

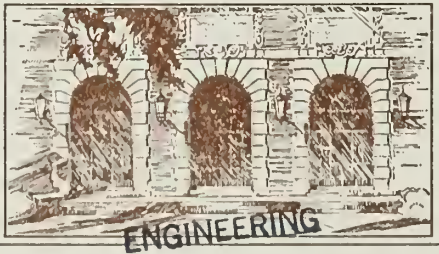


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# Center for Advanced Computation

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CAC Document No. 7

ECONOMIC RESEARCH GROUP WORKING  
PAPER NO. 1

Progress Report on the Development of  
a Large-Scale Conditional Consistent  
Economic and Manpower  
Forecasting Model

By: Roger H. Bezdek





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## ABSTRACT

This paper summarizes the progress in the development of a large-scale economic and manpower impact model at the Center for Advanced Computation of July 1971. The first two sections of this report provide the rationale for the model and give a nontechnical description of the methodology and workings of the general system. The third section of this report indicates the type of computerized system which is presently (summer 1971) on-line and available for use in the study of pressing economic and social problems. The fourth section tells of improvements in the model being undertaken and outlines the plans for the development of an expanded system in the near future. Appendices include several tables specifying the economic categories contained in the model, a list of references where additional information pertaining to this model may be obtained, and a mathematical statement of the model.



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## INTRODUCTION

Certain effects upon the economy and the labor market are likely to be generated by expenditures upon different types of economic programs and activities reflecting alternate national priorities. Knowledge of these effects is critically required for a variety of purposes. This type of information can prove invaluable in relation to a number of problem areas including economic and manpower policy formulation, manpower forecasting, the development of adequate educational and vocational training programs, the analysis of requirements for critical occupations, and assessment of the feasibility and potential for reordering national priorities to emphasize different goals and objectives. A large-scale computerized economic model capable of accurately and consistently generating this type of information in great detail is presently being developed at the Center for Advanced Computation at the University of Illinois under the supervision of Roger Bezdek and Hugh Folk. The purpose of this report is threefold: 1) to familiarize the reader with the basic methodology and workings of this model; 2) to indicate the stage of development of the model at the present time and the type of empirical system presently on-line; and 3) to indicate the extensions of the model presently being developed and planned.

### THE WORKINGS OF THE MODEL

Theoretically the model is entirely straightforward and is based on economic input-output analysis. A brief mathematical statement of the

model has been included as an appendix to this report; here the workings of the model shall be explained in less rigorous terms.

Economic input-output analysis is essentially an empirical simplification of general equilibrium theory and, subject to a number of restrictions, is capable of yielding a large amount of data relating to the workings of the economy. The economic model developed here represents an extension of the open input-output model in several directions. Holding the structure of the economy and labor market constant it generates detailed economic and manpower effects from alternate distributions of national expenditures reflecting different goals and priorities. As illustrated in Figure 1, the generating mechanism of the model operates in the following sequence:

- 1) The goals, priorities, and objectives to be simulated and analyzed are specified in advance. The model is general and is capable of handling a wide range of different types of priority and economic program reorientations. The precise set of economic, social, and political programs analyzed may be developed by the researcher, administrator or government decision maker utilizing the model.

- 2) This hypothetical program-priority decision is next translated into expenditures upon distinct types of public and private economic activities. The model accounts for all public and private expenditures, but the programs of the Federal and the state and local governments are singled out for special attention.

3) Each individual economic activity has unique requirements for the output of different industries, and the sum of all these output requirements comprise the direct output requirements associated with a specific set of national priorities and program expenditures.

4) Due to the need which industries have for the outputs of other industries as inputs to themselves the total output requirements from any single industry will be considerably larger than those created directly, and the total output of the economy is the sum of the direct and the indirect output requirements from every industry. The direct output requirements are felt immediately and are usually concentrated in certain industries; the indirect output requirements take longer to be felt and are present in all industries.

