast, for example, creates bottlenecks at those ports, but it also can have tremendous adverse repercussions on workers, consumers, and industries located within that region, as well as in other regions of the country.

Although the preceding statements seem obvious and beyond dispute, the investigation of many important economic issues, such as transportation strikes, the energy and environmental crises, and inflation, is often conducted at a national, rather than at the frequently more relevant regional, level. The national studies that have been made and are being made can therefore be misleading, or

---

*I am deeply grateful for the assistance received from Mary M. Shirley, Kathryn L. Norris, Margaret Feiger, and particularly from John A. Makdisi in doing the calculations for this paper. The results presented are preliminary and are based upon research that was done for the Office of Systems Analysis and Information of the U.S. Department of Transportation under contract #DOT-OS-10222. I take full responsibility for the conclusions, which are not necessarily those of the sponsoring agency. The author is an Associate Professor of Urban Studies and Planning at the Massachusetts Institute of Technology.

inapplicable, or, if a regional analysis is made, it generally has been an extremely limited study. Part of the reason for the neglect of the regional or multiregional studies is that tools for both types of studies have been developed so slowly and that detailed regional statistics have seldom been readily available. The concern of the present paper is to present a discussion of the application of a new analytical tool, the multiregional input-output model, to investigate the transportation requirements in different regions of the United States.

The General Framework

A national input-output model provides a completely consistent framework within which the interdependence of the transportation sector with the rest of the economy can be described and analyzed. A multiregional input-output model provides a basis for consistent estimates of transportation requirements by industry and region, and all the many interactions between changes in the rest of the economy and transportation can be studied in considerable industrial and regional detail. Whenever changes in one sector of the economy greatly affect another sector, an economic analysis of only the one industry or region usually fails to account for the entire impact of a given change. The complex linkages between transportation and other industries can be observed in most day-to-day economic activity. Now, however, it is becoming more and more obvious that changes in one region of the economy will have both direct and indirect effects not only on that region, but on other regions, as

well; and it is, in fact, almost impossible to analyze any regional economic issue without giving specific consideration to transportation. On the other hand, in the United States, most of the general conclusions made about transportation at the national level have almost no relevance if applied to a particular region.

For these reasons, the analysis of transportation presented in this paper has been based upon a multiregional input-output (MRIO) model. It is both a comprehensive and a multipurpose tool. On the basis of this preliminary study, the model appears to have a great potential for aiding in systematic studies of regional economic policies in general and of transportation policy in particular. Most previous regional economic analyses were restricted to the study of a single region at a time. Generally, only the direct effect of a given variation in economic activity was measured, and only the net inflow or outflow of a commodity was established. In contrast to these previous studies, the use of the MRIO model has four advantages: (1) indirect, as well as direct, repercussions can be measured; (2) gross, rather than just net, shipments of commodities to and from each region can be estimated; (3) all analyses can be made providing considerable industrial and regional detail while maintaining an internal consistency of all calculations; (4) the framework can be used to make analyses of the industrial and regional impact of economic policy decisions for the nation as a whole, and at the same time, economic analysts in each region or group of regions can use the basic results of the calculations to provide controls in their own investigations of economic problems particular to the region or group of regions under study.

The Specific Model Employed

From 1967 to 1970, under a contract between the Economic Development Administration of the U.S. Department of Commerce and the Harvard Economic Research Project, a complete multiregional input-output table was assembled for the United States for 1963, and supplemental historical state final demand estimates were made for 1947 and 1958. The six major components of final demand were also projected to 1970 and 1980. From 1971 to 1972, the multiregional input-output research was continued under a contract at Harvard University with the Office of Systems Analysis and Information of the U.S. Department of Transportation.[1]

All of the multiregional statistics were assembled according to the 87-industry classification scheme of the Bureau of Economic Analysis (formerly the Office of Business Economics) for 51 regions (50 states plus the District of Columbia) whenever feasible and have been made consistent with the published national input-output tables. The seven sets of data available from the multiregional study are listed in Table 1.

For the determination of interregional shipments among the states, three fixed trade coefficient models have been tested within the multiregional input-output framework: point estimate gravity,

---

[1]As of July 1, 1972, the multiregional research project has been moved to the Department of Urban Studies and Planning at the Massachusetts Institute of Technology.

Table 1

MULTIREGIONAL INPUT-OUTPUT DATA
FOR THE UNITED STATES*

	Name of Matrix	Matrix Dimension**	Years		
1.	Final demands (6 matrices for each year)	88x53	1947	1958	1963
***2.	Payrolls, Employment, and Outputs				
	Payrolls	88x53	1947	1958	1963
	Employment	88x53	1947	1958	1963
	Outputs	88x53	1947	1958	1963
***3.	Projected Final Demands (6 matrices for each year)	88x53		1970	1980
4.	Regional Input-Output Tables (44 matrices)	87x87			1963
5.	Interregional Trade Flows (61 matrices)	45x45			1963
6.	Projected Outputs	80x45		1970	1980
7.	Projected Interregional Trade Flows (61 matrices for each year)	45x45		1970	1980

*All data listed in this table are available on computer tapes from the National Technical Information Service, Washington, D. C.

