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Publication Date
1975-04-01

LBL-3829 c.1
UC-2
TID-4500-R62

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April 1975

Prepared for the U. S. Energy Research and Development Administration under Contract W-7405-ENG-48

LBL-3829

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ABSTRACT

This paper describes the use of a Multiregional Input-Output Model of the United States to assess the short-term economic impacts of a severe resource shortage. Income and employment multipliers are developed on a national and regional basis to assess the impact of a sudden curtailment in coal output. Beginning with an 82 sector (2 digit SIC level) interindustry structure, key sectors, particularly those which are heavy coal consumers, are disaggregated to permit more detailed analysis.

Instead of adopting a comparative static view and solving the model for a new equilibrium condition based on curtailed coal output, an initial change is introduced and computations are run iteratively so that impacts can be assessed "round by round." By working out sequentially the effects of each round of interactions, a rudimentary time dimension is introduced. To make the problem more manageable, a two-region model was set up for each state of interest, one region being the particular state and the other the rest of the nation.

1. Introduction

The oil shortages of last winter highlighted the need for an analysis of short term impacts of a severe resource shortage on the economy. In anticipation of an impending coal strike the Bureau of Mines approached LBL to perform this type of analysis in order to estimate the short term impact of a cessation in coal production.

As a first approximation it was proposed that income and employment multipliers[1] be developed on a national and regional basis to assess the impact of a drop in coal output. A drop in coal output would lead to a drop in income and also to a drop in output of other sectors in the economy. This new output vector would be computed with the help of the MRIO[2] model. The above analysis will be presented in greater detail in the next section. However, it should be emphasized that due to time pressures the model presented is of a preliminary nature and further refinements will be required. At the same time any critical observations or suggestions toward improving the model are most welcome.

Certain key economic sectors were disaggregated as shown in Table 1. Some of these sectors were disaggregated (1) to show more detail for heavy coal consuming sectors and (2) others because they were energy resource sectors.

Input-output tables, essentially at the 2-digit SIC level with the above additions, were used at the national[3] and regional[2] level to estimate the direct and indirect impacts of a drop in coal output.

2. The Model

The equations of the column coefficient multiregional I-O model are derived in Appendix A. They can be written as:

$$\vec{Z} = A\vec{X} + \vec{Y} \tag{1}$$

$$\vec{X} = C\vec{Z} \tag{2}$$

where $\vec{X},\vec{Y},\vec{Z}$ are vectors with components X_i^g = final demand for commodity i in region g; Y_i^g = final demand for commodity i in region g; Z_i^g = total amount of commodity i consumed in region g.

With the usual ordering of the vector components, A is a block diagonal matrix of regional I-O matrices. It shows the distribution of commodities within regions. C is a trade flow matrix, consisting of diagonal blocks. It gives the proportion of the consumption of a particular commodity in a particular region that is imported from other regions.

We want to trace the effects of initial changes in the coal sectors (i.e., the coal sector for each region). Although the I-O model is static, we hope to approximate the dynamic situation by solving iteratively, each cycle corresponding to some reasonable time period.(1)

Equations (1) and (2), expressed in increments, give

$$\Delta\vec{Z} = A\Delta\vec{X} + \Delta\vec{Y} \tag{3}$$

$$\Delta\vec{X} = C\Delta\vec{Z} \ . \tag{4}$$

These will be iterated in the form

$$\Delta\vec{Z}_k = A\Delta\vec{X}_k + \Delta\vec{Y}_k \tag{5}$$

$$\Delta\vec{X}_{k+1} = C\Delta\vec{Z}_k . \tag{6}$$

Equation (5) says that in cycle k there are reductions $\Delta\vec{Z}_k$ in the commodities consumed within each region, caused by both reductions in production $\Delta\vec{X}_k$ and reduction in final demand $\Delta\vec{Y}_k$ in that region. Equation (6) distributes these shortages to all regions through the trade matrix C, giving the changes $\Delta\vec{X}_{k+1}$ in output for the next cycle.

