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MULTIREGIONAL INTERACTIONS BETWEEN ENERGY AND TRANSPORTATION

by

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ABSTRACT

Because of the number and complexity of the issues that will determine the use of coal by the electric-generating plants, an important asset of policy makers will be the availability of a method of analysis that allows for quick studies of many different combinations of assumptions and policies. The present prototype study is designed to show how the multiregional input-output model can be used to investigate each different assumption and policy alternative. For this paper, the analysis has necessarily been restricted to two issues. First, the results of using regional rather than national technologies in the model are assessed. This part of the analysis clearly shows the importance of conducting regional, rather than national, studies of energy and transportation, providing insight into the extent of regional and industrial repercussions that can be anticipated if significant changes occur either in the different technologies currently being used to generate electricity or in the regional mix of the present technologies. Second, the results of altering trade coefficients are examined. This part of the analysis shows the importance of considering changes in shipping origins and destinations for coal and also shows the regional and industrial impacts that can be expected if a significant quantity of the total coal used is mined west of the Mississippi.

MULTIREGIONAL INTERACTIONS BETWEEN ENERGY AND TRANSPORTATION

Karen R. Polenske*

Energy is a word that has taken on new and dramatic meaning in the United States, as elsewhere, within the last few years. This country's current energy problems are closely interconnected with its other economic problems: transportation, urban development, environmental, and so on. Therefore, as efforts are made to understand and solve some of the energy problems, the need for a comprehensive and systematic analysis of energy at a multiregional level, where the interconnection with related economic problems among all regions of the country can be observed most accurately, becomes increasingly evident. The impact of almost all changes in the demand for and supply of energy varies significantly among different regions. An increase in the demand for electricity on the East Coast, for example, will have differential impacts on the coal, oil, electrical-equipment, and other industries, and the repercussions of the increase will affect workers, consumers, and industries located in other regions of the country, as well as those on the East Coast. As will become apparent later in this paper, the interconnection between energy and transportation is most effectively studied within a multiregional framework.

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*I am deeply grateful for the assistance received from Paul F. Levy, who did the calculations for the paper. The results presented are preliminary and subject to revision.

Although the need for a multiregional study seems obvious and beyond dispute, the investigation of changes in demand for electricity and other forms of energy and the economic issues connected with those changes is usually conducted at a national, rather than at the frequently more relevant multiregional, level; or the studies are often restricted to a single region. A number of energy studies have been conducted for one industry, such as petroleum, or for one region, such as New England. These studies, however, do not account for the repercussions among other industries and regions of the country. Part of the reason for the neglect of multiregional studies of energy is that the economic tools of analysis for this type of study have been developed slowly and that detailed sets of statistics that are consistent from region to region have seldom been readily available. Inasmuch as the tools and data required to analyze energy problems at a national level have not only been available, but also have been constantly refined, relatively small amounts of time and funds are necessary for the national studies. Many of the conclusions of these studies, however, so far as a given region is concerned, are misleading or inapplicable.[1]

Now, the general public, government officials, and industry have become vitally interested in having energy policies analyzed with specific reference to their impact on particular areas of the

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[1]In his study The Residential Demand for Electricity in New England, for example, the elasticity of demand for electricity (with respect to price or income) obtained by Paul F. Levy for New England is significantly different from that obtained in national studies [7].

country, as well as the repercussions among regions. Methods of analyzing energy at the multiregional level will have to be formulated and procedures developed for conducting the studies quickly and effectively at a minimum of expense. In the present study, a multiregional framework has been used to analyze the interactions between electricity, coal, and freight transportation.

Defining the Scope of the Study

The energy sector can be defined to include three major groups of industries: fuel (coal, gas, and petroleum), construction (plant and equipment used by the energy industries), and private and public electric power. The transportation sector can likewise be defined to include three major categories: passenger transportation, freight transportation (rail, truck, air, water, pipeline, and other), and transportation equipment.