**The matrix dimensions include row and column sums.

***These data were assembled for the study by Jack Faucett Associates, Inc., under a subcontract with the Harvard Economic Research Project.

column coefficient, and row coefficient.[2] The first implementation of the model has been made using the column coefficient model, for which only a limited amount of actual regional data is needed, namely: base-year technical coefficients, a_{ij}^{h}, base-year trade coefficients, c_{i}^{gh}, and a set of final demands, y_{i}^{h}, for the given year. When the model is implemented, the outputs, x_{i}^{go}, and the interregional trade flows, x_{i}^{gh}, are determined for all regions and industries in the economy.[3]

The Empirical Results

Because a general overview of the regional material was impossible to obtain from the extremely detailed 44-region, 79-industry data, the multiregional model was also implemented at a 9-region, 10-industry level of aggregation. The regional aggregation system for the nine census regions is given in the

---

[2]The comparisons of the three models are given in a paper written by Karen R. Polenske (May 1970). The gravity model was originally described in a paper written by Wassily Leontief and Alan Strout entitled "Multiregional Input-Output Analysis" (1963, Chap. 7). The first empirical testing of the complete multiregional input-output model for the United States is discussed in a report by Karen R. Polenske (December 1970),prepared for the Economic Development Administration of the U.S. Department of Commerce, and a complete and updated specification of the MRIO model is now available in a report written by Karen R. Polenske, Carolyn W. Anderson, and Mary M. Shirley for the Office of Systems Analysis and Information of the U.S. Department of Transportation (1972).

[3]The i designates the producing industry, j the purchasing industry, g the shipping region, and h the receiving region. The o indicates summation over all regions.

appendix, Table A-1, and the industrial aggregation system is given in Table A-2. The ten industries were chosen to highlight those industries that are of the greatest importance to the transportation of commodities in the United States; therefore, the livestock, mining, and transportation equipment industries were kept separate. The nine census regions in some ways distort the importance of transportation among areas of the country, because such a large percentage of the total production and consumption is situated within Region 2, Middle Atlantic, and Region 3, East North Central. As shown in Table 2, these two regions produced over 50 percent of the products of Industry 7, Transportation equipment and ordnance, Industry 8, Other manufacturing industries, and Industry 9, Machinery and equipment, and over 35 percent of the products of the remaining manufacturing and service industries. These are, however, all industries that transport commodities of high value but relatively low tonnage. Nevertheless, for high-tonnage commodities, such as Industry 1, Livestock, almost 20 percent of the production is concentrated in the East North Central region, while 30 percent is produced in the West North Central region. For Industry 2, Other agriculture, the corresponding percentages are 18 and 23. Mining is highly concentrated in one region, with 38 percent of the total production occurring in Region 7, West South Central. Given the location of the automobile industry, it is not surprising that the East North Central region alone produced 47 percent of the output of Industry 7, Transportation equipment.

Of the nine regions, three are relatively small consumers, as well as producers, as shown in Table 3. They are: Region 1, New

TABLE 2

REGIONAL DISTRIBUTION OF 1963 PRODUCTION
(percent)

	1 NEW ENGLAND	2 MIDDLE ATLANTIC	3 EAST NORTH CENTRAL	4 WEST NORTH CENTRAL	5 SOUTH ATLANTIC	6 EAST SOUTH CENTRAL	7 WEST SOUTH CENTRAL	8 MOUNTAIN	9 PACIFIC	10 TOTAL
1 LIVESTOCK	2	7	19	30	9	7	10	8	9	100
2 OTHER AGRICULTURE	1	5	18	23	13	8	12	6	13	100
3 MINING	2	9	9	7	8	5	38	13	8	100
4 CONSTRUCTION	5	14	17	7	13	5	10	6	21	100
5 FOOD. TOBACCO	3	16	20	15	16	7	8	3	12	100
6 FABRICS. TEXTILE PRDS.	9	33	6	2	36	8	3	0	4	100
7 TRANSP. EQUIP.. ORDNANCE	4	12	47	8	6	2	4	1	16	100
8 MANUF. PRDS.. EXC. MACH.	6	23	28	5	10	5	10	2	11	100
9 MACHINERY. EQUIPMENT	10	27	36	6	5	3	3	1	10	100
10 SERVICES	6	24	20	8	12	4	8	4	14	100
11 INDUSTRY TOTAL	6	21	23	8	12	5	8	3	13	100

TABLE 3

REGIONAL DISTRIBUTION OF 1963 CONSUMPTION
(percent)

