THE MULTIREGIONAL INPUT-OUTPUT PRICE MODEL: TRANSPORTATION CASE STUDY

by

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SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE
DEGREE OF

MASTER OF CITY PLANNING

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

SEPTEMBER 1978

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Department of Urban Studies and Planning
September 22, 1978

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ABSTRACT

The purpose of this research was to develop a version of the multiregional input-output (MRIO) model for use in forecasting the effect of transportation price increases on regional commodity prices. In the thesis particular attention is given to the impact of a transportation price increase on the price of commodities produced in Massachusetts and New England. The heavy reliance of the New England region on the transportation industry is discussed, particularly in the shipment of commodities into and out of the area.

The multiregional accounting procedures are reviewed to show how the data concerning the use of transportation services are handled in regional accounts and subsequently in the MRIO price model. The MRIO price model is extended theoretically from national input-output price models used in previous research efforts.

The MRIO price model is tested empirically with a hypothetical transportation price increase of 20 percent throughout the United States. Estimates are provided of commodity price changes in Massachusetts, the rest of New England, and the rest of the United States.

The prices of certain industries, particularly those dealing with extractive minerals, lumber, chemical, stone, and clay products, will be more severely affected than others by increases in transportation prices. Consideration is given to possible modifications of the MRIO price model to incorporate effects of changes in modal freight rates and to relax some of the assumptions of the initial model concerning constant technology and trade coefficients.

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Chapter 1

INTRODUCTION

The transportation industry plays an important role in the economy of a region. The various modes of transportation are the means by which commodities are shipped into the region, distributed within the region, or exported as manufactured goods from the region to other regions and countries. The prices of commodities within a region, therefore, will be affected by changes in the prices of transportation services.

Transportation prices within a region may change due to a variety of factors. Increases in the costs of fuel, labor, and other inputs will increase operating costs, leading to increases in transportation prices. Development of more efficient methods to utilize the existing capacity of rolling stock may lower operating costs, possibly leading to lower prices. Changes in the institutional structure, such as deregulation or increased regulation of transportation rates or operations, may also affect the prices of transportation services.

In this study, a multiregional input-output (MRIO) model is developed to estimate commodity price changes, using the transportation prices resulting from the implementation of a particular policy. The MRIO model has been used in the past to forecast regional changes in industrial outputs caused by changes in final demand. Pucher used the technique to make freight projections for midwestern railroads [16], and Jack Faucett Associates extended the technique for use in forecasting the employment impacts resulting in the final system plan for Conrail [5]. Input-output models have already been used by Leontief [10], Evers [4], Gupta [6], and other analysts to forecast commodity prices for a national economy.

In this study, the national input-output price model is extended for application at the multiregional level. The MRIO price model is developed and can be used to estimate the effect of a change in price of transportation within a particular region of a national economy on the other commodity prices within the same region and all commodity prices in other regions. Thus, the model is used to show the specific short-run regional differences that occur throughout the entire United States from an initial price increase in the transportation industry.

A summary of the New England transportation industry and its economic impacts is given in Chapter 2. The intermodal competition in this region is examined in regard to the amounts and types of commodities carried by the different modes into, within, and out of the region.

Because of its heavy reliance on imported commodities, New England is a good example of a region where the implementation of a transportation policy may have a marked effect on a regional economy. The New England economy is highly dependent on the transportation industry to ship in the petroleum, minerals, metals, agricultural, and other commodities used as inputs by producing industries and final users in the region; therefore, any changes in transportation prices should have a major impact on the regional economy.

A theoretical discussion of the development of the MRIO price model is presented in Chapter 3. The regional input-output accounting system is described first to demonstrate how the transportation industry is handled within the MRIO price model framework. The model can be used in the analysis of regional commodity price changes resulting from a change in value added or prices in any region and industry. A three-region, three-industry, example is used to clarify the theoretical discussion.

In Chapter 4, the results of a transportation pricing alternative analyzed with the MRIO price model are examined. The MRIO price model developed in the study was implemented using 1963 state MRIO data, aggregated into 3 regions and 79 industries. The industrial classification is given in Table A-1 in the appendix. The results of the study can be updated to a more current year as soon as the MRIO data for new years are assembled. Due to data, time, and financial constraints, the transportation industry was not disaggregated into the various modes. The commodity prices estimated using the model for the particular transportation pricing alternative reflect changes in freight rates of all modes.

For this study, special emphasis was given to the impact of changes in transportation rates on commodity prices in New England. A summary of the results with the implications of the research for future freight-pricing research is given. One area of research that is discussed is the possible extension of the MRIO price model for investigation at a modal level, allowing the model to be used for analysis of freight rate changes in, say, only the railroad industry. Another area of research that is discussed is the extension of the MRIO price model for long-run commodity price forecasts by updating the technical coefficients.

Chapter 2

TRANSPORTATION AND THE NEW ENGLAND ECONOMY

The freight transportation industry plays an important role in the New England economy through the shipping of various commodities into the region, the shipping of commodities to various cities and towns in the region, and the shipping of commodities from New England to other parts of the United States. Commodities such as petroleum, natural gas, minerals, agricultural, and processed food products are shipped into New England and distributed throughout the region. Products mined or manufactured in New England, such as lumber, stone and clay products, and electrical equipment, are shipped out of New England to other regions of the United States.

Four transportation modes are involved in the shipping of the majority of commodities into New England (inflows) and the shipping of commodities within the region and out of the region (outflows). They are rail, truck, air, and water.

In this study, the MRIO price model was used to study the impact of transportation price changes on the New England economy. The New England economy was chosen because of its high dependency upon the freight transportation industry.

COMMODITY FREIGHT MOVEMENTS

Comprehensive data on freight movements of commodities into and out of New England are available from the 1963 MRIO commodity trade-flow tables. In Table 1, the total value of these commodity flows is shown.

Table 1

COMMODITY TRADE FLOWS FOR NEW ENGLAND AND MASSACHUSETTS
(thousands of dollars)

	Total Commodity Trade Into New England From the U.S.	Percentage of Total Trade Into New England From the U.S.	Total Commodity Trade Originating Within Massachusetts	Percentage of Total Trade From Massachusetts To the U.S.
1 LIVESTOCK, PRDTS.	417655	3	129149	1
2 OTHER AGRICULTURE PRDTS.	459547	3	82158	1
3 FORESTRY, FISHERIES	0	0	75541	1
4 AGRI.,FORES.,FISH. SERV.	0	0	4998	0
5 IRON, FERRO. ORES MINING	26913	0	0	0
6 NONFERROUS ORES MINING	1490	0	188	0
7 COAL MINING	89488	1	9	0
8 CRUDE PETRO.,NATURAL GAS	104852	1	10299	0
9 STONE, CLAY MINING	10242	0	25081	0
10 CHEM.,FERT. MIN. MINING	8944	0	61	0
11 NEW CONSTRUCTION	0	0	0	0
12 MAINT., REPAIR CONSTR.	0	0	0	0
13 ORDNANCE, ACCESSORIES	206914	1	114557	1
14 FOOD, KINDRED PRDTS.	2018604	12	1515840	12
15 TOBACCO MANUFACTURES	340393	2	3208	0
16 FABRICS	520596	3	552378	4
17 TEXTILE PRDTS.	101677	1	234044	2
18 APPAREL	708787	4	701987	5
19 MISC. TEXTILE PRDTS.	102181	1	138196	1
20 LUMBER, WOOD PRDTS.	222345	1	85731	1
21 WOODEN CONTAINERS	14113	0	7523	0
22 HOUSEHOLD FURNITURE	174978	1	131460	1
23 OTHER FURNITURE	104359	1	37724	0
24 PAPER, ALLIED PRDTS.	468058	3	563859	4
25 PAPERBOARD CONTAINERS	67222	0	205353	2
26 PRINTING, PUBLISHING	171665	1	360578	3
27 CHEMICALS,SELECT. PRDTS.	360216	2	214393	2
28 PLASTICS, SYNTHETICS	429946	3	205010	2
29 DRUGS, COSMETICS	466227	3	175816	1
30 PAINT, ALLIED PRDTS.	51993	0	57179	0
31 PETROLEUM, RELATED INDS.	779041	5	200846	2
32 RUBBER, MISC. PLASTICS	297587	2	642606	5
33 LEATHER TANNING, PRDTS.	67184	1	189233	1
34 FOOTWEAR, LEATHER PRDTS.	71102	0	489604	4
35 GLASS, GLASS PRDTS.	143550	1	7428	0
36 STONE, CLAY PRDTS.	46630	0	229539	2
37 PRIMARY IRON, STEEL MFR.	780613	5	209583	2
38 PRIMARY NONFERROUS MFR.	696482	4	265221	2
39 METAL CONTAINERS	69695	0	24151	0

Table 1, continued

COMMODITY TRADE FLOWS FOR NEW ENGLAND AND MASSACHUSETTS
(thousands of dollars)

	Total Commodity Trade Into New England From the U.S.	Percentage of Total Trade Into New England From the U.S.	Total Commodity Trade Originating Within Massachusetts	Percentage of Total Trade From Massachusetts To the U.S.
40 FABRICATED METAL PRDTS.	274371	2	169894	1
41 SCREW MACH. PRDTS., ETC.	133719	1	134524	1
42 OTHER FAB. METAL PRDTS.	284239	2	313726	2
43 ENGINES, TURBINES	96716	1	168790	1
44 FARM MACH., EQUIP.	58419	0	6514	0
45 CONSTRUC. MACH., EQUIP.	107666	1	11170	0
46 MATERIAL HANDLING MACH.	76338	0	35941	0
47 METALWORKING MACHINERY	106498	1	214920	2
48 SPECIAL MACH., EQUIP.	123555	1	305156	2
49 GENERAL MACH., EQUIP.	182017	1	160427	1
50 MACHINE SHOP PRDTS.	89155	1	66479	1
51 OFFICE, COMPUT. MACHINES	104090	1	118695	1
52 SERVICE IND. MACHINES	77496	0	85483	1
53 ELECT. TRANSMISS. EQUIP.	265595	2	229987	2
54 HOUSEHOLD APPLIANCES	180590	1	41050	0
55 ELECTRIC LIGHTING EQUIP.	89627	1	166142	1
56 RADIO, TV, ETC., EQUIP.	785678	5	830821	6
57 ELECTRONIC COMPONENTS	228674	1	348775	3
58 MISC. ELECTRICAL MACH.	35935	0	60333	0
59 MOTOR VEHICLES, EQUIP.	1455126	9	322182	3
60 AIRCRAFT, PARTS	191669	1	197753	2
61 OTHER TRANSPORT. EQUIP.	198215	1	105019	1
62 PROFESS., SCIEN. INSTRU.	225200	1	275217	2
63 MEDICAL, PHOTO. EQUIP.	117949	1	212477	2
64 MISC. MANUFACTURING	265858	2	381601	3
65 TOTAL	16375735	100	12853607	100

The New England region imports large quantities of food and kindred products; motor vehicles and equipment; radios, TV's, and communication equipment; metal containers; petroleum and related industry products; apparel; and primary nonferrous manufactured products. Food and kindred products constitute 12 percent of the total value of manufactured commodities imported by New England. Motor vehicles and equipment constitute another 9 percent. ~~Other commodities that are shipped into New England in large amounts are petroleum and allied products; primary iron and steel manufacturing products; primary nonferrous manufacturing products; radio, television, and equipment; and apparel.~~

Information by mode on shipments of manufactured commodities into New England can be obtained from the Census of Transportation, 1972 [19]. These commodities are the products of manufacturing industries corresponding to input-output industries IO-14 through IO-64 in Table 1. Modal freight movements of agricultural and mineral commodities shipped into New England are not included in the Census, but those data can be assembled from miscellaneous transportation statistical sources.

Water transportation is used for virtually all of the petroleum and coal products that are shipped into the New England region. Food and kindred products and pulp, paper, and allied products are carried equally by rail and truck. Of the remaining commodities, trucks carry the largest proportion. Thus, the New England economy is heavily dependent upon water transportation for its petroleum and coal needs, but upon rail and truck transportation for the various other commodities. Air transportation carries less than 1 percent of the total freight imported by the region.

The New England region lacks petroleum and mineral resources and is dependent upon other regions and foreign countries for these commodities. The lack of a large agricultural industry also requires the importation of considerable quantities of food and kindred products. New England does have a large lumber industry in Maine, producing wood, paper, and allied commodities; and sand, gravel, stone, clay, lime, and feldspar are mined in all six states. Major manufacturing industries include electrical machinery in Massachusetts and New Hampshire and ordnance and metal products in Connecticut and Rhode Island. Some manufacturing industries, especially those producing textiles, have been moving out of the region for the past 50 years. The economic base of the region has been shifting to light manufacturing industries, producing goods such as jewelry, electronics, cameras, etc., and to the service industries.