5) Assuming that employment requirements in every industry are proportional to output requirements, each distinct level of industrial output requirements generates an associated level of employment within that industry. Hence again, both direct and indirect requirements for employment are generated within each industry.

6) Finally, occupational employment demands are generated according to the industrial distribution of occupational employment. Several different types of occupational manpower information can be generated: the total employment requirements generated directly and indirectly for each occupation, the occupational requirements generated within any specific industry, the occupational requirements generated by any specific industry, and the structure of interindustry employment demands generated for a particular occupation.

Operationally there are three basic components comprising the model: an activity-industry matrix, an interindustry-employment matrix, and an

industry-occupation matrix. The activity-industry matrix translates expenditures on economic programs and activities into direct industrial output requirement. Its columns index economic activities and its rows index industries. Reading down a column of this matrix indicates how expenditures on a particular economic program or activity are distributed as direct output requirements from different industries. Reading across a row of this matrix shows how the direct requirements for output from a specific industry are generated by expenditures on different programs and activities. The interindustry-employment matrix transforms direct industrial output requirements into direct and indirect interindustry employment demands. Reading down a column of this matrix shows how activity in a specific industry generates employment requirements within all industries. Reading across a row of this matrix illustrates the manner in which employment within an individual industry is generated by activity in all industries. The industry-occupation matrix translates total interindustry employment into occupational manpower requirements. Its rows index industries and its columns index occupations. Reading across a row of this matrix shows the occupational distribution of employment within a specific industry. Reading down a column of this matrix illustrates the industrial distribution of employment within an individual occupation.

#### THE ON-LINE EMPIRICAL SYSTEM

Several preliminary versions of the overall model have already been developed and these are presently on-line at the Center for Advanced Computation. Though preliminary, these models were painstakingly constructed, tested, debugged, and perfected and are currently capable of quickly and efficiently generating a large quantity of useful information in a level of accuracy and detail not obtainable elsewhere.

Basic models have been developed for 1960 and for the years 1972-1976. The base year for these models is 1958; that is, the models stated center expenditures on economic programs and activities in terms of (constant) 1958 dollars. The dimensions of the matrix components of the models and the level of detail of the estimates generated vary according to the target year specified and the specific purpose for which the model is being used.

Input vectors for approximately 80 distinct types of economic programs and activities are presently available for use in the model. These programs and activities account for total gross national product, or national expenditures, and thus include all the components of GNP: personal consumption expenditures, exports and imports, investment, and government expenditures. Since changing priorities or program emphasis very often involves the activities of the Federal, state, and local governments, a special effort has been made to include as many distinct functional government program categories as possible in the model. The model is thus presently capable of analyzing expenditures on a wide range of different types of public programs such as different types of defense activities, educational programs, civilian safety and criminal justice programs, social welfare payments, research and development activities, ecological and environmental programs, health programs, and so forth. A complete listing of the economic activities presently contained in the model is given in Table 1; in addition 70 other types of activities relating to detailed construction and personal consumption

categories are readily available for simulation and analysis if the user so desires. Several different activity input vectors pertaining to years in the period 1958-1976 are available for most of the categories listed in Table 1.

The 80-order industry classification scheme used by the U.S. Office of Business Economics in their recent input-output studies is the basic one relied upon in the model, and these industries are listed in Table 2. Several of the industries in Table 2 have been modified so as to be consistent with the industry conventions adhered to in the other components of the model and several unique industry groups have been added. In addition, data in 367 and 478 industry detail is available for the analysis of special problems requiring greater industrial disaggregation than is provided by the 80-order classification scheme. Occupational manpower requirements are generated for 185 occupational categories, and these are listed in Table 3. Data pertaining to more detailed census occupation categories are also available for use in the model for consideration of special problems.

The model itself is both comprehensive and consistent. It is comprehensive and accounts in an integrated and efficient manner for total gross national product, total gross and net industrial output, total industrial employment, and total occupational employment. There is no overlapping or double counting contained in the activity categories or the industrial or occupational employment categories. The model is also consistent and the methodology followed and the control data used insure that the estimates generated are internally consistent and realistic and do not get out of hand.