In our analysis the initial change is the curtailment of production (gross output) in one industry. The drop in output means that various payments to the household sector (primarily wages and salaries) are reduced. Thus income originating in the industry is immediately affected by the cut in output. This direct income effect is computed by multiplying the change in gross output by the personal income portion of the value added coefficient for the industry concerned (coal, in our case). The drop in income results in a cut in final demand spending of consumers, which sets off a chain of interindustry reactions, reducing output and incomes further through subsequent rounds of interaction. These interactions or rounds of spending become weaker and weaker in their effects. While it is not necessary to carry out a series of iterative calculations in order to arrive at the ultimate effects of an initial stimulus, for our purposes something may be gained by doing so.

In each round we are making assumptions concerning how consumer expenditures respond to changes in household income. We are also bound to make reasonable assumptions about how other elements of final demand will alter in each cycle (see below). In the case of consumer demand we are essentially describing the circular flow of the receipt and spending of income and the adjustments in output and employment which follow. This flow takes real time to actually be completed, although in typical static analysis we compute a new equilibrium set of values, ignoring the process of adjustment through real time.

By working out sequentially the effects of each round of interactions, we are able to introduce a rudimentary time dimension to the problem. In our particular case, the problem is compounded by the constraint on the production side. Neglecting this for a moment, we can say that the time for the indirect and induced impacts of a change in consumer demand to work themselves out is related to the income velocity of money. Assuming an average annual income velocity of four, it would take about one year for four iterations to work themselves out, or each iteration would take about three months.

This analogy between the iterative computational procedure and the circular flow of income does not satisfy the changes initiated through the constraint on the production side in our particular case. On the production side, timing depends on assumptions made with respect to volume of inventories on hand and curtailment of exports. For example, one can equally well say that the length of the first cycle is determined by the time required for inventories of coal to be depleted, rather than by the income velocity of money.

Inventory changes pose a problem due to the lack of data on existing inventories. One possibility is to assume different stocks of coal (10 day supply, 20 day supply, etc.) and repeat the calculations for each choice, assuming, as mentioned above, that the stock would be consumed in the first cycle. Inventories of other critical commodities enter only at the second and following iterations. More sophisticated treatments of inventories may be possible, depending on the data available and the effort required to process it.

Exports of coal might reasonably be assumed to go to zero in the first cycle (except for coal already in transit). Other exports would be unchanged. Assumptions for succeeding cycles would be based on the results of earlier iterations. For example, if the first iteration showed shortages of steel occurring, steel exports could be reduced for the second cycle.

The remaining categories of final demand may be assumed to remain unchanged for purposes of initial analysis, or changes may be included as more information becomes available. Because of the time requirements in this preliminary version of the model, we were not able to calculate the state to state trade flows for the disaggregated sectors. Instead for each state we set up a separate two region model, one region being the state and the other the rest of the nation. For each state we had 89 2X2 trade flow matrices and two 89X89 matrices of direct coefficients. This enables us to analyze first the states in which we expect to see the greatest impact.

3. <u>Data</u>

The 1963 National Interindustry Table developed by the Bureau of Mines[3] shows 408 sectors of the U.S. economy. This table was aggregated to show 89 sectors (see Table 2). The figures in this national table serve as control totals for the regional model. National coefficients were used to split the disaggregated sectors at the regional level. A matrix balancing technique was used to adjust the row and column sums. A similar technique was implemented to adjust the regional totals to agree with the national control totals.

Data for disaggregating the various sectors came from references 4, 5,6,7. Coal and petroleum sectors were disaggregated with information on payrolls, number of employees, value added and value of shipments from 1963 Census of Mineral Industries data.[4] Similar data was obtained from the 1963 Census of Manufacturing Industries[5] and from the 1964 County Business Patterns[6] for the clay products and metal manufacturing sectors. To split the utilities sector information on payrolls and employers was obtained from reference 6, and the 1965 Statistical Abstracts of the U.S.[7] Consumption data for the Minerals sectors came frmm the 1963 Minerals Yearbook.