The transportation industry in New England is involved in delivering commodities to the various cities and towns within the region and in exporting commodities manufactured in the region or imported from abroad to other parts of the United States. Food and kindred products are mainly shipped to points within New England. Commodities such as paper and allied products, fabrics, apparel, footwear and leather products, radios, TV's, communication equipment, and electronic components are exported in sizeable amounts to areas outside of New England. The Census of Transportation, 1972 [19] provides the tonnage distribution of manufactured commodities shipped from Massachusetts and Connecticut by the various modes. The modal distribution of commodities shipped from the other four states was not available. Also, the modal distribution of agricultural and mineral commodities shipped from New England was not available. Only data for Massachusetts, therefore, can be reviewed for these distributions.

Table 2 shows for 1972 the destinations of commodities manufactured in Massachusetts and shipped within and out of the state. Approximately 50 percent of the manufactured commodities originating in Massachusetts are shipped to other parts of New England, where they are used as intermediate inputs or are consumed. Another 24 percent are shipped to the adjacent Middle Atlantic states. The remaining portion goes to other parts of the country. Changes in transportation prices will affect the prices of all of these commodities, but to differing degrees.

Table 3 shows the 1972 distribution of the distance of shipments originating in Massachusetts. Almost 65 percent of the shipments travel less than 200 miles to the bordering New England states or to New York. The high percentage of short freight shipments is ideal for the trucking industry, which dominates New England freight transportation.

NEW ENGLAND TRANSPORTATION INDUSTRY

Water and truck transportation are the two major transportation industries serving New England. Water transportation, along with pipelines, supplies the region with all of its natural gas. Deep-sea tankers unload their cargoes at storage depots at the ports of Boston, Providence, New Haven, New London, Portland, and Searsport, Maine. The trucking industry carries almost 50 percent of the other commodities imported into the region and dominates the distribution of goods produced here, carrying 85 percent of this traffic. The railroad industry carries the remaining 50 percent of other products imported and a small percentage of the exported commodities. Air freight transportation is negligible, compared with these three, carrying less than 1 percent of the total freight shipped into and out of the region. It operates primarily out of Logan Airport in Massachusetts and Bradley Field in Connecticut. This mode carries high-value commodities, such as electrical machinery, instruments, photographic equipment, and medical goods.

The trucking industry in New England is large. There are 1,300 trucking companies located in Massachusetts alone. In addition, 800 other trucking firms from elsewhere in the United States and Canada transport goods to and from the region [2]. Figures from the Census of Transportation, 1972 [19] indicate that almost 240,000 trucks were registered in New England. However, some of these trucks do not operate primarily in the region or serve interstate traffic. The Census estimates that 3.8 million truck-miles were driven annually in transporting commodities in the New England region.

Table 2

DESTINATION OF SHIPMENTS OF MANUFACTURED COMMODITIES ORIGINATING IN MASSACHUSETTS, 1972

Destination	Tons (x1000)	Percentage by Mode: Rail	Truck	Air	Water	Other and Unknown
Rest of New England	6,307	2.8	96.6	--	0.1	0.7
Middle Atlantic	2,927	14.2	84.7	0.1	0.1	1.3
East North Central	1,064	32.0	66.0	0.4	--	1.9
West North Central	216	32.5	65.8	0.6	--	1.3
South Atlantic	1,021	32.3	62.4	0.3	0.5	4.3
East South Central	261	21.3	77.4	0.2	--	1.4
Mountain	40	23.0	74.3	1.8	--	1.2
Pacific	301	60.4	29.7	1.5	7.4	1.3
Total	12,397	13.7	84.8	0.2	0.3	1.3

SOURCE: U.S. Bureau of the Census. Census of Transportation, 1972, Vol. 3, No. 2, Northeast and North Central Regions, GPO, 1976.

Table 3

DISTANCE OF SHIPMENTS ORIGINATING IN MASSACHUSETTS, 1972

Distance in Miles	Percentage	Cummulative Percentage
< 100 miles	44.3	44.3
100-199	19.1	63.4
200-299	7.8	71.2
300-499	7.0	78.2
500-999	14.1	92.3
1,000-1,499	3.9	96.2
> 1,500	4.2	100.0

SOURCE: U.S. Bureau of the Census. *Census of Transportation, 1972*, Vol. III, Part 2, *Northeast and North Central Regions*, GPO, 1976.

The trucking industry has an advantage in New England in that it is more flexible than other modes. An estimated 70 to 80 percent of all New England communities do not have rail service, and these communities are totally dependent upon trucks [2]. A high percentage of the freight movements in the New England region are short-haul trips between the various cities and towns. Because of its flexibility and the existence of many short hauls, the trucking industry is ideally suited for these commodity-freight movements in New England.

The railroad industry in the region consists of two large corporations: Conrail and the Boston & Maine. Several other smaller companies also operate in the region. These include the Maine Central, the Bangor and Aroostook, the Providence and Worcester, the Grand Trunk, the Central Vermont, the Green Mountain, and the Vermont railroads. The major railroad companies and their principal lines and areas of operation are shown in Figure 1.

Conrail, the private corporation formed by the Railroad Revitalization and Regulatory Reform Act of 1976, provides freight services to and from Boston through southern New England. The Boston & Maine filed for bankruptcy in 1970 but is still operating in the central part of New England, providing service from Boston and Portland, Maine, to southern New Hampshire and Vermont, and to western connections with Conrail and the Delaware & Hudson. The Maine Central serves eastern and southern Maine and central New Hampshire and provides connections east to the Atlantic coast and north to the Canadian Pacific line. The

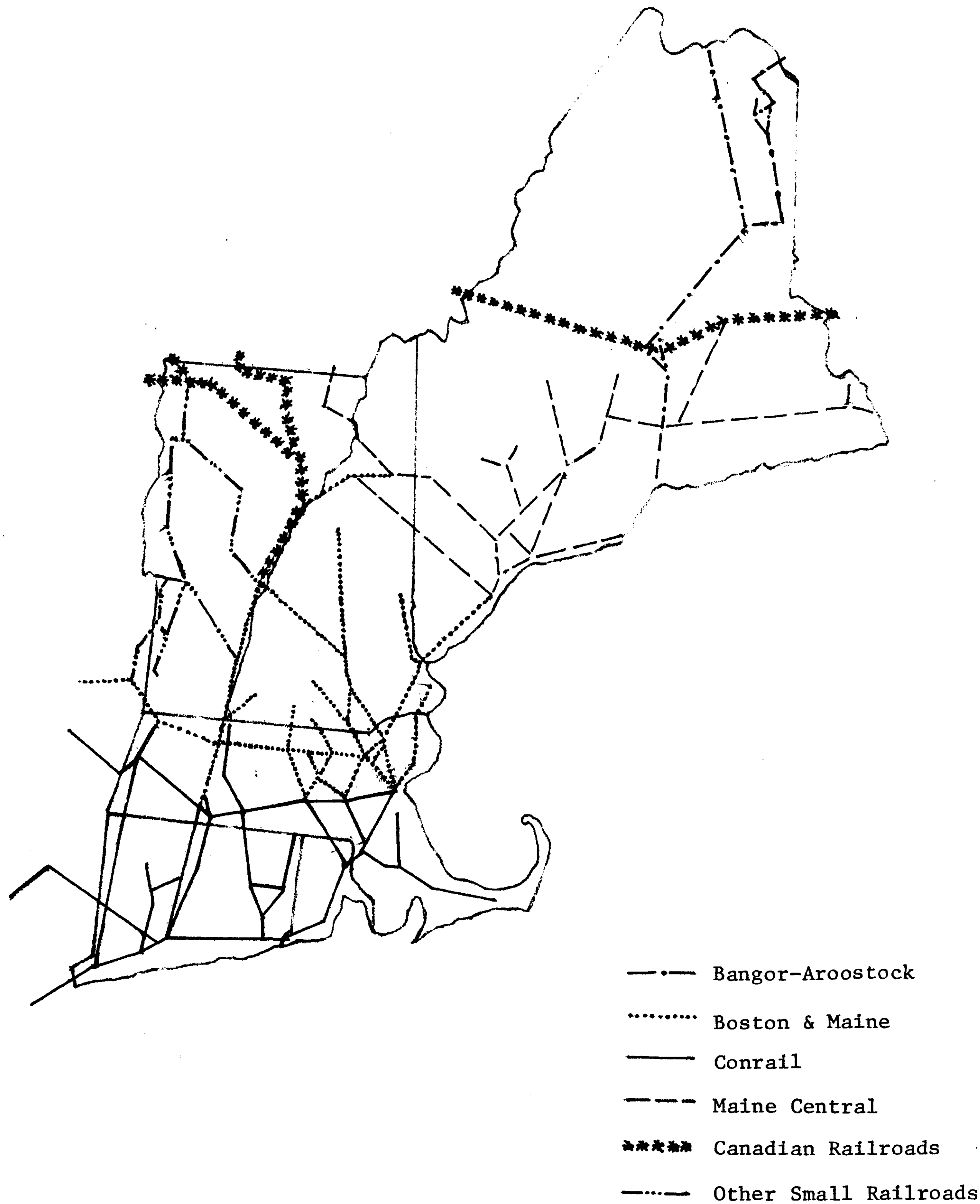

Figure 1. Principal Lines of Major New England Railroads

Bangor-Aroostook serves nothern Maine, most importantly the lumber and paper industries located there. The other smaller railroads serve local shippers.

The total railroad mileage in the New England area in 1975 was 5,333, distributed among the states as shown in Table 4. The railroads in New England are facing heavy competition from the trucking industry, and, to a lesser extent, from the air and water transportation industries. The railroad industry at present carries only 14 percent of the total commodity movements. There is an opportunity for railroads to compete with trucking for the traffic it can handle economically. Railroads are obviously an important component of the total transportation industry in New England.

In Chapter 3, the MRIO price model is developed for use in estimating the commodity prices that would result from increases in total transportation freight rates. The commodity price changes for 79 industries and 3 regions (Massachusetts, rest of New England, and rest of the United States) associated with a particular change in total transportation prices are examined in Chapter 4, and the possibilities of model extensions are discussed.

Table 4

NEW ENGLAND RAILROAD MILEAGE

State	Railroad Mileage
Massachusetts	1,405
Connecticut	656
Maine	1,665
New Hampshire	752
Rhode Island	134
Vermont	716
Total	5,328

SOURCE: Association of American Railroads. Yearbook of Railroad Facts, 1976 Edition.

Chapter 3

THE MULTIREGIONAL INPUT-OUTPUT PRICE MODEL

Multiregional input-output (MRIO) analysis requires a large quantity of regional and industrial data. The MRIO price model consists of two major statistical accounting tables: regional input-output tables and commodity trade-flow tables. Regional input-output tables provide a detailed account of the purchase of commodities and services by industries and final users in a region.

ECONOMIC LINKAGES OF THE TRANSPORTATION INDUSTRY

Changes in the prices of transportation services will affect other commodity prices through the economic linkages between the transportation industries and other industries in the United States. The purchases of transportation services by industries in a region are included in the regional input-output table, a three-region, three-industry, example of which is shown in Figure 2.

The table is represented by a square matrix with the producing industries along the side and the purchasing industries along the top. Each element in the table is the total purchase by the industry or final user listed at the top of the table of commodities or services produced by the industry or factors of production (value added) listed along the side, with the figure valued at the purchaser price, which includes the transportation and the wholesale and retail markups incurred in delivering the commodity to the purchaser. In these tables, each entry in the transportation row denotes the amount paid to transport the products of the respective industry listed at the top of the table. For

		Purchasing Industry				
		Agriculture-Mining	Manufacturing	Transportation and Other Services	Final Demand	Total Consumption
Producing Industry	Agriculture-Mining	42	611	109	68	830
	Manufacturing	59	7,975	1,024	10,248	19,306
	Transportation and Other Services	189	1,299	2,077	7,579	11,144
	Value Added	1,034	7,908	8,678		
	Total Purchases (production)	1,324	17,793	11,888		

NOTE: Figures are close approximations to the actual 1963 data.

Figure 2. Sample Regional Input-Output Table for Massachusetts, 1963
(million dollars)

example, the first entry in the transportation row will be the total cost of shipping all agricultural and mining products in the region.