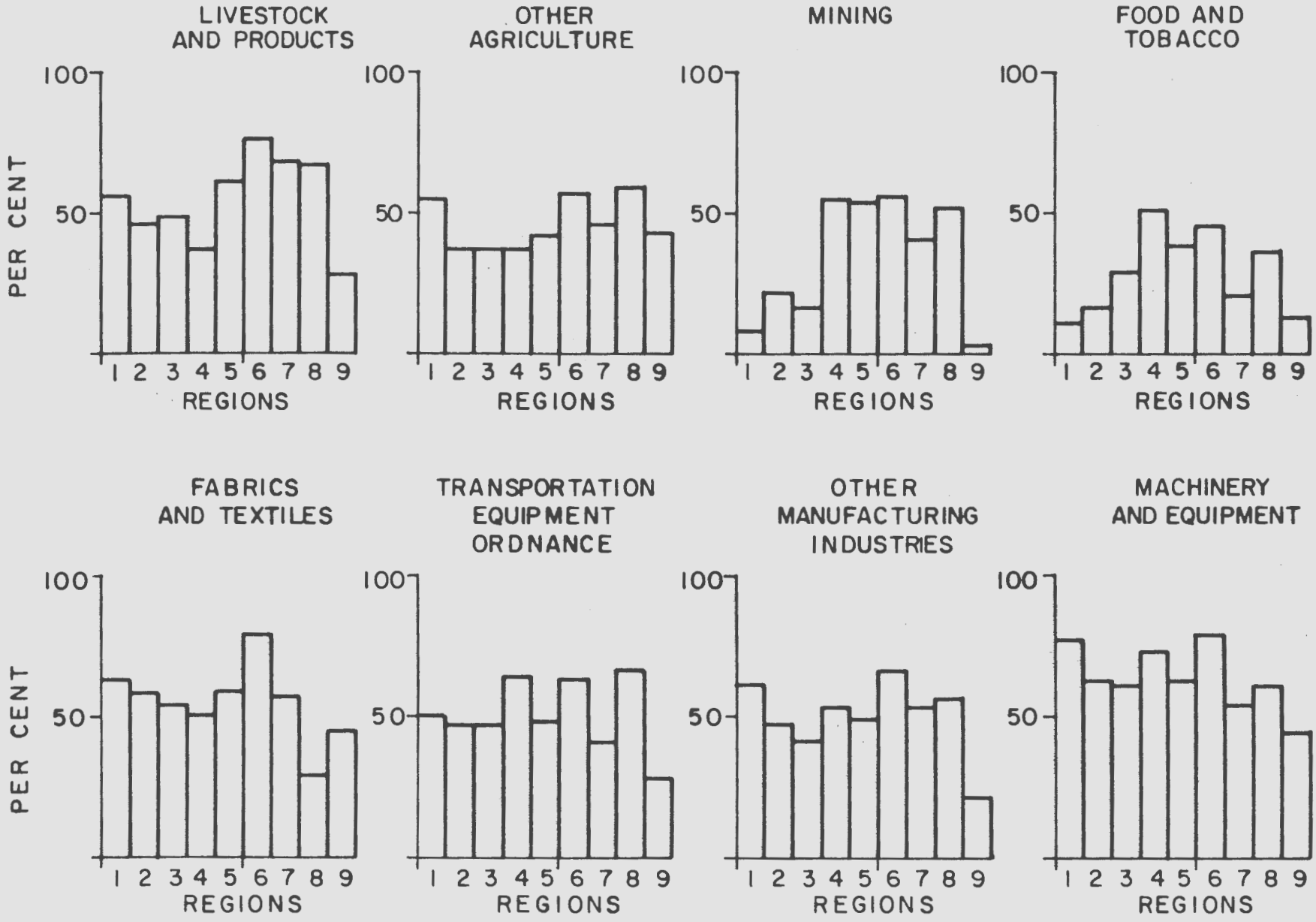
	1 NEW ENGLAND	2 MIDDLE ATLANTIC	3 EAST NORTH CENTRAL	4 WEST NORTH CENTRAL	5 SOUTH ATLANTIC	6 EAST SOUTH CENTRAL	7 WEST SOUTH CENTRAL	8 MOUNTAIN	9 PACIFIC	10 TOTAL
1 LIVESTOCK	3	10	18	28	9	6	9	7	10	100
2 OTHER AGRICULTURE	3	10	19	17	16	7	11	5	12	100
3 MINING	2	16	19	6	8	4	27	7	11	100
4 CONSTRUCTION	5	14	17	7	13	5	10	6	21	100
5 FOOD, TOBACCO	6	21	19	9	13	5	9	4	14	100
6 FABRICS, TEXTILE PRDS.	7	28	15	5	22	6	5	2	9	100
7 TRANSP. EQUIP., ORDNANCE	6	15	31	9	10	3	6	3	17	100
8 MANUF. PRDS., EXC. MACH.	6	21	25	7	12	5	8	3	13	100
9 MACHINERY, EQUIPMENT	7	24	25	7	10	4	6	3	14	100
10 SERVICES	6	24	20	8	12	4	8	4	14	100
11 INDUSTRY TOTAL	6	21	21	8	12	5	8	4	14	100

England, Region 6, East South Central, and Region 8, Mountain. In general, the regional consumption of all products is considerably more dispersed than the production, which naturally leads to the need for the goods to be transported from the place of production to the place of consumption. Only eight of the ten industries have commodities that are transported by the normal modes of transportation. Industry 4, Construction, and Industry 10, Services, are therefore not shown in the bar graphs that will now be discussed.