National column coefficients were used to allocate the regional control totals to each sector. The trade flows for the disaggregated sectors were estimated by taking the difference between total production and total consumption for each region. By assuming no cross hauling between two regions the imports from the rest of the regions to a region can be estimated. Similarly the exports may be computed. Essentially this procedure yields 50 two region MRIO matrices, with the second region being the rest of the nation. These fifty matrices are used individually in equations (3) and (4) to estimate the change in regional output vectors X.

Employment and personal income data from the 1963 MRIO were disaggregated to 89 sectors in proportion to value added. Coefficients were then calculated and used for calculating changes in employment and income and the corresponding multipliers. However the nonhomogeneous type II multiplier requires an exogenous consumption-income relationship. Data on personal consumption expenditure by each sector is available for 1947, 1958, 1963 and 1967 from the I-O tables. Total personal income for these years is also available from National Income Issues of the Survey of Current Business and reference 7. A linear curve was fitted, using a least square polynomial fit routine, for each individual sector to estimate the consumption-income relationship.

So far we have discussed the techniques for estimating matrices A and C and calculation of the multipliers. To start the iterative process described in equations (5) and (6) it is necessary to input the values of $\Delta\vec{X}_k$ and $\Delta\vec{Y}_k$. The values of $\Delta\vec{X}$ were provided by the Bureau of Mines (BOM). The major change in output being in the disaggregated sectors. The consumption-income relationship then enables one to estimate $\Delta\vec{Y}$. These are then fed into equations (5) and (6) to estimate the new output. By setting $\Delta\vec{Y} = 0$ we ignore the induced effect and we can calculate a type I multiplier.

Extensions: Instead of solving the model on a region by region basis a sumultaneous solution of the multiregional matrix will be attempted. It is hoped that the same methodology would be applicable to certain critical metropolitan areas and the method would then be extended to other SMSAs.

Table 1

BUREAU OF MINES' ADDED SECTORS TO COMMERCE-BEA'S 82-PRODUCING SECTORS

1963 Input-Output Model

	BEA 1963 I-O Classification & BOM Additions (BM)		Related Census SIC Codes (1967 Ed.)
	7.00 Coal Mining		
(1)	7.01(BM)	Anthracite Mining & Services	11
(2)	7.02(BM)	Bituminous Coal & Lignite Mining & Services	12
	8.00 Crude Petroleum-Natural Gas		
(3)	8.01(BM)	Crude Petroleum Extraction	1311 part.
(4)	8.02(BM)	Natural Gas Extraction	1311 part.
(5)	8.03(BM)	Natural gas liquids	1321
	36 Stone & Clay Products		
(6)	36.01	Cement, Hydraulic	324
(7)	36.30(BM)	Concrete Products & Ready Mixed Cement (ISP 36.10,36.11 & 36.12)	327
(8)	36.04(BM)	Other Stone & Clay Products (36 less 36.01,36.10,36.11 & 36.12)	325,326,328,& 329
	37 Primary Iron & Steel Manufacturing		
(9)	37.01	Blast Furnaces and basic steel products	331
(10)	37.02	Iron & Steel foundaries	332
(11)	37.10(BM)	Iron & steel forgings & other primary metal manufacturing (ISP 37.03 & 37.04)	3391 & 3399
	38 Primary Nonferrous Metal Manufacturing		
(12)	38.02(BM)	Primary copper & copper rolling & casting (ISP 38.01,38.07 & 38.12)	3331,3351, & 3362
(13)	38.30(BM)	Primary aluminum & aluminum rolling & drawing & casting (ISP 38.04,38.08 & 38.11)	3334,28193,3352 & 3361
(14)	38.40(BM)	Other primary nonferrous metal manufacturing (ISP 38 less 12 & 13)	3332,3333,3339,3341, 3356,3357,3369,& 3392
	68 Electric, Gas, Water and Sanitary Services		
(15)	68.01	Electric utilities	4918 part 493
(16)	68.02	Gas utilities	492 & part 493
(17)	68.03	Water and sanitary services	494,495,496,497 & part 494