The column sums denote the total purchases of commodities and services by the industries and final users in the regions listed at the top of the table. Under the premise of perfect competition, the value of the inputs is equal to the value of the outputs in the base-year accounts. Consequently, the column sums can be interpreted also as the total value of the output produced by the industries listed along the top. By dividing each element in the table by its respective column sum, technical coefficients are obtained, designating the amount of input per unit of output.

The flow of commodities into and out of New England is shown in the commodity trade-flow tables. An example of a commodity trade-flow table is shown in Figure 3.

The commodity trade-flow table is represented by a square matrix with the shipping regions along the side and the receiving regions along the top. Each element in the table denotes the total value of commodities shipped from the regions along the side of the table to the region at the top. Again, the value of commodities is measured in purchaser prices, which includes the transportation and the wholesale and retail markups.

Each column sum denotes the total value of commodities consumed in the region listed at the top of the table. By dividing each element in the table by its respective column sum, a commodity trade coefficient matrix is obtained. Each element denotes the value of a commodity shipped into a specific region as a fraction of the total value of consumption of that commodity in the region.

		Receiving Region			
		Massachusetts	New England	United States	Total
Shipping Region	Massachusetts	261	31	90	382
	New England	110	476	668	1,254
	United States	591	527	69,926	71,044
	Total	962	1,034	70,684	72,680

NOTE: Figures are close approximations to the actual 1963 data.

Figure 3. Sample Commodity Trade-Flow Table for the Agriculture and Mining Industry (million dollars)

To implement the MRIO price model, a set of value-added coefficients is needed, as well as both the technical coefficients and the commodity-trade coefficients. A detailed description of the model is now given.

NOTATIONS

Before describing the MRIO price model, the notational system will be outlined. The model involves the following seven types of variables:

	Physical	Value
Commodity Prices:	p_j^h	p_j^h
Total Output of Commodities:	q_j^h	x_j^h
Intermediate Input:	q_{ij}^h	x_{ij}^h
Total Value Added:	w_j^h	v_j^h
Technical Coefficients:	$f_{ij}^h = \frac{q_{ij}^h}{q_j^h}$	$a_{ij}^h = \frac{x_{ij}^h}{x_j^h}$
Interregional Trade Coefficients:	$d_i^{gh} = \frac{q_i^{gh}}{q_i^h}$	$c_i^{gh} = \frac{x_i^{gh}}{x_i^h}$
Value Added Per Unit of Output:	$z_j^h = \frac{w_j^h}{q_j^h}$	$u_j^h = \frac{v_j^h}{x_j^h}$

Subscripts on the variables refer to industries, where i denotes the producing industry and j denotes the purchasing industry. Superscripts on the variables refer to regions, where g denotes the exporting region and h denotes the importing region.

In this chapter, the word "industry" will refer to the group of firms producing commodities or services that are grouped together into a particular Standard Industrial Classification (SIC) code. The word "commodity" will refer to the specific items produced by an industry.

In the technology matrices, the specific originating region of an input is not known. Therefore, the total value added, technical coefficients, and value-added-per-unit-of-output variables do not include a region of origin (no g superscript). The interregional trade coefficients have a region of origin and destination for each particular commodity but no designation as to which industry purchased the commodity (no j subscript); they will be used to allocate commodities and value added to their proper originating region.

The national price model will be explained first. Because it is used to describe the economy for one contiguous area, no superscripts are needed.

NATIONAL PRICE MODEL

The dual price model for the national economy is based on the assumption that in a competitive economy the value of a commodity is composed of the value of intermediate inputs plus the value added components.

Using a three-industry example, the following system of three equations represents the commodity prices in the national economy:

$$\begin{aligned} p_1q_1 &= p_1q_{11} + p_2q_{21} + p_3q_{31} + p_vw_1 \\ p_2q_2 &= p_1q_{12} + p_2q_{22} + p_3q_{32} + p_vw_2 \\ p_3q_3 &= p_1q_{13} + p_2q_{23} + p_3q_{33} + p_vw_3 \end{aligned} \qquad (1)$$

where

p_jq_j = the value of the commodity j being produced,

p_iq_{ij} = the value of the intermediate input i needed in the production of commodity j, and

$p_v w_j$ = the total value-added component needed in the production of commodity q_j.

By introducing technical coefficients for the intermediate inputs,

$$f_{ij} = \frac{q_{ij}}{q_j}, \tag{2}$$

equation system (1) can be rewritten as:

$$\begin{aligned} p_1 q_1 &= p_1 f_{11} q_1 + p_2 f_{21} q_1 + p_3 f_{31} q_1 + p_v w_1 \\ p_2 q_2 &= p_1 f_{12} q_2 + p_2 f_{22} q_2 + p_3 f_{32} q_2 + p_v w_2 \\ p_3 q_3 &= p_1 f_{13} q_3 + p_2 f_{23} q_3 + p_3 f_{33} q_3 + p_v w_3 \end{aligned} \tag{3}$$

Dividing each equation j by the output, q_j, the following reduced system is obtained:

$$\begin{aligned} p_1 &= p_1 f_{11} + p_2 f_{21} + p_3 f_{31} + z_1 \\ p_2 &= p_1 f_{12} + p_2 f_{22} + p_3 f_{32} + z_2 \\ p_3 &= p_1 f_{13} + p_2 f_{23} + p_3 f_{33} + z_3 \end{aligned} \tag{4}$$

where

$z_j = \frac{p_v w_j}{q_j}$ is the value added required per unit of output of commodity q_j.

The system of equations can be written in the following matrix form:

$$\begin{bmatrix} p_1 \\ p_2 \\ p_3 \end{bmatrix} = \begin{bmatrix} f_{11} & f_{21} & f_{31} \\ f_{12} & f_{22} & f_{32} \\ f_{13} & f_{23} & f_{33} \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ p_3 \end{bmatrix} + \begin{bmatrix} z_1 \\ z_2 \\ z_3 \end{bmatrix} \tag{5}$$

The matrix notation is:

$$P = \begin{bmatrix} p_1 \\ p_2 \\ p_3 \end{bmatrix}, \qquad Z = \begin{bmatrix} z_1 \\ z_2 \\ z_3 \end{bmatrix}, \qquad F^t = \begin{bmatrix} f_{11} & f_{21} & f_{31} \\ f_{12} & f_{22} & f_{32} \\ f_{13} & f_{23} & f_{33} \end{bmatrix}.$$

The F^t matrix is the transpose of the technical coefficient matrix in the primal input-output model.

Writing the matrix system (5) using matrix notation, the following equation is obtained:

$$P = F^t P + Z \tag{6}$$

Now, the prices of commodities in the national economy can be solved for by isolating the P vector on one side of the equation. Solving for the price vector:

$$P - F^t P = Z \tag{7}$$

$$(I - F^t)P = Z \tag{8}$$

$$P = (I - F^t)^{-1} Z \tag{9}$$

Using equation (9), the commodity prices are determined as a function of the $(I - F^t)^{-1}$ matrix and the value-added-per-unit-of-output vector, Z. The $(I - F^t)^{-1}$ matrix is the exact transpose of the $(I - F)^{-1}$ matrix in the primal input-output model.

NORMALIZED PRICES

To derive the dual price equation system (4), each element in the equation system (3) is divided by the actual physical output of the respective commodity. Thus, the price vector represents the actual price of the commodity, and each element in the F^t matrix is the physical unit of intermediate input per unit of output of the commodity.

However, virtually all input-output data are collected in value terms rather than physical terms. To implement the model, either a physical technical coefficient matrix must be obtained or prices of commodities must be normalized to 1.0. As the MRIO data are in value terms ($p_{ij}q_{ij}$), commodity prices are normalized to 1.0 to allow for the use of technical coefficients measured in value terms.

The following example will clarify what is meant by normalizing prices to 1.0. Suppose the steel industry sells 200 tons of its product to the railroad industry at a price of $50 per ton. The total value of the transaction is $50 x 200 = $10,000. If commodity prices are normalized, this figure is to be interpreted as a flow of 10,000 fictional tons at a price of one dollar per ton.

The normalization of commodity prices to 1.0 allows the technical coefficient matrix, measured in value terms, to be used in the price model. By the use of the truncated price model developed later in the paper, commodity price changes can be computed as deviations from 1.0. A computed price of $1.25, for example, is interpreted as a 25 percent increase from the base price.

MULTIREGIONAL PRICE MODEL

The MRIO price model is an expansion of the national price model by the inclusion of trade of intermediate inputs between regions. Whereas in the national price model the intersectoral linkages in a national economy can be shown, in the MRIO price model, the interregional as well as the interindustrial linkages in a regional economy can be shown. In other words, the MRIO model can be used to trace the interdependencies of a particular industry in a region with other industries within its region and with industries outside its region.

Assumptions of the MRIO Price Model

The MRIO price model is based on the premise that the economy is competitive: in equilibrium, the price of a commodity must therefore be equal to the costs of producing one unit of the commodity. A price equation system can then be written in which commodity prices are a function of the costs of intermediate inputs and value added required for the production of one unit of the commodity.

Given a system of price equations describing a multiregional economy, three assumptions are made in order to implement the model. These three assumptions are constant technology, constant trade relationships, and constant industrial shares for each industry in a region.

The assumption of constant technology implies that the relationship of intermediate inputs required for production of a unit of output stays constant although input prices may change. This assumption does not allow for factor substitution to occur in response to relative changes in input prices. It is a severe limitation when the price model is used for long-range forecasts, because factor substitution will occur in the long run, resulting in inaccuracies in the technical coefficients. For example, increases in railroad shipping rates will ultimately force producers to switch to other modes of transportation, such as trucking and water. However, in the short run, the assumption is less important, as producers have set methods for transporting their goods and will not respond immediately to price changes.

The assumption of constant trade coefficients implies that trade relationships between regions will not change as input prices change. This constancy is unlikely to hold over time, especially if transportation rates increase. Higher shipping costs in one region will force producers to shift the importing of intermediate production inputs to regions where freight rates are lower. However, the shifting of trade relationships will not occur immediately, because producers will have commitments to firms that produce the intermediate inputs.

The assumption of constant industrial shares for each industry in a region is made in order to reduce the amount of data required to implement the model. The assumption implies that all industries in a region import identical fractions of a particular intermediate input from a particular region. This assumption reduces the commodity trade-flow requirements by two-thirds.

Model Implementation

To implement the MRIO price model, three basic sets of data are required: trade coefficients, technical coefficients, and value-added-per-unit-of-output coefficients. The expanded trade-coefficient matrix (C) is constructed from individual commodity trade-coefficient matrices. Using the three-region, three-industry, case, three commodity trade-coefficient matrices are needed. Figure 4 shows the organization

Industry 1

Shipping Region \ Receiving Region	1	2	3
1	c_1^{11}	c_1^{12}	c_1^{13}
2	c_1^{21}	c_1^{22}	c_1^{23}
3	c_1^{31}	c_1^{32}	c_1^{33}

Industry 2

Shipping Region \ Receiving Region	1	2	3
1	c_2^{11}	c_2^{12}	c_2^{13}
2	c_2^{21}	c_2^{22}	c_2^{23}
3	c_2^{31}	c_2^{32}	c_2^{33}

Industry 3

Shipping Region \ Receiving Region	1	2	3
1	c_3^{11}	c_3^{12}	c_3^{13}
2	c_3^{21}	c_3^{22}	c_3^{23}
3	c_3^{31}	c_3^{32}	c_3^{33}

Figure 4. Commodity Trade Coefficient Matrices for Three Regions and Three Industries

of these commodity trade-coefficient matrices. Each of the three matrices gives the interregional trade coefficients for a specific commodity. For example, the c_1^{21} term in the matrix for industry 1 denotes the flow of commodity 1 into region 1 from region 2, divided by the total flow of commodity 1 into region 1 from all regions. Thus, the coefficients in each column will sum to 1.0, as all of the specific commodity received by the particular region will be accounted for in the column sum. This formulation of the commodity trade-coefficient matrices is known as the column coefficient model.

To implement the model, each of the commodity-trade coefficients is rearranged into an expanded trade-coefficient matrix, composed of nine 3 x 3 diagonal block matrices, as shown in Figure 5. Each diagonal block matrix contains, along the principal diagonal, the trade coefficients for each of the three commodities shipped from a specific region to another region. Elements off the main diagonal of each block matrix are zero.