For the present study of the multiregional interactions between energy and transportation, the analysis has been restricted to the inputs of coal into the private electric-power industry and the resulting derived demand for the transportation of coal, which basically affects the rail, water, and truck modes of shipping. The aim of this static input-output study is to show how the multiregional input-output (MRIO) model that was described in a paper presented by the writer at the 1971 international input-output conference [9] can be used to analyze the regional impacts of alternative energy policies for the coal industry and to show how an analysis of the freight transportation industry is made simultaneously when this conceptual framework is used. Although the basic MRIO model has been used for the analysis, it is of course evident that supplemental multiregional models may have to be developed if an analysis in greater depth is required. A modal-split model, for example, can be developed and linked into the MRIO model for an intensive analysis of the impact of a specific energy policy on substitutions among modes of transportation, or to analyze the impact that modal shifts have upon the supply of and demand for energy.

The analysis is restricted to the period 1963 through 1980. At present, base-year MRIO data are available only for 1963, and projections of the gross regional product figures have been made to 1970 and 1980. (The methodology used to assemble these data is explained in a series of five volumes published by Lexington Books, D. C. Heath and Company [10;11;13;14;15].) All of the MRIO data are available for 79 industries and 51 regions (50 states plus the District of Columbia) and are consistent with national input-output data published by the Bureau of Economic Analysis, U.S. Department of Commerce, for 1963 and by the Bureau of Labor Statistics, U.S. Department of Labor, for 1970 and 1980. For this study, the data were aggregated to 18 industries (refer to the appendix, Table A-1), generally keeping separate those industries that are large users of coal, and the 9 U.S. census regions (refer to the appendix, Table A-2). These industrial and regional aggregations were selected to facilitate the presentation of results for this paper, but different aggregation schemes could be used if desired for a particular policy analysis.

The results that can be obtained from a multiregional input-output study of energy and transportation are unique in several respects.

- The economic analyses stress the interactions that can be expected to occur among industries and regions, given a specific energy policy; provide an assessment of the regional disparities inherent in the changing demand for and supply of energy; and allow for investigating within a consistent framework the regional consequences of specific policies designed to conserve energy and to improve the environment.

- The multiregional energy data base is comprehensive, and it can be linked into by other analysts for subregional (Boston as part of Massachusetts) or subindustry (fossil-fuel electric generation facilities as a subcomponent of the private electric power industry) studies.

- The input, output, and interregional shipments data are specified in considerable industrial and regional detail and cover a long span of years.

- The energy and transportation data are comprehensive in that they show the inputs of energy used by all industries in each region of the country and the interregional shipments among all regions, and, furthermore, the industrial and regional data are internally consistent, so that the results obtained from implementing the model reflect the interactions that occur among all industries and regions.

- The results take into account the mix of energy supplied in each region. For example, hydroelectric power is dominant in the Pacific and petroleum is dominant in the New England and the West South Central regions, while a mix of energy sources is used in other regions.

At the same time, it should be stressed that if the results of multiregional energy analyses are to be of value, the theoretical work on the MRIO and other models that can be used must be extended and expanded, and additional data on energy that can be incorporated into the MRIO model must be assembled.

Electricity Generation

The processes used to generate electricity vary widely from one region of the country to another. In the West, where ample water supplies are available, the principal process is hydro. In the West South Central area, oil- and gas-burning generators are used almost exclusively. In the East North Central and East South Central regions, coal-burning generators are dominant.

Coal has played a very important role in the development of electric-generating capacity in the United States, but its role is undergoing significant changes. Although many of the published figures are not given separately for coal used by electric utilities and coal used by other industries, some data are available. In 1970, coal represented only 56 percent of the fossil fuel used in steam-electric generating plants, a decline from 65 percent in 1963, as shown in Table 1. But the regional variations in the coal/oil-and-natural-gas percentages are even more extreme. No coal is used as inputs for fossil-fuel electricity generation in either the West South Central or Pacific regions, while coal represents approximately 90 percent of the fossil fuel used by electric utilities in both the East North Central and East South Central regions. The only two regions that show an increase in the use of coal relative to oil and natural gas from 1963 to 1970 are the West North Central and Mountain regions.

Table 1

1963 AND 1970 DISTRIBUTION OF FUEL USE
STEAM-ELECTRIC GENERATING PLANTS

Region		1963		1970	
No.	Name	Coal	Oil and Natural Gas	Coal	Oil and Natural Gas
		(Percent)		(Percent)	
1	New England	63	37	16	84
2	Middle Atlantic	75	25	55	45
3	East North Central	96	4	90	10
4	West North Central	49	51	57	43
5	South Atlantic	79	21	66	34
6	East South Central	92	8	89	11
7	West South Central	0	100	0	100
8	Mountain	40	60	56	41
9	Pacific	0	100	0	100
	United States	65	35	56	44

Note: Percentages are based upon BTUs used for fossil-fuel steam-electric generation.