Figure 1, which shows the percentage of production shipped out of each region, indicates that the regional dependency on trade to provide a market for production is in general 50 percent or less. Of the total production of livestock in Region 2, Middle Atlantic, for example, 46 percent is shipped to other regions, the remaining 54 percent being consumed within the region. Of the total goods produced in each region, the percentage that is shipped out of the region to other regions varies considerably from industry to industry. In each of the nine regions, considerably less than 50 percent of the products of Industry 5, Food and tobacco, is shipped out of the region. (The only exception is Region 4, West North Central, where 51 percent is shipped out.) Obviously, bread, milk, and many other food products are produced and consumed locally, even if the region is reduced to that of a metropolitan area. For five of the nine regions, mineral products are also mainly consumed within the region where they are produced. Here, the expense of shipping heavy commodities long distances is a factor contributing to the location of the consuming industries. For crops, six of the nine regions ship less than 50

FIGURE 1

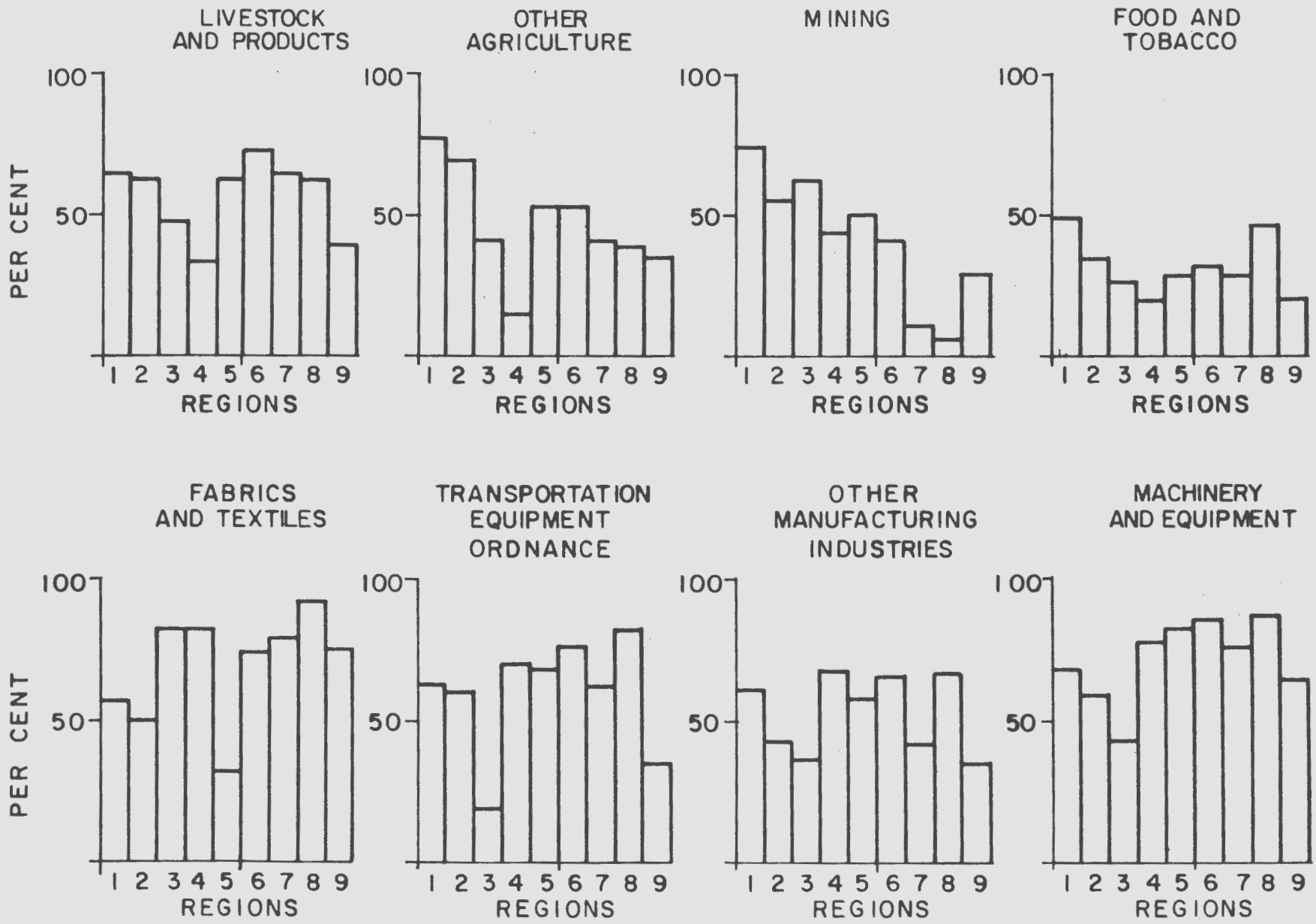
1963 PERCENTAGE OF REGIONAL PRODUCTION SHIPPED OUT



percent of the output to other regions. Again, the weight, and in the case of fruits and vegetables, the perishability, of the commodity are factors contributing to the lack of long-distance transport of the products. Of the remaining five industries, Industry 9, Machinery and equipment, is the one where in all except the Pacific region 50 percent or more of the products are shipped outside the region. As the industry is defined for this analysis, it contains a diverse array of establishments, producing everything from farm machinery to household appliances to medical and scientific instruments. One final observation should be made about the information presented in Figure 1. For each industry, the Pacific region, number 9, has a very low percentage of regional production shipped out compared with the other regions, showing a high dependency on its own production.