The second basic set of data required is the expanded technical coefficient matrix ($\hat{A}$), which is constructed from individual regional technical coefficient matrices, as shown in Figure 6. For the three-region, three-industry, case, three regional matrices are needed, each giving the technical coefficients for a particular region. Technical coefficients detail the amount of a particular commodity or service consumed in the production of one unit of output. For example, the a_{21}^{1} term in the matrix for region 1 denotes the amount of commodity 2 needed for the production of one unit of commodity 1 in region 1. The

		Receiving Region								
			1			2			3	
		c_1^{11}	0	0	c_1^{12}	0	0	c_1^{13}	0	0
	1	0	c_2^{11}	0	0	c_2^{12}	0	0	c_2^{13}	0
		0	0	c_3^{11}	0	0	c_3^{12}	0	0	c_3^{13}
		c_1^{21}	0	0	c_1^{22}	0	0	c_1^{23}	0	0
Shipping Region	2	0	c_2^{21}	0	0	c_2^{22}	0	0	c_2^{23}	0
		0	0	c_3^{21}	0	0	c_3^{22}	0	0	c_3^{23}
		c_1^{31}	0	0	c_1^{32}	0	0	c_1^{33}	0	0
	3	0	c_2^{31}	0	0	c_2^{32}	0	0	c_2^{33}	0
		0	0	c_3^{31}	0	0	c_3^{32}	0	0	c_3^{33}

Figure 5. Expanded Trade Coefficient Matrix for Three Regions and Three Industries

Region 1

Producing Industry	Purchasing Industry 1	2	3
1	a^{1}_{11}	a^{1}_{12}	a^{1}_{13}
2	a^{1}_{21}	a^{1}_{22}	a^{1}_{23}
3	a^{1}_{31}	a^{1}_{32}	a^{1}_{33}

Region 2

Producing Industry	Purchasing Industry 1	2	3
1	a^{2}_{11}	a^{2}_{12}	a^{2}_{13}
2	a^{2}_{21}	a^{2}_{22}	a^{2}_{23}
3	a^{2}_{31}	a^{2}_{32}	a^{2}_{33}

Region 3

Producing Industry	Purchasing Industry 1	2	3
1	a^{3}_{11}	a^{3}_{12}	a^{3}_{13}
2	a^{3}_{21}	a^{3}_{22}	a^{3}_{23}
3	a^{3}_{31}	a^{3}_{32}	a^{3}_{33}

Figure 6. Regional Technical Coefficient Matrices for Three Regions and Three Industries

three matrices are arranged along the main diagonal blocks of a 9 x 9 matrix to form the expanded technical coefficient matrix used in the implementation of the three-region, three-industry, model, as shown in Figure 7.

The third basic set of data is the value-added-per-unit-of-output vector. Each element in this vector denotes the value added required for producing one unit of output of a particular commodity in a region. For the three-region, three-industry case, this vector is arranged as shown in Figure 8. The u_2^1 term denotes the value added of commodity 2 needed per unit of output of commodity 2 in region 1.

With these three basic sets of data, the MRIO price model can be implemented. The national input-output price model (in value terms) is written as $P = A^tP + U$, where A^tP is the value of intermediate inputs needed to produce one unit of output, and U is the value added per unit of output. In the MRIO price model, trade between regions is introduced into the system by the expanded trade-flow matrix.

The trade of commodities needed as intermediate inputs for the production of a particular commodity in a region is represented by the transpose of the matrix multiplication of the expanded trade-flow matrix (C) times the expanded technical coefficient matrix ($\hat{A}$). In matrix notation, this is written as $(C\hat{A})^t$. Each element in the $(C\hat{A})^t$ matrix represents the amount of commodity i imported from region g needed to produce commodity j in region h. An example, using the three-region, three-industry, case, of the $(C\hat{A})^t$ matrix is shown in Figure 9. The $c_1^{12}a_{12}^2$ term in the fifth row and first column of the

		Purchasing Region								
		1			2			3		
		a_{11}^{1}	a_{12}^{1}	a_{13}^{1}	0	0	0	0	0	0
	1	a_{21}^{1}	a_{22}^{1}	a_{23}^{1}	0	0	0	0	0	0
		a_{31}^{1}	a_{32}^{1}	a_{33}^{1}	0	0	0	0	0	0
		0	0	0	a_{11}^{2}	a_{12}^{2}	a_{13}^{2}	0	0	0
Producing Region	2	0	0	0	a_{21}^{2}	a_{22}^{2}	a_{23}^{2}	0	0	0
		0	0	0	a_{31}^{2}	a_{32}^{2}	a_{33}^{2}	0	0	0
		0	0	0	0	0	0	a_{11}^{3}	a_{12}^{3}	a_{13}^{3}
	3	0	0	0	0	0	0	a_{21}^{3}	a_{22}^{3}	a_{23}^{3}
		0	0	0	0	0	0	a_{31}^{3}	a_{32}^{3}	a_{33}^{3}

Figure 7. Expanded Technical Coefficient Matrix for Three Regions and Three Industries

$$
\text{Region}\quad
\begin{matrix} \\ 1 \\ \\ \\ 2 \\ \\ \\ 3 \\ \\ \end{matrix}
\begin{bmatrix} u_1^1 \\ u_2^1 \\ u_3^1 \\ u_1^2 \\ u_2^2 \\ u_3^2 \\ u_1^3 \\ u_2^3 \\ u_3^3 \end{bmatrix}
$$

Figure 8. Value-Added-Per-Unit-Of-Output Vector for Three Regions and Three Industries

		Purchasing Region								
		1			2			3		
		$c_1^{11}a_{11}^1$	$c_2^{11}a_{21}^1$	$c_3^{11}a_{31}^1$	$c_1^{21}a_{11}^1$	$c_2^{21}a_{21}^1$	$c_3^{21}a_{31}^1$	$c_1^{31}a_{11}^1$	$c_2^{31}a_{21}^1$	$c_3^{31}a_{31}^1$
	1	$c_1^{11}a_{12}^1$	$c_2^{11}a_{22}^1$	$c_3^{11}a_{32}^1$	$c_1^{21}a_{12}^1$	$c_2^{21}a_{22}^1$	$c_3^{21}a_{32}^1$	$c_1^{31}a_{12}^1$	$c_2^{31}a_{22}^1$	$c_3^{31}a_{32}^1$
		$c_1^{11}a_{13}^1$	$c_2^{11}a_{23}^1$	$c_3^{11}a_{33}^1$	$c_1^{21}a_{13}^1$	$c_2^{21}a_{23}^1$	$c_3^{21}a_{33}^1$	$c_1^{31}a_{13}^1$	$c_2^{31}a_{23}^1$	$c_3^{31}a_{33}^1$
		$c_1^{12}a_{11}^2$	$c_2^{12}a_{21}^2$	$c_3^{12}a_{31}^2$	$c_1^{22}a_{11}^2$	$c_2^{22}a_{21}^2$	$c_3^{22}a_{31}^2$	$c_1^{32}a_{11}^2$	$c_2^{32}a_{21}^2$	$c_3^{32}a_{31}^2$
Producing Region	2	$c_1^{12}a_{12}^2$	$c_2^{12}a_{22}^2$	$c_3^{12}a_{32}^2$	$c_1^{22}a_{12}^2$	$c_2^{22}a_{22}^2$	$c_3^{22}a_{32}^2$	$c_1^{32}a_{12}^2$	$c_2^{32}a_{22}^2$	$c_3^{32}a_{32}^2$
		$c_1^{12}a_{13}^2$	$c_2^{12}a_{23}^2$	$c_3^{12}a_{33}^2$	$c_1^{22}a_{13}^2$	$c_2^{22}a_{23}^2$	$c_3^{22}a_{33}^2$	$c_1^{32}a_{13}^2$	$c_2^{32}a_{23}^2$	$c_3^{32}a_{33}^2$
		$c_1^{13}a_{11}^3$	$c_2^{13}a_{21}^3$	$c_3^{13}a_{31}^3$	$c_1^{23}a_{11}^3$	$c_2^{23}a_{21}^3$	$c_3^{23}a_{31}^3$	$c_1^{33}a_{11}^3$	$c_2^{33}a_{21}^3$	$c_3^{33}a_{31}^3$
	3	$c_1^{13}a_{12}^3$	$c_2^{13}a_{22}^3$	$c_3^{13}a_{32}^3$	$c_1^{23}a_{12}^3$	$c_2^{23}a_{22}^3$	$c_3^{23}a_{32}^3$	$c_1^{33}a_{12}^3$	$c_2^{33}a_{22}^3$	$c_3^{33}a_{32}^3$
		$c_1^{13}a_{13}^3$	$c_2^{13}a_{23}^3$	$c_3^{13}a_{33}^3$	$c_1^{23}a_{13}^3$	$c_2^{23}a_{23}^3$	$c_3^{23}a_{33}^3$	$c_1^{33}a_{13}^3$	$c_2^{33}a_{23}^3$	$c_3^{33}a_{33}^3$

Figure 9. $(C\hat{A})^T$ Matrix for Three Regions and Three Industries

matrix denotes the amount of commodity 1 exported from region 1 to region 2 and used in the production of one unit of commodity 2 in region 2.

To determine the value of the intermediate inputs needed to produce one unit of output, each term in the $(C\hat{A})^t$ matrix must be postmultiplied by the corresponding price of commodity i imported from region g. This is accomplished by postmultiplying the $(C\hat{A})^t$ matrix by the P vector, where the P vector consists of the prices of all commodities in all regions. Using the three-region, three-industry, case, the P vector is shown in Figure 10. Each term of the $(C\hat{A})^t P$ vector represents the sum of the value of intermediate inputs imported from all industries and all regions required for the production of one unit of a particular commodity in a specific region. It is the total value of all intermediate inputs required to produce one unit of that particular commodity.

Just as intermediate inputs are traded from region to region, so must the value-added-per-unit-of-output components be reallocated to their region of origin. This is accomplished by row-multiplying the transposed expanded trade-flow matrix (C^t) by the value-added-per-unit-of-output vector (U). The value added per unit of output for the production of a particular commodity in a region is reallocated to the region of origin by the trade coefficients for the particular commodity in its production region. The trade coefficients for a particular commodity in a region are contained in the respective column for that commodity and region in the commodity trade-coefficient matrices (see Figure 4). As was noted earlier, a column-coefficient trade model is

$$P = \begin{bmatrix} p_1^1 \\ p_2^1 \\ p_3^1 \\ p_1^2 \\ p_2^2 \\ p_3^2 \\ p_1^3 \\ p_2^3 \\ p_3^3 \end{bmatrix}$$

Figure 10. Commodity Price Vector for Three Regions and Three Industries

used where the sum of trade coefficients in each column is equal to 1.0. If the u_j^h terms are factored out of the respective terms in the $C^t rmU$ vector, the sum of the trade coefficients is equal to one. Therefore, the $C^t rmU$ vector is identical to the U vector.

$$\underline{C^t rmU \text{ Vector (Factored)}} \qquad \underline{U \text{ Vector}}$$

$$\begin{bmatrix} (c_1^{11} + c_1^{21} + c_1^{31})u_1^1 \\ (c_2^{11} + c_2^{21} + c_2^{31})u_2^1 \\ (c_3^{11} + c_3^{21} + c_3^{31})u_3^1 \\ (c_1^{12} + c_1^{22} + c_1^{32})u_1^2 \\ (c_2^{12} + c_2^{22} + c_2^{32})u_2^2 \\ (c_3^{12} + c_3^{22} + c_3^{32})u_3^2 \\ (c_1^{13} + c_1^{23} + c_1^{33})u_1^3 \\ (c_2^{13} + c_2^{23} + c_2^{33})u_2^3 \\ (c_3^{13} + c_3^{23} + c_3^{33})u_3^3 \end{bmatrix} = \begin{bmatrix} u_1^1 \\ u_2^1 \\ u_3^1 \\ u_1^2 \\ u_2^2 \\ u_3^2 \\ u_1^3 \\ u_2^3 \\ u_3^3 \end{bmatrix} \qquad (10)$$

The prices of commodities in the base MRIO price model are the sum of the value of intermediate inputs imported from all industries and regions required for the production of one unit of output of a particular commodity plus the value added per unit of output required for that commodity. Expressed in matrix notation, this is:

$$P = (C\hat{A})^t P \qquad + \qquad U \qquad (11)$$

value of intermediate inputs per unit of output	value added per unit of output

where

P = commodity price vector,

C = expanded trade-flow matrix,

$\hat{A}$ = expanded technical coefficient matrix, and

U = value-added-per-unit-of-output vector.

Using the three-region, three-industry, example, a system of nine equations represents the commodity prices in the multiregional economy, as shown in Figure 11.