SOURCE: Thomas D. Duchesneau, Interfuel Substitutability in the Electric Industry. Washington, D.C.: Federal Trade Commission, 1972.

A complete picture of the importance of coal for the production of electric power, however, has to account for the relative position of fossil fuels in total electricity generation as well as the regional distribution of fossil-fuel generating plants. (These distributions are shown in Tables 2 and 3, respectively.) Thus, in 1970, 97.2 percent of the electricity in the East North Central region was generated by fossil-fuel generating plants, and this represented 22.5 percent (or over one-fifth) of the total 1970 United States fossil-fuel production. The importance of coal as one of the three fossil fuels consumed can be determined by referring to the figures in Table 1. At present, the two principal competitors of fossil fuels, nuclear and hydroelectric power, are geographically isolated. Nuclear plants are located only in the three regions in the Northeast and on the West Coast, and over 65 percent of hydroelectric generating capacity is located in the Mountain and Pacific regions. Within the next decade, therefore, the main choice in most regions of the country will be whether to use coal- or oil- or gas-generating plants.

Regional variations also occur in the production and consumption of coal. The three states of West Virginia, Pennsylvania, and Kentucky produced over 59 percent of the total bituminous coal, but the consumption of coal is more widely spread among states, the six principal consumers being Pennsylvania, Ohio, Illinois, Indiana, Michigan, and New York. Variations in the 1963 shipments of coal among the 9 U.S. census regions are shown in Table A-3 in the appendix in the form of total supply coefficients. Each column gives the fraction of total

Table 2

1963 AND 1970 REGIONAL DISTRIBUTION
OF ELECTRICITY BY GENERATION PROCESS
(Percent)

Region		1963					1970				
No.	Name	Fossil	Hydro	Nuclear	Other	Total	Fossil	Hydro	Nuclear	Other	Total
1	New England	83.8	12.9	2.7	0.6	100.0	83.8	7.7	7.9	0.6	100.0
2	Middle Atlantic	84.4	14.7	0.7	0.1	100.0	83.9	12.1	3.9	0.2	100.0
3	East North Central	97.6	1.4	0.5	0.5	100.0	97.2	1.3	1.0	0.4	100.0
4	West North Central	84.0	12.8	0.1	3.1	100.0	84.2	13.5	--	2.2	100.0
5	South Atlantic	90.3	9.4	0.0	0.3	100.0	94.8	5.0	0.0	0.2	100.0
6	East South Central	84.1	15.9	--	0.0	100.0	87.1	12.9	--	0.0	100.0
7	West South Central	97.4	1.4	--	1.2	100.0	96.9	2.6	--	0.5	100.0
8	Mountain	54.0	44.9	--	1.1	100.0	62.5	37.0	--	0.5	100.0
9	Pacific	40.4	59.4	0.1	0.1	100.0	37.4	60.0	2.5	0.1	100.0
	United States	81.1	18.0	0.3	0.5	100.0	82.0	16.2	1.4	0.4	100.0

0.0 Less than 0.05 percent
-- Zero generation
Note: Totals may not add to 100 percent due to rounding. Percentages are based upon BTUs used for electricity generation.

SOURCES: Edison Electric Institute. Statistical Bulletin of the Electrical Industry, 1963 and Statistical Bulletin of the Electrical Industry, 1970. New York: Edison Electric Institute, 1964 and 1971, respectively.

Table 3

1963 AND 1970 GENERATION-PROCESS DISTRIBUTION
OF ELECTRICITY BY REGION
(Percent)

Region		1963					1970				
No.	Name	Fossil	Hydro	Nuclear	Other	Total	Fossil	Hydro	Nuclear	Other	Total
1	New England	3.9	2.7	29.3	4.2	3.8	4.1	1.9	22.1	6.1	4.0
2	Middle Atlantic	15.6	12.3	29.5	4.0	15.0	14.2	10.4	37.6	6.0	13.9
3	East North Central	25.2	1.7	32.9	17.5	20.9	22.5	1.5	14.0	19.7	18.9
4	West North Central	6.4	4.4	2.3	34.7	6.1	6.6	5.4	--	36.5	6.4
5	South Atlantic	15.7	7.4	0.0	7.7	14.1	18.6	5.0	0.0	8.1	16.1
6	East South Central	11.6	9.9	--	0.4	11.2	10.2	7.6	--	0.2	9.6
7	West South Central	11.1	0.7	--	21.0	9.3	13.5	1.8	--	14.9	11.5
8	Mountain	3.1	11.5	--	9.0	4.6	3.6	10.8	--	5.4	4.7
9	Pacific	7.5	49.6	6.0	1.5	15.0	6.8	55.6	26.4	3.1	15.0
	United States	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