The model in the format and detail discussed above is presently available for use in the analysis of a wide range of problems relating to manpower forecasting and analysis, economic planning, feasibility and sensitivity analysis, educational and vocational planning, and national priority reordering. Although developed very recently the models discussed here have already found widespread use and application. For example, the 1960 system was used to test hypothesis that the manpower requirements of the United States are sensitive to shifting national priorities, and it also used to classify occupations on the basis of their sensitivity to specific types of priority reorderings. The model relating to the mid-1970's was used to simulate in detail the economic and manpower effects which would be generated by the Urban Coalition's suggested radical reorderings of national priorities and Federal budget outlays. Further, this approach has also been used to develop broad guidelines for long-range university planning on a regional level. While these examples do suggest the widespread applicability of the models developed here they do not begin to exhaust the possibilities of these models and additional applied research is presently underway to adopt this approach to the study of other problem areas.

#### PENDING IMPROVEMENTS IN THE MODEL

Extensions and improvements of the existing models are currently proceeding simultaneously in a number of areas. But while the model will continuously be in a state of being improved, expanded, and perfected, a basic model utilizing the most contemporary data and techniques will always

be on-line for use in the study and analysis of pressing social and economic problems. In this sense, then, the system is very much "user oriented".

One major and important type of extension of the model which is presently under way is the more accurate updating and projection of it and the addition of more detail to each of its components. The model pertaining to the mid-1970's is in the process of being revised, re-evaluated, and retested, and work on other models relating to the early 1980's is also beginning. Aside from this, additional detail relating to economic activities and industrial and occupational manpower categories is being integrated into the various components of the existing models. For instance, major attention is being devoted to the activity-industry matrix so that more functional economic programs of the Federal and state and local governments can be included efficiently for analysis. Also, the tie-in between the industry specification of the interindustry-employment matrix and those of the industry-occupation matrix is being revised and perfected.

Work is also progressing on the introduction of supply considerations and constraints into the model. Essentially this requires the development of methods of projecting the supply of manpower likely to be available within each occupational category in the specified target year by using data on the present occupational manpower supply, rates of attrition for each occupation, and rates of transition among and within occupational groups. With the development of the supply side of the model the manpower demands generated by the model on the basis of a certain set of assumptions for a particular year can be compared with the manpower supply likely to exist in that year. This



ould allow determination of the feasibility of the policy in question and  
ould also pinpoint those categories likely to become bottlenecks if the  
ypothetical policy was actually adopted.

Coefficient sensitivity and error variance analyses are also presently  
eing conducted. These studies are serving a dual purpose: identification  
f the sensitive and critical coefficients within each component of the model  
erves to indicate the formal mathematical and theoretical properties of the  
odel and the accuracy of the estimates generated, and these analyses also  
erve to indicate those subcomponents of the model at which the data requirements  
re the most critical.

Finally, regionalization of the model is scheduled to begin shortly.  
his improvement will allow the disaggregation of the national economic and  
anpower effects generated into effects generated within different regions  
f the nation and this, in turn, shall aid greatly in the formulation of  
egional economic, manpower, and educational policies.

The empirical system is presently set up on a Burroughs 6500  
equential digital computer. Early next year the model will be transferred  
o the ILLIAC IV parallel computer. This transfer will greatly enhance the  
ata input and analytic capabilities of the system and will also make feasible  
a almost unlimited number and type of computations and matrix operations  
volving the model. In addition, ILLIAC IV will be tied into a nationwide  
omputer net and the model will thus be able to accept inputs from any part of  
e nation and also be capable of delivering outputs nationwide.