The prices of commodities can be solved for by isolating the P vector on one side of the equation, as shown in equations 12-14:

$$P - (C\hat{A})^t P = U \tag{12}$$

$$[I - (C\hat{A})^t]P = U \tag{13}$$

$$P = [I - (C\hat{A})^t]^{-1} U \tag{14}$$

Using equation (14), the commodity prices are determined as a function of the $[I - (C\hat{A})^t]^{-1}$ matrix and the value-added-per-unit-of-output vector. The base MRIO price model can be used to estimate commodity price changes due to increases or decreases in the value added component needed in the production of certain commodities. An increase in the value added per unit of output for a particular industry in a region can be substituted in the appropriate term in the U vector. Using equation (14), the commodity price vector (P) can be calculated by matrix-multiplying the $[I - (C\hat{A})^t]^{-1}$ matrix by the revised U vector.

EMPIRICAL TESTING OF THE MRIO PRICE MODEL

The base MRIO price model was set up using data for the three-region, three-industry, case. A test of the base price model,

$$p_1^1 = c_1^{11}a_{11}^1p_1^1 + c_2^{11}a_{21}^1p_2^1 + c_3^{11}a_{31}^1p_3^1 + c_1^{21}a_{11}^1p_1^2 + c_2^{21}a_{21}^1p_2^2 + c_3^{21}a_{31}^1p_3^2 + c_1^{31}a_{11}^1p_1^3 + c_2^{31}a_{21}^1p_2^3 + c_3^{31}a_{31}^1p_3^3 + u_1^1$$

$$p_2^1 = c_1^{11}a_{12}^1p_1^1 + c_2^{11}a_{22}^1p_2^1 + c_3^{11}a_{32}^1p_3^1 + c_1^{21}a_{12}^1p_1^2 + c_2^{21}a_{22}^1p_2^2 + c_3^{21}a_{32}^1p_3^2 + c_1^{31}a_{12}^1p_1^3 + c_2^{31}a_{22}^1p_2^3 + c_3^{31}a_{32}^1p_3^3 + u_2^1$$

$$p_3^1 = c_1^{11}a_{13}^1p_1^1 + c_2^{11}a_{23}^1p_2^1 + c_3^{11}a_{33}^1p_3^1 + c_1^{21}a_{13}^1p_1^2 + c_2^{21}a_{23}^1p_2^2 + c_3^{21}a_{33}^1p_3^2 + c_1^{31}a_{13}^1p_1^3 + c_2^{31}a_{23}^1p_2^3 + c_3^{31}a_{33}^1p_3^3 + u_3^1$$

$$p_1^2 = c_1^{12}a_{11}^2p_1^1 + c_2^{12}a_{21}^2p_2^1 + c_3^{12}a_{31}^2p_3^1 + c_1^{22}a_{11}^2p_1^2 + c_2^{22}a_{21}^2p_2^2 + c_3^{22}a_{31}^2p_3^2 + c_1^{32}a_{11}^2p_1^3 + c_2^{32}a_{21}^2p_2^3 + c_3^{32}a_{31}^2p_3^3 + u_1^2$$

$$p_2^2 = c_1^{12}a_{12}^2p_1^1 + c_2^{12}a_{22}^2p_2^1 + c_3^{12}a_{32}^2p_3^1 + c_1^{22}a_{12}^2p_1^2 + c_2^{22}a_{22}^2p_2^2 + c_3^{22}a_{32}^2p_3^2 + c_1^{32}a_{12}^2p_1^3 + c_2^{32}a_{22}^2p_2^3 + c_3^{32}a_{32}^2p_3^3 + u_2^2$$

$$p_3^2 = c_1^{12}a_{13}^2p_1^1 + c_2^{12}a_{23}^2p_2^1 + c_3^{12}a_{33}^2p_3^1 + c_1^{22}a_{13}^2p_1^2 + c_2^{22}a_{23}^2p_2^2 + c_3^{22}a_{33}^2p_3^2 + c_1^{32}a_{13}^2p_1^3 + c_2^{32}a_{23}^2p_2^3 + c_3^{32}a_{33}^2p_3^3 + u_3^2$$

$$p_1^3 = c_1^{13}a_{11}^3p_1^1 + c_2^{13}a_{21}^3p_2^1 + c_3^{13}a_{31}^3p_3^1 + c_1^{23}a_{11}^3p_1^2 + c_2^{23}a_{21}^3p_2^2 + c_3^{23}a_{31}^3p_3^2 + c_1^{33}a_{11}^3p_1^3 + c_2^{33}a_{21}^3p_2^3 + c_3^{33}a_{31}^3p_3^3 + u_1^3$$

$$p_2^3 = c_1^{13}a_{12}^3p_1^1 + c_2^{13}a_{22}^3p_2^1 + c_3^{13}a_{32}^3p_3^1 + c_1^{23}a_{12}^3p_1^2 + c_2^{23}a_{22}^3p_2^2 + c_3^{23}a_{32}^3p_3^2 + c_1^{33}a_{12}^3p_1^3 + c_2^{33}a_{22}^3p_2^3 + c_3^{33}a_{32}^3p_3^3 + u_2^3$$

$$p_3^3 = c_1^{13}a_{13}^3p_1^1 + c_2^{13}a_{23}^3p_2^1 + c_3^{13}a_{33}^3p_3^1 + c_1^{23}a_{13}^3p_1^2 + c_2^{23}a_{23}^3p_2^2 + c_3^{23}a_{33}^3p_3^2 + c_1^{33}a_{13}^3p_1^3 + c_2^{33}a_{23}^3p_2^3 + c_3^{33}a_{33}^3p_3^3 + u_3^3$$

$$P = [C\hat{A}]^tP + U$$

Figure 11. System of Nine Price Equations in Nine Unknowns for Three Regions and Three Industries

$P = [I - (C\hat{A})^t]^{-1}U$, was performed to insure that the entire nine-equation system was internally consistent.

In the model, the price per unit of the commodity produced (the left-hand side of the equation) equals the value of intermediate inputs required for a unit of production plus the value added required per unit of output (the right-hand side of the equation). In the three-region, three-industry, model, if the nine commodity prices are substituted into the nine-equation system (11), the left-hand and right-hand side for each equation must be equal in order for the entire system to be consistent. Since all commodity prices are normalized to 1.0, the price vector (P) calculated with the base model should be a 9 x 1 column vector with each element equal to 1.0.

The empirical testing of the three-region, three-industry, model resulted in a 9 x 1 vector with each commodity price equal to 1.0. This result established that the model was set up correctly and served as a check before proceeding to the implementation of the truncated model for changes in any industrial output price.

TRUNCATED MRIO PRICE MODEL

The commodity price changes resulting from changes in the value added per unit of output needed to produce a particular commodity in a region can be estimated using the base MRIO price model. This model can be extended to trace the price repercussions in a multiregional economy resulting from regional commodity price changes.

The base MRIO price model serves as the foundation for the development of the truncated model to estimate commodity prices resulting from commodity price changes. To implement the truncated model, certain commodity prices are exogenously determined. For example, if the price of transportation services in a particular region has increased by 20 percent over the base price, the transportation commodity price is exogenously set to 1.2. The price increase in that region will affect the commodity prices in other industries and regions through the use of the higher-priced transportation services as intermediate inputs in their production. The column that corresponds to the use of this higher-priced transportation service is truncated from the $(C\hat{A})^t$ matrix. The row in the $(C\hat{A})^t$ matrix that corresponds to the use of the other commodities as intermediate inputs in the production of the higher-priced transportation service is also truncated, as the exogenously determined price is assumed not to be affected by other commodity prices. If the base model consists of n equations and an n x n $(C\hat{A})^t$ matrix, the truncated model will consist of $n - \alpha$ equations and an $(n - \alpha) \times (n - \alpha)$ $(C\hat{A})^t$ matrix, where α is the number of commodity prices determined exogenously.

One final step is required. Each element in the column of the $(C\hat{A})^t$ matrix that denotes the use of the higher-priced transportation services as intermediate inputs in the production of other commodities is multiplied by the exogenously determined price and added into the model. The linkages between the exogenously determined transportation industry and other industries in the same region and in other regions are included in the model.

To illustrate the development of the truncated model in detail, the three-region, tnree-industry, case will be used to estimate the effect of a 20 percent increase in the price of the commodity produced by the first industry in the first region. The price is exogenously determined such that $p_1^1 = 1.2$. The commodity prices for the other industries in region 1 and for all industries in regions 2 and 3 are now affected by the price increase. These eight commodity prices can be written in an 8 x 1 P* vector where the p_1^1 term is now eliminated (the * will indicate a truncated matrix).

The price increase of industry 1 in region 1 affects the other industry prices through the trade of its commodities and their use as intermediate inputs in the production of other commodities. The elements in the first column of the $(C\hat{A})^t$ matrix (see Figure 9) represent the trade and use of commodity 1 from region 1 as intermediate inputs. When each element of this vector is multiplied by the exogenous set price of commodity 1 in region 1, each term is the value of the intermediate input of commodity 1 from region 1 needed to produce one unit of the commodity manufactured by the particular industry. This vector is the immediate production cost effect and is denoted as the T vector in matrix notation.

The first term in the T vector is truncated, as this is the input of commodity 1 for the production of commodity 1 within the first region. The truncated T* vector is now obtained, as shown in Figure 12.

The $(C\hat{A})^t$ matrix (Figure 9) is truncated to an 8 x 8 $(C\hat{A})^{t*}$ matrix, where the column corresponding to the outflow of industry 1 from region 1 to other industries and regions and the row corresponding

$$T^* = \begin{bmatrix} c_1^{11} a_{12}^1 p_1^1 \\ c_1^{11} a_{13}^1 p_1^1 \\ c_1^{12} a_{11}^2 p_1^1 \\ c_1^{12} a_{12}^2 p_1^1 \\ c_1^{12} a_{13}^2 p_1^1 \\ c_1^{13} a_{11}^3 p_1^1 \\ c_1^{13} a_{12}^3 p_1^1 \\ c_1^{13} a_{13}^3 p_1^1 \end{bmatrix}$$

where

$$p_1^1 = 1.2$$

Figure 12. Truncated Immediate Production Cost Effect Vector (T*) with p_1^1 Set Exogenously

to the inflow of commodities as intermediate inputs for the production of commodity 1 in region 1 are excluded. The truncated $(C\hat{A})^{t*}$ matrix is matrix-multiplied by the P* vector to obtain the value of intermediate-inputs-per-unit-of-output vector.

Finally, the value-added-per-unit-of-output vector (U), as shown in Figure 8, must be truncated to an 8 x 1 vector, U*, where the term corresponding to the value added per unit of output for commodity 1 in region 1 is excluded.

The prices of commodities are equal to the sum of the value of intermediate inputs (other than those of commodity 1 from region 1) required for the production of one unit of output in the particular industry, the immediate production cost effect of the use of the higher-priced commodity 1 from region 1, and the value added required per unit of output. Therefore, the price of a commodity is equal to the total production costs per unit of output.

The eight-equation system can be written in matrix notation as:

$$P^* = (C\hat{A})^{t*}P^* + T^* + U^* \tag{15}$$

where

P^* = the truncated commodity price vector,

$(C\hat{A})^{t*}P^*$ = the truncated value of intermediate-input-per-unit-of-output vector, excluding the commodities where prices are determined exogenously,

T^* = the truncated <u>immediate</u> production cost effect vector for those commodities whose price is determined exogenously, and

U^* = the truncated value-added-per-unit-of-output vector.

By writing out equation (15) in full, an eight-equation system in eight unknowns is obtained. This eight-equation system differs from the nine-equation system (see Figure 11) obtained from the base price model by the exclusion of the price equation for commodity 1 in region 1. The T* vector is the first column of terms in the nine-equation system that corresponds to the cost of using commodity 1 from region 1 as an intermediate input (that is, the first column of $c_j^{gh} a_{ij}^h p_j^g$ terms in the nine-equation system, shown in Figure 11).

The commodity prices can be solved for by isolating the P* vector on one side of the equation and solving equation (15):

$$P^* - (C\hat{A})^{t*} P^* = T^* + U^* \quad (16)$$

$$[I - (C\hat{A})^{t*}] P^* = T^* + U^* \quad (17)$$

$$P^* = [I - (C\hat{A})^{t*}]^{-1} [T^* + U^*] \quad (18)$$

After solving equation (15) for the commodity prices, P*, the value-added-per-unit-of-output for industry 1 in region 1 must be recalculated using the exogenously set $p_1^1 = 1.2$ and the eight estimated commodity prices. This revised value-added-per-unit-of-output term can be interpreted as the new amount of value added required per unit of output, with all commodity prices having reached the new short-run equilibrium.