0.0 Less than 0.05 percent
-- Zero generation
Note: Figures may not add to 100 percent due to rounding. Percentages are based upon BTUs used for electricity generation.

SOURCES: Edison Electric Institute. Statistical Bulletin of the Electrical Industry, 1963 and Statistical Bulletin of the Electrical Industry, 1970. New York: Edison Electric Institute, 1964 and 1971, respectively.

supply of coal that originates in each of the 9 respective regions. New England, for example, received 43 percent of its coal from the Middle Atlantic, 46 percent from the South Atlantic, and 11 percent from the East South Central regions, while the East South Central region was mainly supplied from internal sources--75 percent of its coal supply originating within the region.

Of total coal consumption, the percentage purchased by electric utilities has increased dramatically from 13 percent (72 million tons) at the end of World War II to 46 percent (174 million tons) in 1960 and to 66 percent (326 million tons) in 1971 [19, p. 4]. Thus, a study of the amount of coal purchased by the electric utilities seems to be especially pertinent. In terms of dollars, however, the consumption of coal by electric utilities represents less than 20 percent of the total value of coal purchases [16]. The major reason for this vast difference between the percentages calculated from tonnage and value data is the special low freight rates obtained by the utilities, especially since 1963, when the unit trains began operating between the mine mouth and the utilities. In 1963, coal shipments accounted for 24.8 percent of the total tonnage carried by rails and for about 12.4 percent of the rail freight receipts. Of the total bituminous coal shipped, just over 70 percent was shipped by rail in 1963, a decline from 90 percent in 1933. The unit train concept, in fact, was an attempt by the railroads to offset the competition being generated by water and trucking firms, which are the main competitors of rail for coal shipments. For all commodities, the share of railroads in intercity ton miles has declined from 74.3 percent in 1930 to 40.8 percent in 1970. During the same period, the share of coal in total energy sources has declined from 59.1 percent to 20.1 percent [12]. The impact that changes in the consumption of coal by electric utilities in various regions of the country has had on the transportation industry, particularly railroads, is therefore important to study.

Policy Alternatives for Regions

A number of different economic, physical, and technological factors must be considered when determining whether or not coal should be used to generate electricity. Among the most important are: relative fuel costs; transportation costs; the heat (BTU per pound), ash, and sulfur content of the coal; the ash-fusion temperature; the rank (determined by the different proportions of mineral ash, fixed carbon, volatile matter, and moisture); and the agglomeration properties (whether coal will coke or burn freely) of the coal [19, p. 10].

Current and proposed energy, transportation, and environmental policies will affect the use of coal by electric-generating plants. Of the different energy-related issues, the most important ones related to coal, at least for the short and intermediate terms, undoubtedly are those associated with the availability and price of oil. In the longer run, of course, the advancement of nuclear, solar, and other new sources of power will alter the mix of generating processes used. One of the main transportation issues pertaining to coal use is whether or not rail freight transportation can be revitalized, especially in the Northeast. Two major environmental issues affect coal, the first being air-quality standards in general and sulfur-pollution restrictions in particular and the second being the strip-mining restrictions presently imposed by the Environmental Protection Agency. To a certain extent, the two restrictions have an exactly opposite effect on the mining of coal.

If the sulfur-pollution restrictions alone are imposed, the net effect in the short run is to force more and more production of coal in the Mountain states of Wyoming and Montana as well as in North Dakota, where the sulfur content of the coal is extremely low, thus creating a major shift in the transportation of coal. On the other hand, if rigid strip-mining restrictions alone are imposed, the net effect in the short run is to keep the present location of coal production, thereby maintaining the current distribution of coal among the states.