FIGURE 1

Schematic Representation of the Manpower Demand Generating Mechanism of the Model

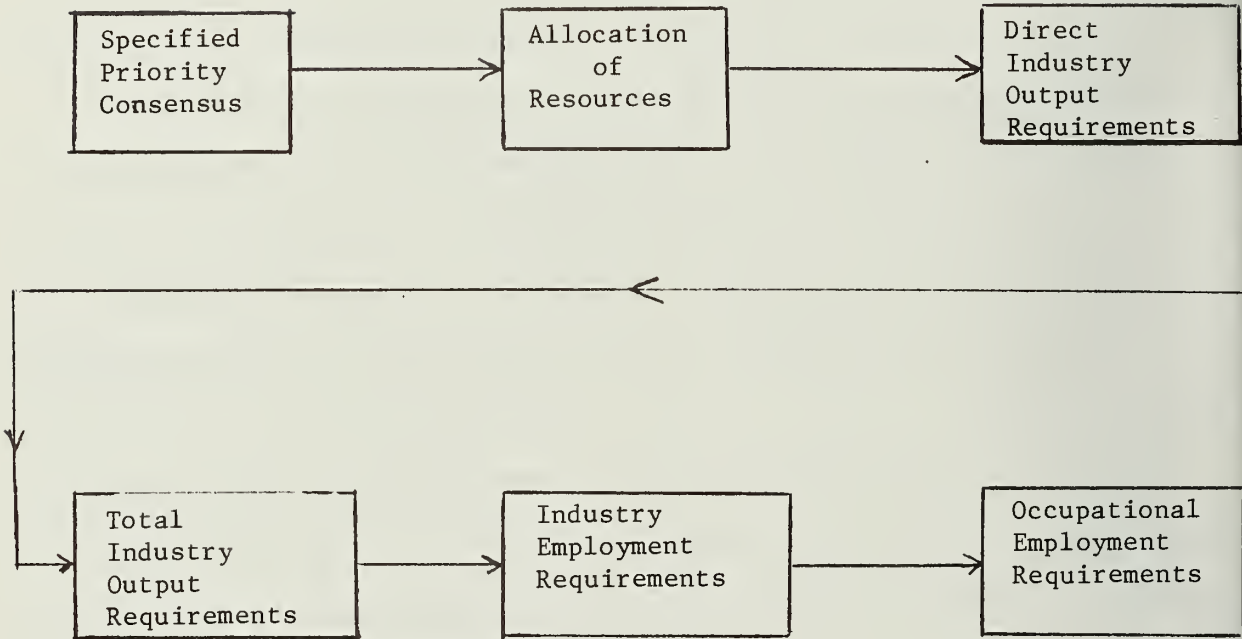


TABLE 1

ECONOMIC ACTIVITY CATEGORIES

Personal Consumption Expenditures

- Food and tobacco
- Clothing, accessories, and jewelry
- Personal care
- Housing
- Household operation
- Medical care and death expenses
- Personal business
- Transportation
- Recreation
- Private education and research
- Religious and welfare activities
- Foreign travel and remittances, net

Gross Private Domestic Investment

- Private fixed capital investment
- Net inventory change

Net Exports

Federal Government Expenditures

- National defense
  - Intelligence and communications
  - Airlift and seairlift
  - Research and development
  - Operation, maintenance, and administration
  - Other national defense

- Health
  - Health facilities
  - National health insurance
  - Other health

- Transportation
  - Highways
  - Railroad and mass transit
    - New facilities
    - Improvement of existing facilities

Table 1 (Cont.)

- Supersonic transport and civil aviation
- Merchant marine
- Inland navigation

Social Welfare

- Law enforcement, criminal justice, and civilian safety

- Education, arts, and humanities

  - Education and cultural facilities

  - Other educational, arts, and humanities

- Environment, natural resources, and sanitation

  - Water and sewer facilities

  - Flood control and irrigation

  - Waste treatment facilities

  - Multiple purpose water resource projects

  - Locks, dams, and reservoirs

  - Other environment, natural resources, and sanitation

- Metropolitan development and housing

  - Urban renewal and model cities

  - Housing subsidies

- Foreign economic and military assistance

- Research and development

- National Aeronautics and Space Administration

- Atomic Energy Commission

- Fiscal relief to state and local governments

  - Educational grants

  - Revenue sharing and interest subsidies

- Other Federal

State and Local Government Expenditures

- Education

- Health, welfare, and sanitation

- Civilian safety

Table 1 (Cont.)