Since the price of commodity 1 in region 1 was determined exogenously, the corresponding value-added-per-unit-of-output term becomes the new unknown variable. The revised value-added-per-unit-of-output term can be calculated by substituting the nine new commodity prices into the equation for commodity 1 in region 1 and solving for the u_1^1 term as follows:

$$p_1^{1*} = c_1^{11} a_{11}^1 p_1^{1*} + c_2^{11} a_{21}^1 p_2^{1*} + c_3^{11} a_{31}^1 p_3^{1*}$$

$$+ c_1^{21} a_{11}^1 p_1^{2*} + c_2^{21} a_{21}^1 p_2^{2*} + c_3^{21} a_{31}^1 p_3^{2*} \qquad (19)$$

$$+ c_1^{31} a_{11}^1 p_1^{3*} + c_1^{31} a_{21}^1 p_2^{3*} + c_3^{31} a_{31}^1 p_3^{3*} + u_1^1$$

Isolating u_1^1 on one side of the equation,

$$u_1^1 = p_1^{1*} - c_1^{11} a_{11}^1 p_1^{1*} - c_2^{11} a_{21}^1 p_2^{1*} - c_3^{11} a_{31}^1 p_3^{1*}$$

$$- c_1^{21} a_{11}^1 p_1^{2*} - c_2^{21} a_{21}^1 p_2^{2*} - c_3^{21} a_{31}^1 p_3^{2*} \qquad (20)$$

$$- c_1^{31} a_{11}^1 p_1^{3*} - c_1^{31} a_{21}^1 p_2^{3*} - c_3^{31} a_{31}^1 p_3^{3*}$$

Placing equation (16) into more general notation, the following is obtained:

$$u_j^h = p_j^h - \sum_{i=1}^{m} \sum_{g=1}^{n} c_j^{gh} a_{ij}^h p_i^{g*} \qquad (21)$$

where

u_j^h = the value added per unit of output for the particular industry j in region h whose price is exogenously set,

p_i^{g*} = the new short-run equilibrium commodity prices,

m = the total number of industries, and

n = the total number of regions.

Using equation (18), the commodity prices are a function of the $[I - (C\hat{A})^{t*}]^{-1}$ matrix, the truncated value-added-per-unit-of-output vector, U*, and the immediate production cost effect vector, T*. The truncated model can be extended to estimate commodity price changes resulting from a number of exogenously determined prices. If α prices were exogenously set, the $(C\hat{A})^t$ matrix would be truncated to an $(n - \alpha)(n - \alpha)$ $(C\hat{A})^{t*}$ matrix, where columns and rows correspond to the inflows and outflows of those commodities. The U vector would also be truncated to an $(n - \alpha) \times 1$ vector. Those terms corresponding to the U vector for those industries whose prices have been exogenously set will be excluded in the truncated U* vector. There will be α $(n - \alpha) \times 1$ immediate production cost effect vectors, T, corresponding to those industries whose prices have been set.

Equation (18) can be used to estimate commodity price changes for a variety of combinations of initial regional and commodity price increases and decreases. The truncated model can be used to conduct policy analyses for a wide range of pricing alternatives. These policy alternatives can be analyzed by the appropriate truncation of the $(C\hat{A})^t$ matrix and U vector and the creation of a T* vector reflecting the regional and industrial commodity price changes.

APPLICABILITY OF THE MRIO MODEL PRICE DETERMINATIONS

The MRIO price model is based upon the premise of perfect competition where commodity prices must equal production costs. Therefore, the model is applicable in areas where a competitive economy exists. In economies where free competition does not exist as a result of monopolies or government subsidization of production costs, the model may underestimate or overestimate commodity prices.

The implementation of the MRIO price model involves three assumptions: (1) fixed technical relationships through time, (2) fixed trade relationships through time, and (3) constant industrial shares for each industry in a region.

The first and second assumptions limit the applicability of the price model to forecasts in the short-run time span, where industries are not able to undergo factor substitution and existing trade relationships change. The estimates produced by the price model can be thought of as the short-run equilibrium prices, where increases in input costs are passed on through final commodity prices. As the estimates are made further into the future, they will become less accurate, as factor substitution and shifting trade relationships make technical and trade coefficients less reliable.

The third assumption reduces the amount of data required to implement the model. However, this is done at the cost of introducing inaccuracies in the allocation of intermediate inputs to producing industries.

Due to these assumptions, the MRIO price model should only be used to provide short-run commodity price estimates, say from one to ten years. Firms will not react to commodity price changes in the short run, as commitments for productive inputs are already established. However, in the long run, factor substitution and changes in trade patterns will occur as firms adjust to new relative input prices. In the long run, the MRIO price model, as presently formulated with assumptions of fixed technical and trade relationships, will not account for these responses by the firms to new relative prices. Consequently, long-run commodity price forecasts will be less accurate. Dynamic multiregional input-output price models can be developed to account for these shifts through intertemporal linkages of technical and trade coefficients. This is an area for future research, which will be discussed later.

Chapter 4

ANALYSIS OF A TRANSPORTATION PRICING ALTERNATIVE AND CONCLUSIONS

The truncated MRIO price model can be used for analyzing transportation freight rate increases. An example of the types of analyses that can be made is presented here, using the 1963 multiregional data for 3 regions and 79 industries. In these data, warehousing is included in the transportation industry; however, it is a relatively small component. A more serious problem is that the transportation industry is not separated into the various modes. The results of implementing the model therefore reflect rate changes in all of the transportation industry, rather than rate changes in individual modes. Data are available at a modal level, so it is anticipated that specific results of modal freight-rate changes can be examined in future research efforts. The methodological technique developed in this study will provide complete commodity price changes at the regional level. The extension of this technique for estimating modal freight-rate changes is discussed in detail in the section on future areas of research at the end of this chapter.

The three regions analyzed in the study are the state of Massachusetts, the rest of New England, and the rest of the United States. These regions were selected so that the repercussions of possible transportation freight rate changes could be observed at the local Massachusetts and New England level. The industrial classification is given in Table A-1 in the appendix.

The extent of the direct economic linkages between transportation and each of the 79 industries is indicated by the magnitude of the technical coefficients shown in the transportation row of the three regional input-output tables. Each technical coefficient in the row denotes the value of transportation services required per unit of total output for the particular industry. The industries in the three regions requiring the most transportation services for producing a unit of output are shown in Table 5. The data for all 79 industries are shown in Table A-2 in the appendix.

As shown in the table, extractive industries, such as stone, clay, coal, iron, chemical, fertilizer, and mineral mining require approximately 15 to 25 cents of transportation services per dollar of output. Federal government enterprises in New England, especially the postal service, relied heavily upon the transportation industry in 1963, requiring about 9 cents of input per dollar of output. Industries involved in the manufacture of basic wood, iron, metal, petroleum, agricultural, chemical, and glass products require approximately 4 to 15 cents of transportation services per dollar of output. For the other industries, intermediate input costs associated with transportation are on the order of one to three cents. The industries that require a high proportion of transportation services to market their outputs would of course be the most sensitive to transportation freight-rate increases.

Table 5

DIRECT INPUTS REQUIRED FROM THE TRANSPORTATION INDUSTRY
PER DOLLAR OF OUTPUT
(in dollars)

Massachusetts			Rest of New England			Rest of United States		
IO No.	Industry	Direct Inputs	IO No.	Industry	Direct Inputs	IO No.	Industry	Direct Inputs
9	Stone & Clay Mining	0.2632	9	Stone & Clay Mining	0.2303	7	Coal Mining	0.2253
2	Other Agriculture Prdts.	0.1423	78	Federal Gov't Enterprise	0.0951	9	Stone & Clay Mining	0.2190
35	Glass & Glass Prdts.	0.1330	31	Petroleum, Related Inds.	0.0861	5	Iron, Ferro. Ores Mining	0.2005
20	Lumber & Wood Prdts.	0.1294	20	Lumber & Wood Prdts.	0.0714	10	Chem. & Fert. Min. Mining	0.1428
78	Federal Gov't Enterprise	0.0951	65	Transport. & Warehousing	0.0665	78	Federal Gov't Enterprise	0.0951
31	Petroleum, Related Inds.	0.0800	37	Primary Iron, Steel Mfr.	0.0644	8	Crude Petro., Natural Gas	0.0760
37	Primary Iron, Steel Mfr.	0.0777	2	Other Agriculture Prdts.	0.0625	20	Lumber & Wood Prdts.	0.0739
27	Chemicals, Select. Prdts.	0.0669	36	Stone & Clay Prdts.	0.0610	65	Transport. & Warehousing	0.0738
65	Transport. & Warehousing	0.0664	21	Wooden Containers	0.0604	36	Stone & Clay Prdts.	0.0616
21	Wooden Containers	0.0630	27	Chemicals, Select. Prdts.	0.0539	21	Wooden Containers	0.0567
1	Livestock & Prdts.	0.0628	35	Glass & Glass Prdts.	0.0539	3	Forestry & Fisheries	0.0531
36	Stone & Clay Prdts.	0.0554	6	Nonferrous Ores Mining	0.0484	24	Paper & Allied Prdts.	0.0480
3	Forestry & Fisheries	0.0446	30	Paint & Allied Prdts.	0.0465	35	Glass & Glass Prdts.	0.0449
24	Paper & Allied Prdts.	0.0433	39	Metal Containers	0.0411	27	Chemicals, Select. Prdts.	0.0436
39	Metal Containers	0.0403	3	Forestry & Fisheries	0.0395	37	Primary Iron, Steel Mfr.	0.0435

SUMMARY OF RESULTS

A transportation pricing alternative was implemented using the 79-industry, 3-region, version of the MRIO model by setting the price of transportation in the three regions exogenously.[1] Equation (18) in Chapter 3 formed the theoretical basis for the calculations. The truncated price model was used to analyze the effects of an increase of 20 percent in the price of transportation services throughout the entire United States. Such an alternative would correspond to an across-the-board increase of 20 percent in the shipping rates of all four modes--rail, truck, water, and air transportation. Such an increase would be felt in the prices of commodities in Massachusetts, the whole New England area, and the rest of the United States. The prices for the industries in these three regions that are most affected by the increase are shown in Table 6, with a complete listing of all price changes being given in Table A-3 in the appendix.

As shown in the table, industries in Massachusetts and the New England region dealing with stone, clay minerals, and with wood, paper, and allied products show the largest increases in prices--ranging from 2 to 6 percent. Industries in New England manufacturing chemical, plastic, and small metal products show price increases ranging from 1 to 2 percent. In the case of New England, as these industries are

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[1]These 1963 MRIO data were aggregated from the full-scale, 79-industry, 51-region data that are available on computer tape from the National Technical Information Service. The data were transformed from producer to purchaser prices before implementing the MRIO price model.

Table 6

COMMODITY PRICE INCREASES FOR INDUSTRIES MOST AFFECTED BY
A 20 PERCENT INCREASE IN THE PRICE OF TRANSPORTATION
THROUGHOUT THE UNITED STATES
(in dollars)

Massachusetts			Rest of New England			Rest of United States		
IO No.	Industry	Commodity Price Change	IO No.	Industry	Commodity Price Change	IO No.	Industry	Commodity Price Change
9	Stone & Clay Mining	1.0549	9	Stone & Clay Mining	1.0477	7	Coal Mining	1.0516
2	Other Agriculture Prdts.	1.0323	31	Petroleum, Related Inds.	1.0214	9	Stone & Clay Mining	1.0463
20	Lumber & Wood Prdts.	1.0318	21	Wooden Containers	1.0213	5	Iron, Ferro. Ores Mining	1.0434
35	Glass & Glass Prdts.	1.0293	36	Stone & Clay Prdts.	1.0213	10	Chem. & Fert. Min. Mining	1.0324
37	Primary Iron, Steel Mfr.	1.0225	37	Primary Iron, Steel Mfr.	1.0212	20	Lumber & Wood Prdts.	1.0225
21	Wooden Containers	1.0224	20	Lumber & Wood Prdts.	1.0208	36	Stone & Clay Prdts.	1.0212
78	Federal Gov't Enterprise	1.0207	78	Federal Gov't Enterprise	1.0207	21	Wooden Containers	1.0208
31	Petroleum, Related Inds.	1.0202	2	Other Agriculture Prdts.	1.0174	78	Federal Gov't Enterprise	1.0207
36	Stone & Clay Prdts.	1.0202	27	Chemicals, Select. Prdts.	1.0163	37	Primary Iron, Steel Mfr.	1.0179
27	Chemicals, Select. Prdts.	1.0183	39	Metal Containers	1.0163	8	Crude Petro., Natural Gas	1.0169
1	Livestock & Prdts.	1.0177	35	Glass & Glass Prdts.	1.0155	24	Paper & Allied Prdts.	1.0163
39	Metal Containers	1.0167	25	Paperboard Containers	1.0149	31	Petroleum, Related Inds.	1.0150
24	Paper & Allied Prdts.	1.0160	30	Paint & Allied Prdts.	1.0140	27	Chemicals, Select. Prdts.	1.0142
38	Primary Nonferrous Mfr.	1.0133	24	Paper & Allied Prdts.	1.0136	25	Paperboard Containers	1.0140
25	Paperboard Containers	1.0129	28	Plastics & Synthetics	1.0133	35	Glass & Glass Prdts.	1.0139
28	Plastics & Synthetics	1.0126	40	Fabricated Metal Prdts.	1.0117	1	Livestock & Prdts.	1.0138
30	Paint & Allied Prdts.	1.0119	50	Machine Shop Prdts.	1.0114	39	Metal Containers	1.0138
40	Fabricated Metal Prdts.	1.0117	1	Livestock & Prdts.	1.0112	3	Forestry & Fisheries	1.0130
3	Forestry & Fisheries	1.0115	38	Primary Nonferrous Mfr.	1.0111	2	Other Agriculture Prdts.	1.0125

an important part of the region's economic base, transportation price increases may have a serious impact on the regional economy.