The consequences of sulfur-pollution restrictions must be considered seriously, because a large proportion of the coal mined east of the Mississippi has a sulfur content higher than the 0.7 percent maximum being recommended by the Environmental Protection Agency. In the northern part of West Virginia, for example, the sulfur content of most of the coal is 4 percent [8, p. 136].

A long-run policy of strict sulfur-pollution restrictions will of course force managers of electric-generating plants to invest in various means of removing sulfur from coal. Four major methods are now available: stack-gas scrubbing (removal of sulfur as the gas is burned); physical desulfurization (removal of sulfur pyrites by subjecting crushed coal to froth flotation); chemical desulfurization (removal of sulfur through a variety of techniques, leaving the coal in the form of a solid, liquid, or gas--depending upon the process employed); fluidized-bed construction (removal of sulfur by the use of a boiler designed to mix coal with a layer of granular particles that move about as air is passed rapidly upward).[2]

Because of the number and complexity of the issues that will determine the use of coal by the electric-generating plants, an important asset of policy makers will be the availability of a method of analysis that allows for quick studies of many different combinations of assumptions and policies. The present prototype study is designed to show how the MRIO model can be used to investigate each different assumption and policy alternative. For this paper, the analysis has necessarily been restricted to two issues. First, the results of using regional rather than national technologies are assessed. This part of the analysis clearly shows the importance of conducting regional, rather than national, studies of energy and transportation, providing insight into the extent of regional and industrial repercussions that can be anticipated if significant changes occur either in the different technologies currently being used to generate electricity or in the regional mix

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[2] Carl Strauss, a student at the Massachusetts Institute of Technology, is writing a paper explaining the four techniques in more detail.

of the present technologies. Second, the results of altering trade coefficients are examined. This part of the analysis shows the importance of considering changes in shipping origins and destinations for coal and also shows the regional and industrial impacts that can be expected if a significant quantity of the total coal used is mined west of the Mississippi.

Before the calculations were made, the following four major adjustments were made to the original set of MRIO data:

(1) Product mix variation. The 1963 national direct input coefficients for gas and water (subcomponents of IO-68, Electric, gas, water, & sanitary services [16]) were weighted by the respective two separate sets of regional outputs assembled by Jack Faucett Associates, Inc. [4] to reflect differences in the mix of production of the two subindustries in each region.

(2) Electric-generating-process-mix variation. The electricity portion of IO-68 was subdivided into four electric-generating processes: fossil fuel, hydro, nuclear, and other (internal combustion). The 1963 national direct input coefficients for each of the four processes that had been assembled at the Harvard Economic Research Project by Rudyard Istvan [5] were then weighted by regional outputs for each process. The regional outputs were estimated for this study using data for the four generation processes on kilowatt hours of electricity generated in each region. The kilowatt-hour data were obtained from publications of the Edison Electric Institute [2; 3] and were adjusted to dollar values for each region by using

Istvan's national output data for each process [6]. The 1963 regional technology coefficients are given in the appendix, Table A-5. The same procedure was used to estimate a set of 1970 technology coefficients, except that national outputs for each process were obtained directly from unpublished Bureau of Labor Statistics data.

(3) Fuel input variation. The national fossil-fuel generation coefficients estimated by Istvan were adjusted to reflect differences in the use of coal (IO-7, Coal mining) and oil (IO-8, Crude petroleum & natural gas) in each region. The 1963 adjustment factors used for this calculation are shown in Table 1 (page 7). This adjustment was made to the 1963 and 1970 technology data.

(4) The 1963 transportation flows for coal were adjusted to reflect a 1970 distribution of the product, using shipments data obtained from a Bureau of Mines publication for bituminous coal and lignite [18] and the Minerals Yearbook, 1970 [17] for anthracite. All of the anthracite shipments data were converted into equivalent bituminous coal tonnage data; the two sets of data were added and multiplied by prices per ton obtained from the Minerals Yearbook, 1970 to obtain estimates in terms of dollars. The 1970 column trade coefficients calculated using these value data are given in the appendix, Table A-4.

After data in the base-year input-output and trade tables have been adjusted, a new set of consistency checks must be made between the row and column sums of the new sets of data to assure consistency of the accounting system.