The geographic isolation of the Pacific region is indicated also by the bar graphs in Figure 2. These graphs show the percentage of regional consumption that is shipped into each region. For example, 64 percent of the consumption of livestock in New England is supplied from outside the region, with the remaining 36 percent being shipped from within the New England region. The bar graphs thus indicate the dependency of the regions upon other regions to provide needed inputs and to satisfy final demand. The taller the bar, the more dependent the region is upon other regions; the shorter the bar, the closer the region comes to satisfying its intermediate and final consumers with its own production. Small producing regions, such as the Mountain region, show a high dependency on other regions

FIGURE 2
1963 PERCENTAGE OF REGIONAL CONSUMPTION SHIPPED IN



for all products except mining. Similarly, the West North Central region has a low dependency on trade to supply its needs for raw materials, while a large amount of its demand for manufactured and finished products is fulfilled by goods shipped from outside the region. On the other hand, a large producing region, such as the East North Central, shows a low dependency on other regions as sources of supply.

Tables 4 and 5 give the 1963 percentage distribution of region-to-region shipments for each of the eight commodities that are transported. The first is for the tonnage and the second is for the value flows. For both tables, the sum of each column adds to 100 percent, except for rounding errors. The 1963 interregional trade flows were first estimated in terms of tons and then a set of regional prices was assembled to convert the tonnage flows to values. Each of the two sets of estimates was initially made at the 44-region level for the 61 commodities that are transported. These data were then aggregated to 9 regions and 10 industries for use in calculations made for this paper. The same type of data is available for 1970 and 1980.

For three of the eight industries, the percentage of intraregional shipments (goods produced and consumed within the same region) for the tonnage data is always equal to or less than the corresponding percentage for the value flows. The industries are: Industry 1, Livestock and products; Industry 2, Other agriculture; and Industry 7, Transportation equipment and ordnance. These are all industries dominated by high-weight commodities. The reverse is

TABLE 4
COLUMN PERCENTAGE DISTRIBUTION
1963 COLUMN COEFFICIENT INTERREGIONAL SHIPMENTS
(TONNAGE)

INDUSTRY 1
LIVESTOCK

	1	2	3	4	5	6	7	8	9
1	19	10			02				
2	47	28			19	06	02		
3	20	26	50	13	30	32	12	03	04
4	02	05	28	60	09	32	38	28	06
5	07	18	06		19	05	03	01	01
6	02	06	06	02	10	12	11	03	02
7	01	04	05	11	08	09	16	09	04
8			03	10	01	02	13	20	11
9	02	03	01	04	02	01	06	38	72

INDUSTRY 2
OTHER AGRIC

	1	2	3	4	5	6	7	8	9
1	13	06	01		02				
2	39	31	04	01	15	03	01		
3	13	24	55	07	30	37	10	03	01
4	01	02	21	71	04	17	30	09	06
5	19	18	06	01	28	08	03	01	01
6	02	01	01	01	07	12	03		
7	03	03	02	02	07	12	39	04	04
8	01	02	02	05	01	03	04	36	24
9	09	13	09	12	06	08	11	47	62

INDUSTRY 3
MINING

	1	2	3	4	5	6	7	8	9
1	72								
2	10	67	02		08	01			
3		02	57	06	02	03			
4	01	02	07	77	01	01	01	01	
5	10	13	10	01	76	08			
6	02	02	05	01	07	74	01		
7	05	14	15	11	07	12	95	03	03
8			04	04			02	95	07
9						01		01	89

INDUSTRY 5
FOOD, TOBACCO

	1	2	3	4	5	6	7	8	9
1	59	02							
2	20	74	04	01	08	01	01	01	01
3	08	09	76	08	09	15	05	04	02
4	07	06	11	81	05	08	10	05	03
5	02	05	02	01	63	02	01	01	01
6	01	01	02	01	11	64	05	01	
7	01	01	02	03	02	08	76	06	01
8	01	01	02	02	01		01	62	05
9	01	02	02	03	02	01	02	19	87

TABLE 4 (CONT'D)
COLUMN PERCENTAGE DISTRIBUTION
1963 COLUMN COEFFICIENT INTERREGIONAL SHIPMENTS
(TONNAGE)

INDUSTRY 6
TEXTILE PRODUCTS

	1	2	3	4	5	6	7	8	9
1	31	11	05	02	07	04	02	08	03
2	34	45	35	20	21	19	18	28	16
3	02	05	19	16	02	03	04	08	07
4	01		02	11		01	03	04	01
5	27	31	29	25	59	52	30	16	37
6	04	06	06	04	10	15	06	07	02
7			02	20	01	04	24	05	03
8								08	
9	01	01	02	02		01	13	15	31

INDUSTRY 7
TRANS EQUIP

	1	2	3	4	5	6	7	8	9
1	07	05	02		03		01		01
2	29	30	13	08	16	07	03	01	04
3	51	46	79	68	48	40	35	27	41
4	02	04	04	17	01	16	30	26	02
5	05	12	01	01	28	20	04		
6	02	01	01	01	02	12	02	01	01
7			01	02		02	21	06	
8	02							04	
9	03	01		02	02	02	03	34	50