Mining industries in the rest of the United States also demonstrate a high sensitivity to transportation price increases. The price for coal mining increased by 5.1 percent, stone and clay mining by 4.6 percent, iron and ferrous ores mining by 4.3 percent, chemical fertilizer mineral mining by 3.2 percent, in response to a transportation price increase of 20 percent. Industries producing stone, clay, and lumber products show price increases of 2 to 3 percent. Agricultural goods, petroleum and related products, chemical, glass, and primary iron and steel products show price increases ranging from 1 to 2 percent.

The results indicate the strong reliance and dependency of these mineral extractive industries upon the prices of transportation services. These industries require between 20 to 30 cents of transportation services to produce one dollar's worth of output (see Table 5, page 59). Consequently, their prices have risen by 3 to 6 percent in response to an increase of 20 percent in transportation prices. The agriculture, lumber, and petroleum industries, in addition to industries producing manufactured commodities, show a lesser impact from the transportation price change. These industries require less direct expenditures on transportation services per dollar's worth of output.

Again, as in the New England region, transportation price increases will have a substantial effect on a few industries, especially those dealing with the mining of natural minerals. Agricultural and petroleum industries will be somewhat affected, while manufacturing industries will exhibit only small price changes.

Under the alternative of a 20 percent increase in the price of transportation services throughout the United States, only a small number of industries in the three regions exhibit large price increases. These are industries involved in the mining of mineral resources. Their prices consistently show a 3 to 6 percent increase. The agriculture, lumber, and related products industries, and primary iron and steel manufacturing exhibit increases of 2 to 3 percent. A wide variety of industries exhibit price increases of 1 to 2 percent. Generally, these industries are involved in the manufacture of basic metal, chemical, petroleum, or glass products. Industries manufacturing complex products such as machinery, electrical equipment, and motor vehicles exhibit price increases of less than 1 percent. The analysis should now be extended in a number of ways to provide a more in-depth analysis of the economic consequences of these changes.

FUTURE AREAS OF RESEARCH

The technique of multiregional input-output analysis has been applied to the estimation of commodity price changes resulting from increases in the transportation freight rates in a specific region through the development of the truncated MRIO price model. In this model, the price of transportation services in a region is exogenously set to some number that reflects a possible price increase. These exogenously determined prices are used as inputs into the model to estimate the other commodity prices.

The truncated MRIO price model can be elaborated to forecast commodity prices resulting from freight rate increases for a specific mode, such as railroads. To do this, the transportation industries must be divided into subindustries for each of the different modes. The contribution of transportation services by each mode to the other industries for the production of their commodities must be determined. These are the technical coefficients corresponding to the use of a specific mode's service as an intermediate productive input. Likewise, the value-added component of the transportation industry must be allocated to the various modes. Finally, trade coefficients denoting the trade of each transportation mode's service between regions must be determined. With these revised coefficients, the truncated model can be implemented by setting the transportation price of a particular mode in a region exogenously to reflect a given pricing alternative. The other commodity prices can be solved for using equation (18). Thus, the truncated model can be applied for policy analyses for various combinations of regional freight rate changes for the different modes of transportation. This flexibility makes it a valuable tool for analyzing regional and modal freight-rate adjustments.

Another area of research is in the relaxation of the rigid assumptions made in order to implement the truncated MRIO price model. Summarizing briefly (see Chapter 3), these assumptions were: (1) fixed technical coefficients, (2) fixed trade relationships, and (3) constant industrial shares for each industry in a region. These assumptions restrict the use of the truncated model to short-run price forecasts in which technical and trade relationships do not adjust to the shifts in relative prices of inputs. In the long run, the technical and trade relationships will change, and price forecasts will become increasingly inaccurate.

A method to account for changes in technical relationships over time is to use the estimated prices to update the technical coefficients. The truncated MRIO price model can be used to estimate new commodity prices for a future time period. The new relative prices of inputs in that future time period will result in factor substitution. The technical coefficients for the base year can be adjusted to account for factor substitution by multiplying each old technical coefficient by the ratio of the estimated future price and the base price for each commodity and region. The model will then become dynamic in nature by estimating commodity prices, using those prices to update the technical and trade coefficients, then estimating a new round of commodity prices, and so on. The model can then be used to estimate the long-run price effects of transportation freight rate changes.

The proposed model extensions will be valuable in refining the model for use in making actual transportation policy decisions.

Appendix A

Table A-1

INPUT-OUTPUT INDUSTRY NUMBERS, TITLES, AND RELATED SIC CODES

Industry Number	Industry Title	Related SIC Codes (1957 edition)
1	Livestock & livestock products	013, pt. 014, 0193, pt. 02, pt. 0729
2	Other agricultural products	011, 012, pt. 014, 0192, 0199, pt. 02
3	Forestry & fishery products	074, 081, 082, 084, 086, 091
4	Agricultural, forestry, & fishery services	071, 0723, pt. 0729, 085, 098
5	Iron & ferroalloy ores mining	1011, 106
6	Nonferrous metal ores mining	102, 103, 104, 105, 108, 109
7	Coal mining	11, 12
8	Crude petroleum & natural gas	1311, 1321
9	Stone & clay mining & quarrying	141, 142, 144, 145, 148, 149
10	Chemical & fertilizer mineral mining	147
11	New construction	138, pt. 15, pt. 16, pt. 17, pt. 6561
12	Maintenance & repair construction	pt. 15, pt. 16, pt. 17
13	Ordnance & accessories	19
14	Food & kindred products	20
15	Tobacco manufactures	21

Table A-1, continued

Industry Number	Industry Title	Related SIC Codes (1957 edition)
16	Broad & narrow fabrics, yarn & thread mills	221, 222, 223, 224, 226, 228
17	Miscellaneous textile goods & floor coverings	227, 229
18	Apparel	225, 23 (excluding 239), 3992
19	Miscellaneous fabricated textile products	239
20	Lumber & wood products, except containers	24 (excluding 244)
21	Wooden containers	244
22	Household furniture	251
23	Other furniture & fixtures	25 (excluding 251)
24	Paper & allied products, except containers & boxes	26 (excluding 265)
25	Paperboard containers & boxes	265
26	Printing & publishing	27
27	Chemicals & selected chemical products	281 (excluding alumina pt. of 2819), 286, 287, 289
28	Plastics & synthetic materials	282
29	Drugs, cleaning, & toilet preparations	283, 284
30	Paints & allied products	285
31	Petroleum refining & related industries	29
32	Rubber & miscellaneous plastics products	30

Table A-1, continued

Industry Number	Industry Title	Related SIC Codes (1957 edition)
33	Leather tanning & industrial leather products	311, 312
34	Footwear & other leather products	31 (excluding 311, 312)
35	Glass & glass products	321, 322, 323
36	Stone & clay products	324, 325, 326, 327, 328, 329
37	Primary iron & steel manufacturing	331, 332, 3391, 3399
38	Primary nonferrous metals manufacturing	2819 (alumina only), 333, 334, 335, 336, 3392
39	Metal containers	3411, 3491
40	Heating, plumbing, & fabricated structural metal products	343, 344
41	Screw machine products, bolts, nuts, etc., & metal stampings	345, 346
42	Other fabricated metal products	342, 347, 348, 349 (excluding 3491)
43	Engines & turbines	351
44	Farm machinery & equipment	352
45	Construction, mining, oil field machinery & equipment	3531, 3532, 3533
46	Materials handling machinery & equipment	3534, 3535, 3536, 3537
47	Metalworking machinery & equipment	354

Table A-1, continued

Industry Number	Industry Title	Related SIC Codes (1957 edition)
48	Special industry machinery & equipment	355
49	General industrial machinery & equipment	356
50	Machine shop products	359
51	Office, computing, & accounting machines	357
52	Service industry machines	358
53	Electric transmission & distribution equipment & electrical industrial apparatus	361, 362
54	Household appliances	363
55	Electric lighting & wiring equipment	364
56	Radio, TV, & communication equipment	365, 366
57	Electronic components & accessories	367
58	Miscellaneous electrical machinery, equipment, & supplies	369
59	Motor vehicles & equipment	371
60	Aircraft & parts	372
61	Other transportation equipment	373, 374, 375, 379
62	Professional, scientific, & controlling instruments & supplies	381, 382, 384, 387
63	Optical, ophthalmic, & photographic equipment & supplies	383, 385, 386
64	Miscellaneous manufacturing	39 (excluding 3992)
65	Transportation & warehousing	40, 41, 42, 44, 45, 46, 47

Table A-1, continued

Industry Number	Industry Title	Related SIC Codes (1957 edition)
66	Communications, except radio & TV broadcasting	481, 482, 489
67	Radio & TV broadcasting	483
68	Electric, gas, water, & sanitary services	49
69	Wholesale & retail trade	50 (excluding manufacturers sales offices), 52, 53, 54, 55, 56, 57, 58, 59, pt. 7399
70	Finance & insurance	60, 61, 62, 63, 64, 66, 67
71	Real estate & rental	65 (excluding 6541 and pt. 6561)
72	Hotels & lodging places; personal & repair services, except automobile repair	70, 72, 76 (excluding 7694 and 7699)
73	Business services	6541, 73 (excluding 7361, 7391, and pt. 7399), 7694, 7699, 81, 89 (excluding 8921)
74	Research & development	. . . . . .
75	Automobile repair & services	75
76	Amusements	78, 79
77	Medical, educational services, & nonprofit organizations	0722, 7361, 80, 82, 84, 86, 8921
78	Federal government enterprises	. . . . . .
79	State & local government enterprises	. . . . . .

Table A-1, continued

Industry Number	Industry Title	Related SIC Codes (1957 edition)
80a	Directly allocated imports of goods & services	. . . . . .
80b	Transferred imports of goods & services	. . . . . .
81	Business travel, entertainment, & gifts	. . . . . .
82	Office supplies	. . . . . .
83	Scrap, used, & secondhand goods	. . . . . .
84	Government industry	. . . . . .
85	Rest of the world industry	. . . . . .
86	Household industry	. . . . . .
87	Inventory valuation adjustment	. . . . . .
88	Personal consumption expenditures	. . . . . .
89	Gross private fixed capital formation	. . . . . .
90	Net inventory change	. . . . . .
91	Net exports	. . . . . .
92	Federal government purchases	. . . . . .
93	State & local government net purchases	. . . . . .