Three basic sets of calculations, represented by the three matrix equations below, were performed using the adjusted data:

(1) $X = (C^{-1} - \hat{A})^{-1} Y$

(2) $X = (C^{-1} - \hat{A}_*)^{-1} Y$

(3) $X = (C_*^{-1} - \hat{A}_*)^{-1} Y$

m number of industries--in the present calculations, 18.

n number of regions--in the present calculations, 9.

$*$ adjusted coefficients.

X column vector $(mn \cdot 1)$ giving total production. Each element describes the amount of output of commodity i produced in region g.

Y column vector $(mn \cdot 1)$ giving the total final demand. Each element describes the total amount of commodity i consumed by final users in region g regardless of the place where the good was produced.

$\hat{A}$ block diagonal matrix $(mn \cdot mn)$ with n square matrices $(m \cdot m)$ of input coefficients along the diagonal describing the structure of production in each region. For the United States MRIO model, separate regional technical coefficients were assembled for each region. (A ^ is used to designate a block diagonal matrix.)

$\hat{A}_*$ block diagonal matrix $(mn \cdot mn)$ with the same basic information as $\hat{A}$, but with the column of coefficients for IO-68, Electric, gas, water, & sanitary services, adjusted using the procedures described on pages 15 and 16.

C — square matrix (nm•nm) filled with diagonal matrices (m•m). Each element c_i^{gh} describes the fraction of total consumption of commodity i in region h that is imported from region g. The sum of each column of this matrix must equal 1, since the coefficients are proportions of total consumption. It is assumed that each industry within region h will consume the same fraction as imports:

$$c_i^{gh} = c_{i1}^{gh} = c_{i2}^{gh} = \ldots = c_{im}^{gh}$$

C_* — square matrix (nm•nm) with the same basic information as C, but adjusted to represent the 1970 trade flows of coal.

Final demands for 1963, 1970, and 1980 were used to obtain output estimates for each of the three years. Summary tables of these calculations are just now being prepared, so a detailed analysis is not yet possible to make. Although the results of these calculations can be easily summarized, considerably more time and effort will be required to trace through all the implications.

The first calculation of regional outputs was made to determine the 1963, 1970, and 1980 base-year outputs before alterations were made to the technology and trade data. The 1963 base-year technology and trade coefficients were combined with the final demands for each of the three years to obtain estimated regional outputs for the three respective years. The next step was to alter the technology coefficients for the electricity, gas, and water industry (the 18th industry in the aggregated set of data) and to perform the round of calculations shown by the second equation. A comparison of the results of the first and second calculations shows the errors inherent in energy analyses if an assumption is made that electricity-generation technology is the same in all regions. Not surprisingly, the results most affected by the use of regional, rather than national, technologies are those relating to coal, petroleum, electricity, petroleum and refining, and plastics industries. This comparison also indicates the importance of using a multiregional model, such as MRIO, for analyses of future shifts in the relative distribution of electricity-generating processes among regions or for analyses of the regional repercussions of significant shifts in the types of generation processes used throughout the country.

The interesting feature of this comparison is that while the use of regional, rather than national, technologies for the electricity, gas, and water industry (the 18th industry) reduced the amount of coal required directly and indirectly in the West South Central and Pacific regions, the actual amount of coal produced in these two regions was not reduced because of the repercussions of changes in direct and indirect requirements in other regions of the country. This is quickly seen by looking along the rows of the table of direct and indirect changes in output that was calculated, but the table is too large (162x162) to be included in this paper. For policy makers, this type of detailed information on specific policy alternatives will be valuable in determining specific industries and regions affected.

The third calculation of regional outputs was made to compare the results of altering the trade flows for coal in addition to the adjustment already made for regional technological differences in the electricity, gas, and water industry. These results show that the greatest impact is for the coal industry. The amount of coal produced declined by more than 20 percent in the Middle Atlantic and South Atlantic regions. In all other regions, except New England, the outputs increased, the largest increases occurring in the West South Central, Mountain, and Pacific regions. The net effect of the alterations in coal shipments between 1963 and 1970 was to increase coal production in the West and decrease it in the East. (This calculation was made using 1970 final demands and altering only the trade coefficients; therefore, these particular results do not reflect what actually occurred between 1963 and 1970, but they do indicate how shifts in coal shipments have directly and indirectly influenced coal production. In the aggregate, almost no other flows are affected, although, once again, the regional and industrial repercussions of this change vary and will have to be summarized from the large 162x162 table showing direct and indirect output changes on an industry-by-industry and region-by-region basis.