INDUSTRY 8
MANUF. PROD

	1	2	3	4	5	6	7	8	9
1	39	04	01	01	01	01			
2	22	59	08	02	11	03	01	01	01
3	02	08	73	20	06	15	04	04	01
4			04	58		07	03	03	
5	03	07	04	02	51	07	02	01	
6	01	01	03	02	07	49	04	01	
7	31	17	04	07	23	17	82	07	01
8			01	05			01	64	09
9	01	03	01	03	01	01	02	18	87

INDUSTRY 9
MACH., EQUIP

	1	2	3	4	5	6	7	8	9
1	32	11	06	05	09	04	05	04	04
2	29	35	20	14	24	19	20	19	16
3	28	41	60	45	37	47	34	30	30
4	03	04	05	22	06	09	08	12	07
5	03	03	03	02	14	06	03	04	03
6	02	02	02	03	05	10	03	02	02
7		01	01	03	01	03	16	04	02
8			01	01			02	07	02
9	03	03	03	04	04	03	09	17	33

TABLE 5
COLUMN PERCENTAGE DISTRIBUTION
1963 COLUMN COEFFICIENT INTERREGIONAL SHIPMENTS
(VALUE)

INDUSTRY 1
LIVESTOCK

	1	2	3	4	5	6	7	8	9
1	36	11			02				
2	39	38	01		16	05	02		
3	10	15	53	09	20	27	07	02	05
4	02	03	21	67	07	24	28	22	08
5	10	23	09	01	38	07	04	01	03
6	02	06	07	02	09	28	10	04	04
7	01	03	05	11	06	07	36	10	07
8			03	09	01	02	10	38	11
9	01	01		02	01		02	23	61

INDUSTRY 2
OTHER AGRIC

	1	2	3	4	5	6	7	8	9
1	23	04	01		01				
2	19	31	02		05	01			
3	08	16	59	03	15	18	05	01	01
4	02	02	16	85	04	10	23	08	06
5	26	24	07	01	47	06	02	01	01
6	08	04	03	01	15	47	06	01	01
7	05	05	03	02	10	13	59	05	09
8	02	03	03	03	01	02	02	61	17
9	07	11	06	05	03	03	03	24	65

INDUSTRY 3
MINING

	1	2	3	4	5	6	7	8	9
1	26								
2	30	45	02		11	01			01
3	03	03	38	11	02	04			
4	01	03	15	56	01	01	01	01	
5	14	09	07	02	50	08	01	01	05
6	04	04	04	01	11	59	02		
7	21	33	26	21	22	24	89	03	05
8		04	07	09	02	03	06	94	18
9						01			71

INDUSTRY 5
FOOD, TOBACCO

	1	2	3	4	5	6	7	8	9
1	51	01							
2	17	65	03	01	06		01	01	01
3	09	10	73	08	07	11	05	04	04
4	11	08	11	80	05	08	12	09	04
5	07	12	06	05	71	06	06	03	05
6	02	02	03	02	08	68	05	04	01
7	01	01	01	02	01	06	71	08	01
8	01	01	01	01			01	53	04
9	01	01	01	02	01		01	19	79

TABLE 5 (CONT'D)
COLUMN PERCENTAGE DISTRIBUTION
1963 COLUMN COEFFICIENT INTERREGIONAL SHIPMENTS
(VALUE)

INDUSTRY 6
TEXTILE PRODUCTS

	1	2	3	4	5	6	7	8	9
1	43	12	04	02	04	03	02	06	02
2	29	50	41	31	15	19	31	29	28
3	02	03	18	10	01	03	06	11	08
4			02	18		01	05	03	01
5	22	27	25	23	68	44	21	17	29
6	04	07	06	05	09	26	06	07	02
7	01		02	06	01	03	21	05	04
8								08	
9	01	01	02	03	01	02	10	15	25

INDUSTRY 7
TRANS EQUIP

	1	2	3	4	5	6	7	8	9
1	38	05	01	01	05	01	02	01	02
2	16	40	07	06	11	04	03	01	03
3	32	38	81	46	39	32	24	21	21
4	01	04	04	30	01	14	22	21	03
5	03	10	01	01	32	16	03		01
6	02	01	01	01	03	24	02	02	01
7			01	06	01	04	38	07	02
8	03			02	01		01	18	01
9	04	02	03	08	07	05	06	29	66

INDUSTRY 8
MANUF. PROD

	1	2	3	4	5	6	7	8	9
1	40	07	03	03	04	02	02	02	02
2	30	58	15	08	19	09	06	06	08
3	08	15	64	35	14	22	13	15	10
4	01	01	04	33	01	05	05	06	02
5	07	09	05	04	43	11	05	02	03
6	02	02	03	04	08	35	06	03	01
7	09	06	04	07	09	14	59	11	03
8			01	03	01		02	34	05
9	02	01	02	03	02	01	03	20	66

INDUSTRY 9
MACH., EQUIP

	1	2	3	4	5	6	7	8	9
1	33	13	06	06	11	06	06	05	05
2	32	42	22	16	25	21	18	17	18
3	22	31	58	40	30	34	27	23	23
4	03	03	04	23	05	07	06	12	06
5	03	03	03	02	18	09	03	05	04
6	01	02	02	02	05	15	03	03	02
7		01	01	05	02	04	25	06	03
8				01			01	14	02
9	05	04	03	05	04	03	10	17	37

true, however, for Industry 3, Mining, another industry with high-weight commodities. For this industry, none of the intraregional tonnage percentages are larger than the corresponding value percentage. This provides an example where aggregation of commodities is causing distortion in the analysis, because IO-8, Crude petroleum & natural gas, represents more than one-half of the total production of the mining sector and has a substantially different distribution of interregional shipments from that of the other mining industries.