TABLE 2

1 Livestock and livestock products.
2 Other agricultural products.
3 Forestry and fishery products.
4 Agricultural forestry, fishery services.
5 Iron and ferroalloy ores mining.
6 Nonferrous metal ores mining.
7 Anthracite mining and services.
8 Bituminous coal and lignite mining, services.
9 Crude petroleum extraction.
10 Natural gas extraction.
11 Natural gas liquids.
12 Stone and clay mining and quarrying.
13 Chemical and fertilizer mineral mining.
14 New construction.
15 Maintenance and repair construction.
16 Ordinance and accessories.
17 Food and kindred products.
18 Tobacco manufactures.
19 Broad and narrow fabrics.
20 Miscellaneous textile goods, floor cover.
21 Apparel.
22 Miscellaneous fabricated textile products.
23 Lumber and wood products.
24 Wooden containers.
25 Household furniture.
26 Other furniture and fixtures.
27 Paper and allied products.
28 Paperboard containers.
29 Printing and publishing.
30 Chemicals and selected products.
31 Plastics and synthetic materials.
32 Drugs, cleaning, toilet preparations.
33 Paints and allied products.
34 Petroleum refining.
35 Rubber and miscellaneous plastics products.
36 Leather, tanning and industrial.
37 Footwear and other leather products.
38 Glass and glass products.
39 Cement, hydralic.
40 Concrete products, ready mixed cement.
41 Other stone and clay products.
42 Blast furnaces, basic steel products.
43 Iron and steel foundries.
44 Other primary metal manufacturing.
45 Primary copper, rolling and drawing.
46 Primary aluminum, rolling and drawing.
47 Other primary nonferrous metal manufacturing.
48 Metal containers.
49 Heating, plumbing and structural.
50 Stamping, screw machine products.

TABLE 2 (cont'd.)

51 Other fabricated metal products.
52 Engines and turbines.
53 Farm machinery and equipment.
54 Construction, mining and oilfield.
55 Materials handling equipment.
56 Metalworking machinery and equipment.
57 Special industry machinery.
58 General industrial machinery.
59 Machine shop products.
60 Office, computing, accounting machinery.
61 Service industry machinery.
62 Electric industrial equipment.
63 Household appliances.
64 Electric lighting and wiring equipment.
65 Radio, television, communications equipment.
66 Electronic components.
67 Miscellaneous electrical machinery.
68 Motor vehicles and equipment.
69 Aircraft and parts.
70 Other transportation equipment.
71 Scientific and control instruments.
72 Optical and photographic equipment.
73 Miscellaneous manufacturing.
74 Transportation and warehousing.
75 Communications, except radio and television.
76 Radio and television broadcasting.
77 Electric utilities.
78 Gas utilities.
79 Water and sanitary services.
80 Wholesale and retail trade.
81 Finance and insurance.
82 Real estate and rental.
83 Hotels, personal and repair services.
84 Business services.
85 Automobile repairs and services.
86 Amusements.
87 Medical, educational, service, and nonprofit.
88 Federal government enterprises.
89 State and local government enterprises.

Footnotes and References

†On leave from San Jose State University.

*On leave from Fordham University.

1. F.T. Moore and J.W. Peterson, "Regional Analysis: An Interindustry Model of Utah," RE & S, 37 (1955), pp.363-83.

2. Karen R. Polenske, A Multiregional Input-Output Model for the U.S., Report No. 21, EDA, U.S. Department of Commerce, Washington, D.C., December 1970.

3. Input-Output Structure of the U.S. Economy: 1963. Vol. 1 -Transactions data for detailed industries. Vol. 2 -Direct requirements for detailed industries. Vol. 3-Total requirements for detailed industries, A Supplement to the Survey of Current Business, OBE, U.S. Department of Commerce, Washington, D.C., 1969.

4. Census of Mineral Industries 1963, U.S. Bureau of the Census, U.S. Government Printing Office, Washington, D.C.

5. Census of Manufacturing Industries 1963. U.S. Bureau of Census, U.S. Government Printing Office, Washington, D.C.

6. County Business Patterns 1964. U.S. Bureau of the Census, Department of Commerce, Washington, D.C.

7. The National Income and Product Accounts of the U.S. 1929-1965, Statistical Tables, U.S. Department of Commerce, Office of Business Economics, 1966.