CONCLUSION

The differences that appear when the estimated regional outputs obtained from the three sets of calculations are compared at an aggregate level are not surprising. The use of the MRIO model, however, allows a policy maker not only to investigate changes at an aggregate level, but also to explore the details of the changes on an industry-by-industry and region-by-region basis. This amount of detail is required to determine the specific impacts of given energy policies. To assist in an evaluation, the results of the present calculations are being summarized, and a detailed analysis of the results is being prepared. Transportation analysts will especially want to look at the effects of different energy policies on transportation flows. Again, summaries of these calculations must be prepared. In addition, the analysis can be extended with the use of regional employment data to determine the effect on the labor force in each region, or, as mentioned earlier, an analysis of substitutions among different modes of shipments can be undertaken by linking a modal-split model into the MRIO model.

APPENDIX

Table A-1

MULTIREGIONAL INPUT-OUTPUT CLASSIFICATION
FOR EIGHTEEN INDUSTRIES

Industry No. MRIO	Industry No. BEA	Industry Title
1	1	Livestock & livestock prdts.
2	2	Other agricultural prdts.
3	7	Coal mining
4	8	Crude petro., natural gas
5		Other mining
	5	Iron & ferro. ores mining
	6	Nonferrous metal ores mining
	9	Stone & clay mining
	10	Chem. & fert. mineral mining
6		Construction
	11	New construction
	12	Maint. & repair construction
7		Food & tobacco
	14	Food & kindred prdts.
	15	Tobacco manufactures
8		Fabrics, apparel, & footwear
	16	Fabrics
	17	Textile prdts.
	18	Apparel
	19	Misc. textile prdts.
	33	Leather tanning & prdts.
	34	Footwear, leather prdts.
9		Transport. equip. & ordnance
	13	Ordnance & accessories
	59	Motor vehicles, equip.
	60	Aircraft & parts
	61	Other transport. equip.
10		Lumber & paper
	20	Lumber & wood prdts.
	21	Wooden containers
	22	Household furniture
	23	Other furniture
	24	Paper & allied prdts.
	25	Paperboard containers
	26	Printing & publishing
11	31	Petroleum, related inds.
12		Plastics & chemicals
	27	Chemicals, selected prdts.
	28	Plastics & synthetics
	29	Drugs & cosmetics
	30	Paint & allied prdts.
	32	Rubber, misc. plastics
13		Glass, stone, clay prdts.
	35	Glass & glass prdts.
	36	Stone & clay prdts.
14	37	Primary iron, steel mfr.
15	38	Primary nonferrous mfr.
16		Machinery & equipment
	39	Metal containers
	40	Fabricated metal prdts.
	41	Screw mach. prdts., etc.
	42	Other fab. metal prdts.
	43	Engines & turbines
	44	Farm mach. & equip.
	45	Construction mach. & equip.
	46	Materials hand. mach. & equip.
	47	Metalworking mach. & equip.
	48	Special mach. & equip.
	49	General mach. & equip.
	50	Machine shop prdts.
	51	Office, computing machines
	52	Service industry machines
	53	Elect. transmission equip.
	54	Household appliances
	55	Electric lighting equip.
	56	Radio, TV, etc., equip.
	57	Electronic components
	58	Misc. electrical mach.
	62	Professional, scien. instru.
	63	Medical, photo. equip.
	64	Misc. manufacturing
17		Services
	3	Forestry & fishery prdts.
	4	Ag., for., & fish. services
	65	Transportation & warehousing
	66	Communications, exc. brdcast.
	67	Radio & TV broadcasting
	69	Wholesale & retail trade
	70	Finance & insurance
	71	Real estate & rental
	72	Hotels; repair serv., exc. auto
	73	Business services
	74	Research & development
	75	Automobile repair & services
	76	Amusements
	77	Med., ed. serv., nonprof. org.
	78	Federal gov't enterprises
	79	State & local gov't enterp.
18	68	Elec., gas, water, & san. serv.