The analysis at the 9-region and 10-industry level indicates that the West South Central and Pacific regions may be interesting ones to investigate in additional detail. In the first case, the region appears to have a phenomenal rate of growth; in the second case, the region would be interesting to study at a more disaggregated level because of its relative geographic isolation from the rest of the nation. The small number of transportation flows that do occur may therefore be easier to evaluate for this region.

A considerable amount of transportation information is obviously available from the MRIO calculations and can be used to undertake a comprehensive analysis of this important sector of the American economy. As mentioned earlier, the 1970 and 1980 projections of the interregional trade flows are available for 61 industries and for 44 regions. (Plans are being made to extend the data base to the state level within the coming year.) The results presented in this paper are only a representative sample of the enormous quantities of value and tonnage flow data that are

now available from the MRIO model for the United States. The estimates are preliminary and are therefore subject to revision.

Conclusion

One of the major advantages of using an MRIO framework for the analysis of transportation is the assurance that the commodity trade flows are internally consistent, that they can be used in conjunction with other information for a regional economy, such as technology and employment data, and that they are consistent with national aggregates for each commodity. A consistent, integrated approach to transportation analysis is useful for transportation policy decision makers who can analyze the direct and indirect effects that changes in the transportation sector or other sectors of the economy in one region of the United States will have upon transportation in all regions of the country. The present model and information, however, is only a small beginning in this direction.

Two basic needs exist for expanding the present study. One is to extend the transportation data base by including statistics on mode of transport, on regional variations in the transportation margins applied to the commodities produced by the input-output industries, and on regional transportation investment. The other is to extend the theoretical work on the model and to develop supplemental models for transportation to provide a more complete analysis. The transportation flows, for example, need to be analyzed by mode of transportation. This may require the

development of a supplemental modal-split model that can be linked into the basic MRIO framework. In addition, the MRIO model needs to be extended into a dynamic framework where current and future commodity transportation can be examined while accounting for changes in the economy over time. The static fixed coefficient models rely upon a basic assumption that neither the technology nor the trade coefficients change from those of the base period. Even this rather restrictive assumption, however, can be relaxed if projections of the coefficients are available. At the national level, for example, the technical input-output coefficients have been projected to 1970 and 1980, and it will hopefully be just a matter of time before similar projections are made of regional technical coefficients. Although no projections have been made of the trade coefficients, additional in-depth study of commodity transportation would make it possible to alter the regional trade coefficients. In addition, a dynamic framework would take explicit account of capital investment in the economy.

Because fewer data are required and because cross-hauls are explicitly estimated, the fixed coefficient models are superior to models that minimize transportation costs or maximize regional outputs. Transportation models that have cost minimization as their objective function must often be extensively refined to make them applicable for estimating interregional trade flows where cross-hauling occurs among regions. Cross-hauling, for example, accounted for some of the unreasonable results reported by Moses (1960) in his linear programming model for the United States.

As more transportation and other regional data become available, additional testing of alternative transportation models should be done to determine the conditions under which the various models operate most satisfactorily for policy purposes.

As stated earlier, the MRIO methodology provides four important advantages over most other regional study techniques in terms of the amount and consistency of regional and industrial detail supplied in the results and the use of the model and calculations by policy makers. Results of implementing the MRIO model will therefore be important for policy makers, in general, and for transportation policy makers, in particular.

Table A.1

REGIONAL CLASSIFICATION

Regions 9*	Regions 44	States 51	States Name
1	1	18	Maine
	2	44	Vermont
	3	20	Massachusetts
		38	Rhode Island
		28	New Hampshire
		6	Connecticut
2	4	31	New York
	5	37	Pennsylvania
		29	New Jersey
3	6	21	Michigan
		34	Ohio
	7	13	Indiana
		12	Illinois
	8	48	Wisconsin
4	9	22	Minnesota
	10	14	Iowa
	11	24	Missouri
	12	33	North Dakota
	13	40	South Dakota
	14	26	Nebraska
	15	15	Kansas
5	16	7	Delaware
		19	Maryland
	17	8	District of Columbia
	18	45	Virginia
	19	47	West Virginia
	20	32	North Carolina
	21	39	South Carolina
	22	10	Georgia
	23	9	Florida
6	24	16	Kentucky
	25	41	Tennessee
	26	1	Alabama
	27	23	Mississippi
7	28	3	Arkansas
	29	17	Louisiana
	30	35	Oklahoma
	31	42	Texas
8	32	25	Montana
	33	11	Idaho
	34	49	Wyoming
	35	5	Colorado
	36	30	New Mexico
	37	2	Arizona
	38	43	Utah
	39	27	Nevada
9	40	46	Washington
	41	36	Oregon
	42	4	California
	43	50	Alaska
	44	51	Hawaii