Table A-2

DIRECT INPUTS OF TRANSPORTATION SERVICES
REQUIRED PER UNIT OF OUTPUT

	MASSACHUSETTS	REST OF NEW ENGLAND	REST OF THE UNITED STATES
1 LIVESTOCK, PRDTS.	0.0628	0.0227	0.0274
2 OTHER AGRICULTURE PRDTS.	0.1423	0.0625	0.0431
3 FORESTRY, FISHERIES	0.0446	0.0395	0.0531
4 AGRI.,FORES.,FISH. SERV.	0.0077	0.0095	0.0082
5 IRON, FERRO. ORES MINING	0.0000	0.0000	0.2005
6 NONFERROUS ORES MINING	0.0000	0.0484	0.0271
7 COAL MINING	0.0000	0.0000	0.2253
8 CRUDE PETRO.,NATURAL GAS	0.0000	0.0000	0.0760
9 STONE, CLAY MINING	0.2632	0.2303	0.2190
10 CHEM.,FERT. MIN. MINING	0.0000	0.0000	0.1428
11 NEW CONSTRUCTION	0.0075	0.0071	0.0085
12 MAINT., REPAIR CONSTR.	0.0048	0.0048	0.0048
13 ORDNANCE, ACCESSORIES	0.0036	0.0024	0.0039
14 FOOD, KINDRED PRDTS.	0.0147	0.0140	0.0131
15 TOBACCO MANUFACTURES	0.0013	0.0015	0.0027
16 FABRICS	0.0138	0.0088	0.0132
17 TEXTILE PRDTS.	0.0176	0.0183	0.0241
18 APPAREL	0.0039	0.0047	0.0041
19 MISC. TEXTILE PRDTS.	0.0048	0.0039	0.0059
20 LUMBER, WOOD PRDTS.	0.1294	0.0714	0.0739
21 WOODEN CONTAINERS	0.0630	0.0604	0.0567
22 HOUSEHOLD FURNITURE	0.0069	0.0070	0.0089
23 OTHER FURNITURE	0.0084	0.0085	0.0079
24 PAPER, ALLIED PRDTS.	0.0433	0.0317	0.0480
25 PAPERBOARD CONTAINERS	0.0254	0.0394	0.0311
26 PRINTING, PUBLISHING	0.0119	0.0117	0.0127
27 CHEMICALS,SELECT. PRDTS.	0.0669	0.0539	0.0436
28 PLASTICS, SYNTHETICS	0.0301	0.0379	0.0218
29 DRUGS, COSMETICS	0.0182	0.0132	0.0125
30 PAINT, ALLIED PRDTS.	0.0278	0.0465	0.0288
31 PETROLEUM, RELATED INDS.	C.0800	0.0861	0.0287
32 RUBBER, MISC. PLASTICS	0.0172	0.0187	0.0259
33 LEATHER TANNING, PRDTS.	0.0099	0.0172	0.0171
34 FOOTWEAR, LEATHER PRDTS.	0.0042	0.0041	0.0053
35 GLASS, GLASS PRDTS.	0.1330	0.0539	0.0449
36 STONE, CLAY PRDTS.	0.0554	0.0610	0.0616
37 PRIMARY IRON, STEEL MFR.	0.0777	0.0644	0.0435
38 PRIMARY NONFERROUS MFR.	0.0353	0.0235	0.0291
39 METAL CONTAINERS	0.0403	0.0411	0.0232
40 FABRICATED METAL PRDTS.	0.0271	0.0297	0.0245
41 SCREW MACH. PRDTS., ETC.	0.0173	0.0134	0.0195

Table A-2, continued

DIRECT INPUTS OF TRANSPORTATION SERVICES
REQUIRED PER UNIT OF OUTPUT

	MASSACHUSETTS	REST OF NEW ENGLAND	REST OF THE UNITED STATES
42 OTHER FAB. METAL PRDTS.	0.0145	0.0133	0.0195
43 ENGINES, TURBINES	0.0067	0.0092	0.0133
44 FARM MACH., EQUIP.	0.0119	0.0220	0.0093
45 CONSTRUC. MACH., EQUIP.	0.0157	0.0096	0.0083
46 MATERIAL HANDLING MACH.	0.0176	0.0344	0.0168
47 METALWORKING MACHINERY	0.0066	0.0064	0.0074
48 SPECIAL MACH., EQUIP.	0.0062	0.0064	0.0073
49 GENERAL MACH., EQUIP.	0.0132	0.0094	0.0150
50 MACHINE SHOP PRDTS.	0.0269	0.0353	0.0369
51 OFFICE, COMPUT. MACHINES	0.0069	0.0071	0.0074
52 SERVICE IND. MACHINES	0.0084	0.0093	0.0099
53 ELECT. TRANSMISS. EQUIP.	0.0116	0.0123	0.0133
54 HOUSEHOLD APPLIANCES	0.0072	0.0048	0.0059
55 ELECTRIC LIGHTING EQUIP.	0.0137	0.0119	0.0255
56 RADIO, TV, ETC., EQUIP.	0.0054	0.0058	0.0066
57 ELECTRONIC COMPONENTS	0.0089	0.0084	0.0098
58 MISC. ELECTRICAL MACH.	0.0106	0.0121	0.0116
59 MOTOR VEHICLES, EQUIP.	0.0116	0.0116	0.0099
60 AIRCRAFT, PARTS	0.0065	0.0072	0.0071
61 OTHER TRANSPORT. EQUIP.	0.0070	0.0051	0.0077
62 PROFESS., SCIEN. INSTRU.	0.0091	0.0089	0.0113
63 MEDICAL, PHOTO. EQUIP.	0.0070	0.0096	0.0075
64 MISC. MANUFACTURING	0.0092	0.0069	0.0132
65 TRANSPORT., WAREHOUSING	0.0664	0.0665	0.0738
66 COMMUNICA.,EXC. BRDCAST.	0.0036	0.0036	0.0036
67 RADIO, TV BROADCASTING	0.0104	0.0104	0.0104
68 ELEC.,GAS,WATER,SAN.SER.	0.0016	0.0017	0.0017
69 WHOLESALE, RETAIL TRADE	0.0097	0.0080	0.0100
70 FINANCE, INSURANCE	0.0062	0.0061	0.0061
71 REAL ESTATE, RENTAL	0.0010	0.0008	0.0012
72 HOTELS, PERSONAL SERV.	0.0086	0.0086	0.0086
73 BUSINESS SERVICES	0.0113	0.0100	0.0110
74 RESEARCH, DEVELOPMENT	0.0	0.0	0.0
75 AUTO. REPAIR, SERVICES	0.0019	0.0019	0.0019
76 AMUSEMENTS	0.0118	0.0118	0.0118
77 MED.,EDUC. SERVICES	0.0081	0.0081	0.0081
78 FEDERAL GOVT. ENTERPRISE	0.0951	0.0951	0.0951
79 STATE, LOCAL GOVT. ENT.	0.0020	0.0020	0.0020

Table A-3

COMMODITY PRICES
RESULTING FROM A 20% PRICE INCREASE IN TRANSPORTATION SERVICES
THROUGHOUT THE UNITED STATES

	MASSACHUSETTS	REST OF NEW ENGLAND	REST OF UNITED STATES
1 LIVESTOCK, PRDTS.	1.0177	1.0112	1.0138
2 OTHER AGRICULTURE PRDTS.	1.0323	1.0174	1.0125
3 FORESTRY, FISHERIES	1.0115	1.0107	1.0130
4 AGRI.,FORES.,FISH. SERV.	1.0052	1.0062	1.0056
5 IRON, FERRO. ORES MINING	0.0000	0.0000	1.0434
6 NONFERROUS ORES MINING	0.0000	1.0101	1.0094
7 COAL MINING	0.0000	0.0000	1.0516
8 CRUDE PETRO.,NATURAL GAS	0.0000	0.0000	1.0169
9 STONE, CLAY MINING	1.0549	1.0477	1.0463
10 CHEM.,FERT. MIN. MINING	0.0000	0.0000	1.0324
11 NEW CONSTRUCTION	1.0079	1.0090	1.0104
12 MAINT., REPAIR CONSTR.	1.0073	1.0072	1.0072
13 ORDNANCE, ACCESSORIES	1.0030	1.0020	1.0032
14 FOOD, KINDRED PRDTS.	1.0105	1.0101	1.0103
15 TOBACCO MANUFACTURES	1.0095	1.0078	1.0043
16 FABRICS	1.0099	1.0091	1.0094
17 TEXTILE PRDTS.	1.0100	1.0099	1.0104
18 APPAREL	1.0056	1.0056	1.0056
19 MISC. TEXTILE PRDTS.	1.0057	1.0036	1.0060
20 LUMBER, WOOD PRDTS.	1.0318	1.0208	1.0225
21 WOODEN CONTAINERS	1.0224	1.0213	1.0208
22 HOUSEHOLD FURNITURE	1.0088	1.0084	1.0091
23 OTHER FURNITURE	1.0077	1.0080	1.0082
24 PAPER, ALLIED PRDTS.	1.0160	1.0136	1.0163
25 PAPERBOARD CONTAINERS	1.0129	1.0149	1.0140
26 PRINTING, PUBLISHING	1.0071	1.0071	1.0075
27 CHEMICALS,SELECT. PRDTS.	1.0183	1.0163	1.0142
28 PLASTICS, SYNTHETICS	1.0126	1.0133	1.0101
29 DRUGS, COSMETICS	1.0089	1.0075	1.0069
30 PAINT, ALLIED PRDTS.	1.0119	1.0140	1.0117
31 PETROLEUM, RELATED INDS.	1.0202	1.0214	1.0150
32 RUBBER, MISC. PLASTICS	1.0079	1.0081	1.0094
33 LEATHER TANNING, PRDTS.	1.0094	1.0105	1.0100
34 FOOTWEAR, LEATHER PRDTS.	1.0059	1.0057	1.0060
35 GLASS, GLASS PRDTS.	1.0293	1.0155	1.0139
36 STONE, CLAY PRDTS.	1.0202	1.0213	1.0212
37 PRIMARY IRON, STEEL MFR.	1.0225	1.0212	1.0179
38 PRIMARY NONFERROUS MFR.	1.0133	1.0111	1.0117
39 METAL CONTAINERS	1.0167	1.0163	1.0138
40 FABRICATED METAL PRDTS.	1.0117	1.0117	1.0113

Table A-3, continued

COMMODITY PRICES
RESULTING FROM A 20% PRICE INCREASE IN TRANSPORTATION SERVICES
THROUGHOUT THE UNITED STATES

	MASSACHUSETTS	REST OF NEW ENGLAND	REST OF UNITED STATES
41 SCREW MACH. PRDTS., ETC.	1.0091	1.0089	1.0096
42 OTHER FAB. METAL PRDTS.	1.0080	1.0076	1.0086
43 ENGINES, TURBINES	1.0069	1.0063	1.0075
44 FARM MACH., EQUIP.	1.0039	1.0058	1.0079
45 CONSTRUC. MACH., EQUIP.	1.0056	1.0062	1.0072
46 MATERIAL HANDLING MACH.	1.0082	1.0092	1.0082
47 METALWORKING MACHINERY	1.0051	1.0052	1.0050
48 SPECIAL MACH., EQUIP.	1.0059	1.0058	1.0056
49 GENERAL MACH., EQUIP.	1.0070	1.0067	1.0073
50 MACHINE SHOP PRDTS.	1.0097	1.0114	1.0118
51 OFFICE, COMPUT. MACHINES	1.0039	1.0040	1.0040
52 SERVICE IND. MACHINES	1.0068	1.0054	1.0067
53 ELECT. TRANSMISS. EQUIP.	1.0065	1.0066	1.0069
54 HOUSEHOLD APPLIANCES	1.0056	1.0067	1.0067
55 ELECTRIC LIGHTING EQUIP.	1.0082	1.0079	1.0101
56 RADIO, TV, ETC., EQUIP.	1.0038	1.0035	1.0043
57 ELECTRONIC COMPONENTS	1.0055	1.0054	1.0054
58 MISC. ELECTRICAL MACH.	1.0060	1.0064	1.0064
59 MOTOR VEHICLES, EQUIP.	1.0083	1.0081	1.0085
60 AIRCRAFT, PARTS	1.0045	1.0051	1.0049
61 OTHER TRANSPORT. EQUIP.	1.0065	1.0062	1.0083
62 PROFESS., SCIEN. INSTRU.	1.0053	1.0055	1.0056
63 MEDICAL, PHOTO. EQUIP.	1.0052	1.0055	1.0048
64 MISC. MANUFACTURING	1.0069	1.0063	1.0074
65 TRANSPORT., WAREHOUSING	1.2000	1.2000	1.2000
66 COMMUNICA.,EXC. BRDCAST.	1.0016	1.0016	1.0016
67 RADIO, TV BROADCASTING	1.0038	1.0038	1.0038
68 ELEC.,GAS,WATER,SAN.SER.	1.0054	1.0054	1.0048
69 WHOLESALE, RETAIL TRADE	1.0031	1.0028	1.0032
70 FINANCE, INSURANCE	1.0032	1.0031	1.0032
71 REAL ESTATE, RENTAL	1.0012	1.0011	1.0012
72 HOTELS, PERSONAL SERV.	1.0038	1.0038	1.0038
73 BUSINESS SERVICES	1.0034	1.0031	1.0035
74 RESEARCH, DEVELOPMENT	1.0000	1.0000	1.0000
75 AUTO. REPAIR, SERVICES	1.0036	1.0036	1.0036
76 AMUSEMENTS	1.0043	1.0042	1.0042
77 MED.,EDUC. SERVICES	1.0032	1.0031	1.0031
78 FEDERAL GOVT. ENTERPRISE	1.0207	1.0207	1.0207
79 STATE, LOCAL GOVT. ENT.	1.0042	1.0042	1.0041

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