Table A-2

MRIO REGIONAL CLASSIFICATION

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

*The names of the 9 census regions are:

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

Table A-3

1963 COLUMN COEFFICIENTS
INDUSTRY 3, COAL MINING

Shipping Region \ Receiving Region	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
1 New England	.004	.000	.0	.0	.0	.0	.0	.0	.0
2 Middle Atlantic	.426	.716	.069	.002	.184	.0	.0	.0	.140
3 East North Central	.0	.005	.488	.580	.019	.093	.087	.0	.0
4 West North Central	.0	.0	.0	.214	.0	.0	.040	.000	.0
5 South Atlantic	.460	.263	.274	.131	.579	.152	.318	.256	.594
6 East South Central	.110	.016	.169	.070	.218	.755	.524	.0	.0
7 West South Central	.0	.0	.0	.002	.0	.0	.031	.066	.0
8 Mountain	.0	.0	.0	.001	.0	.0	.0	.627	.239
9 Pacific	.0	.0	.0	.0	.0	.0	.0	.051	.027
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

.000 Coefficient smaller than .0005
.0 Zero coefficient

SOURCE: John M. Rodgers. State Estimates of Interregional Commodity Trade, 1963. Lexington: Lexington Books, D. C. Heath and Company, 1973.

Table A-4

1970 COLUMN COEFFICIENTS
INDUSTRY 3, COAL MINING

Shipping Region \ Receiving Region	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
1 New England	.0	.0	.0	.0	.0	.0	.0	.0	.0
2 Middle Atlantic	.601	.550	.036	.001	.127	.0	.0	.0	.0
3 East North Central	.059	.126	.591	.427	.024	.068	.058	.0	.0
4 West North Central	.0	.0	.000	.293	.0	.0	.073	.0	.0
5 South Atlantic	.330	.284	.185	.038	.468	.215	.194	.0	.0
6 East South Central	.010	.040	.183	.048	.381	.717	.123	.0	.0
7 West South Central	.0	.0	.000	.104	.0	.0	.552	.005	.0
8 Mountain	.0	.0	.005	.069	.0	.0	.0	.978	.901
9 Pacific	.0	.0	.0	.020	.0	.0	.0	.017	.099
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

.000 Coefficient smaller than .0005
.0 Zero coefficient
SOURCES: U.S. Department of Interior, Minerals Yearbook, 1970, GPO, 1971; U.S. Department of Interior, Bureau of Mines, Division of Fossil Fuels, Bituminous Coal and Lignite Distribution, Calendar Year 1970, GPO, 1971.

Table A-5

1963 ADJUSTED REGIONAL TECHNICAL COEFFICIENTS
INDUSTRY 18, ELECTRICITY, GAS, WATER, AND SANITARY SERVICES

Producing Industry		Purchasing Region								
		1	2	3	4	5	6	7	8	9
No.	Title	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific
1	Livestock & livestock prdts.	.000	.000	.000	.000	.000	.000	.000	.000	.000
2	Other agricultural prdts.	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	Coal mining	.056	.049	.054	.045	.066	.076	.000	.045	.000
4	Crude petro., natural gas	.067	.078	.082	.089	.065	.053	.137	.094	.128
5	Other mining	.0	.0	.0	.0	.0	.0	.0	.0	.0
6	Construction	.035	.033	.032	.032	.034	.036	.033	.031	.035
7	Food & tobacco	.001	.001	.001	.001	.001	.000	.001	.001	.001
8	Fabrics, apparel, & footwear	.000	.000	.000	.000	.000	.000	.000	.000	.000
9	Transport. equip. & ordnance	.000	.000	.000	.000	.000	.000	.000	.000	.000
10	Lumber & paper	.000	.001	.000	.001	.000	.000	.000	.000	.000
11	Petroleum, related inds.	.017	.015	.015	.014	.018	.020	.016	.014	.018
12	Plastics & chemicals	.008	.007	.007	.007	.009	.010	.008	.007	.009
13	Glass, stone, clay prdts.	.000	.000	.000	.000	.000	.000	.000	.000	.000
14	Primary iron, steel mfr.	.001	.001	.001	.001	.001	.001	.001	.001	.001
15	Primary nonferrous mfr.	.0	.0	.0	.0	.0	.0	.0	.0	.0
16	Machinery & equip.	.000	.000	.000	.000	.000	.000	.000	.000	.000
17	Services	.129	.135	.095	.107	.084	.077	.078	.088	.095
18	Elec., gas, water, & san. serv.	.210	.226	.240	.243	.217	.204	.237	.251	.210

.000 Coefficient smaller than .0005
.0 Zero coefficient

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