*The names of the 9 census regions are:

1	New England	6	East South Central
2	Middle Atlantic	7	West South Central
3	East North Central	8	Mountain
4	West North Central	9	Pacific
5	South Atlantic		

Table A.2

MULTIREGIONAL INPUT-OUTPUT INDUSTRY CLASSIFICATION

Industry No. MRIO 10	Industry No. MRIO 79	Industry No. OBE	Industry Title
1	1	1	Livestock, prdts.
2	2	2	Other agriculture prdts.
10	3	3	Forestry, fisheries
10	4	4	Agri.,fores.,fish. serv.
3	5	5	Iron, ferro. ores mining
3	6	6	Nonferrous ores mining
3	7	7	Coal mining
3	8	8	Crude petro.,natural gas
3	9	9	Stone, clay mining
3	10	10	Chem.,fert. min. mining
4	11	11	New construction
4	12	12	Maint., repair constr.
7	13	13	Ordnance, accessories
5	14	14	Food, kindred prdts.
5	15	15	Tobacco manufactures
6	16	16	Fabrics
6	17	17	Textile prdts.
6	18	18	Apparel
6	19	19	Misc. textile prdts.
8	20	20	Lumber, wood prdts.
8	21	21	Wooden containers
8	22	22	Household furniture
8	23	23	Other furniture
8	24	24	Paper, allied prdts.
8	25	25	Paperboard containers
8	26	26	Printing, publishing
8	27	27	Chemicals,select. prdts.
8	28	28	Plastics, synthetics
8	29	29	Drugs, cosmetics
8	30	30	Paint, allied prdts.
8	31	31	Petroleum, related inds.
8	32	32	Rubber, misc. plastics
8	33	33	Leather tanning, prdts.
8	34	34	Footwear, leather prdts.
8	35	35	Glass, glass prdts.
8	36	36	Stone, clay prdts.
8	37	37	Primary iron, steel mfr.
8	38	38	Primary nonferrous mfr.
8	39	39	Metal containers
8	40	40	Fabricated metal prdts.
8	41	41	Screw mach. prdts., etc.
8	42	42	Other fab. metal prdts.
9	43	43	Engines, turbines
9	44	44	Farm mach., equip.
9	45	45	Construc. mach., equip.
9	46	46	Material handling mach.
9	47	47	Metalworking machinery
9	48	48	Special mach., equip.
9	49	49	General mach., equip.
9	50	50	Machine shop prdts.
9	51	51	Office, comput. machines
9	52	52	Service ind. machines
9	53	53	Elect. transmiss. equip.
9	54	54	Household appliances
9	55	55	Electric lighting equip.
9	56	56	Radio, TV, etc., equip.
9	57	57	Electronic components
9	58	58	Misc. electrical mach.
7	59	59	Motor vehicles, equip.
7	60	60	Aircraft, parts
7	61	61	Other transport. equip.
9	62	62	Profess., scien. instru.
9	63	63	Medical, photo. equip.
9	64	64	Misc. manufacturing
10	65	65	Transport., warehousing
10	66	66	Communica.,exc. brdcast.
10	67	67	Radio, TV broadcasting
10	68	68	Elec.,gas,water,san.ser.
10	69	69	Wholesale, retail trade
10	70	70	Finance, insurance
10	71	71	Real estate, rental
10	72	72	Hotels, personal serv.
10	73	73	Business services
10	74	74	Research, development
10	75	75	Auto. repair, services
10	76	76	Amusements
10	77	77	Med.,educ. services
10	78	78	Federal govt. enterprise
10	79	79	State, local govt. ent.
11	80	80	Directly allocated imports
12	81	80	Transferred imports
13	82	89	Value added (row)
			Final demand (column)
14	83		Transfers-in (row)
			Transfers-out (column)
15	84		Inventory depletion
16	85	83	Scrap production
17	86	83	Scrap purchases
18	87		Regional total production

REFERENCES

Chenery, H.(1953), "Regional Analysis." In: H. Chenery and P. Clark (eds.) The Structure and Growth of the Italian Economy (U.S. Mutual Security Agency, Rome).

Leontief, W. and A. Strout(1963), "Multiregional Input-Output Analysis." In: T. Barna (ed.) Structural Interdependence and Economic Development (St. Martin's Press, Inc., New York).

Moses, L.N.(1960), "A General Equilibrium Model of Production, Interregional Trade, and Location of Industry." Review of Economics and Statistics 42, 209-224.

Moses, L.N.(1955), "The Stability of Interregional Trading Patterns and Input-Output Analysis." American Economic Review 45, 803-832.

Polenske, K.R.(May 1970), "An Empirical Test of Interregional Input-Output Models: Estimation of 1963 Japanese Production." American Economic Review 60, 76-82.

Polenske, K.R.(December 1970), "A Multiregional Input-Output Model for the United States." EDA Report No. 21, prepared for the Economic Development Administration, U.S. Department of Commerce.

Polenske, K.R., C.W. Anderson, and M.M. Shirley(1972), "A Guide for Users of the United States Multiregional Input-Output Model." Prepared for the Office of Systems Analysis and Information, U.S. Department of Transportation.