Appendix A

The Column Coefficient Multiregional Input-Output Model

Notation

n = number of regions

m = number of sectors

x_i^{go} = total amount of commodity i produced in region g

x_i^{oh} = total amount of commodity i consumed in region h

x_i^{oo} = total amount of commodity i produced (consumed) in all regions

x_i^{gh} = total amount of commodity i shipped from region g to region h

a_{ij}^g = total amount of commodity i delivered from all regions to sector j located in region g per unit of output of commodity j produced in region g

c_i^{gh} = proportion of the total consumption of commodity i in region h that is imported from g

y_i^g = final demand for commodity i in region g

Note that superscripts are used for regions and subscripts for sectors.

Equations

$$x_i^{og} = \sum_{j=1}^{m} a_{ij}^g \, x_j^{go} + y_i^g \qquad \text{(A1)}$$

$$x_i^{gh} = c_i^{gh} \, x_i^{oh} \qquad \text{(A2)}$$

$$x_i^{go} = \sum_{h=1}^{n} x_i^{gh} \qquad \text{(A3)}$$

$$x_i^{oh} = \sum_{g=1}^{n} x_i^{gh} \qquad \text{(A4)}$$

Note that eq.(A4) is unnecessary. Combined with eq.(A2) it gives

$$x_i^{oh} = \sum_{g=1}^{n} c_i^{gh} \, x_i^{oh}$$

i.e.,

$$\sum_{g=1}^{n} c_i^{gh} = 1 \tag{A5}$$

which just expresses the fact that we are dealing with a column coefficient model.

The x_i^{gh} can be eliminated by combining eqs.(A2) and (A3), giving

$$x_i^{go} = \sum_{h=1}^{n} c_i^{gh} x_i^{oh} \tag{A6}$$

To put the model in matrix form, we rewrite eqs.(A1) and (A6) as

$$x_i^{og} = \sum_{j=1}^{m} \sum_{h=1}^{n} a_{ij}^{g} \delta_{gh} x_j^{ho} + y_i^{g} \tag{A7}$$

$$x_i^{go} = \sum_{j=1}^{m} \sum_{h=1}^{n} c_i^{gh} \delta_{ij} x_j^{oh} \tag{A8}$$

We introduce an mn-dimensional vector space in which components are specified by a pair of indices, a superscript (region) and a subscript (sector). In this space the output vector $\vec{X}$, the final demand vector $\vec{Y}$, and the "consumption" vector $\vec{Z}$ have components

$$X_i^g = x_i^{go} \quad Y_i^g = y_i^g \quad Z_i^g = x_i^{og} \tag{A9}$$

We also introduce mn x mn matrices A and C with elements

$$A_{ij}^{gh} = a_{ij}^{g} \delta_{gh} \quad C_{ij}^{gh} = c_i^{gh} \delta_{ij} \tag{A10}$$

Then the sums in eqs. (A7) and (A8) are just multiplications of vectors by matrices, so we immediately get

$$\vec{Z} = A\vec{X} + \vec{Y} \tag{A11}$$

and

$$\vec{X} = C\vec{Z} \tag{A12}$$

Putting $\vec{Z} = C^{-1}\vec{X}$ in eq. (A11) gives the final result

$$(C^{-1}-A)\ \vec{X} = \vec{Y} \qquad (C^{-1}-A)^{-1}\ \vec{Y} = \vec{X} \tag{A13}$$

Equivalently, multiplying eq.(A11) by C and using eq.(A12) gives

$$(I - CA)\ \vec{X} = C\vec{Y} \quad (I - CA)^{-1}\ C\vec{Y} = \vec{X} \tag{A14}$$

An alternative procedure would be to first solve for the consumption vector Z. Substituting eq.(A12) into eq.(A11) gives

$$(I - AC)\ \vec{Z} = \vec{Y} \quad (I - AC)^{-1}\ \vec{Y} = \vec{Z} \tag{A15}$$

Having found $\vec{Z}$, the output vector $\vec{X}$ is given by eq.(A12)

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