Highways

Transit

Public utilities

Electric utilities

Water and gas utilities

Conservation and development

Other state and local

New construction

Residential buildings, nonfarm

One-to-four family apartments

Five-or-more family apartments

Additions and alterations

Public dwelling units

Other residential construction

Nonresidential buildings, total

Offices

Industrial

Educational

Hospital and institutional

Other residential

Public utilities

Railroads and local transit

Gas and petroleum

Electric light and power

Telephone and telegraph

Highways

Military facilities

Oil and gas well drilling and exploration

Water systems

Sewer systems

Conservation and Development

All other public and private new construction

Table 1 (Cont.)

Maintenance and Repair Construction

Residential buildings, nonfarm

Nonresidential buildings

Railroads and local transit

Highways

Military facilities

Water systems and sewer systems

All other public and private maintenance and repair construction

Industry Numbering for Recent Input-Output Studies  
by the U.S. Office of Business Economics

<u>Industry number and industry title</u>	<u>Related SIC codes (1957 edition)</u>
Agricultural, forestry, and fisheries:	
1. Livestock and livestock products	013, pt. 014, 0193, pt. 02, pt. 0729
2. Other agricultural products	011, 012, pt. 014, 0192, 0199, pt. 02
3. Forestry and fishery products	074, 081, 082, 084, 086, 091
4. Agricultural, forestry, and fisheries services	071, 0723, pt. 0729, 085, 098
Mining:	
5. Iron and ferroalloy ores mining	1011, 106
6. Nonferrous metal ores mining	102, 103, 104, 105, 108, 109
7. Coal mining	11, 12
8. Crude petroleum and natural gas	1311, 1321
9. Stone and clay mining and quarrying	141, 142, 144, 145, 148, 149
10. Chemical and fertilizer mineral mining	147
Construction:	
11. New construction	138, pt. 15, pt. 16, pt. 17, pt. 6561
12. Maintenance and repair construction	pt. 15, pt. 16, pt. 17
Manufacturing:	
13. Ordnance and accessories	19
14. Food and kindred products	20
15. Tobacco manufactures	21
16. Broad and narrow fabrics, yarn and thread mills	221, 222, 223, 224, 226, 228
17. Miscellaneous textile goods and floor coverings	227, 229
18. Apparel	225, 23 (exc. 239), 3992
19. Miscellaneous fabricated textile products	239
20. Lumber and wood products, except containers	24 (exc. 244)

Table 2 (cont'd)

<u>Industry number and industry title</u>	<u>Related SIC codes (1957 edition)</u>
21. Wooden containers	244
22. Household furniture	251
23. Other furniture and fixtures	25 (exc. 251)
24. Paper and allied products, except containers and boxes	26 (exc. 265)
25. Paperboard containers and boxes	265
26. Printing and publishing	27
27. Chemicals and selected chemical products	281 (exc. alumina pt. ot 2819), 286, 287, 289
28. Plastics and synthetic materials	282
29. Drugs, cleaning, and toilet preparations	283, 284
30. Paints and allied products	285
31. Petroleum refining and related industries	29
32. Rubber and miscellaneous plastics products	30
33. Leather tanning and industrial leather products	311, 312
34. Footwear and other leather products	31 (exc. 311, 312)
35. Glass and glass products	321, 322, 323
36. Stone and clay products	324, 325, 326, 327, 328, 329
37. Primary iron and 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, and fabricated structural metal products	343, 344
41. Screw machine products, bolts, nuts, etc., and metal stampings	345, 346
42. Other fabricated metal products	342, 347, 348, 349 (exc. 3491)
43. Engines and turbines	351
44. Farm machinery and equipment	352
45. Construction, mining, oil field machinery and equipment	3531, 3532, 3533
46. Materials handling machinery and equipment	3534, 3535, 3536, 3537
47. Metalworking machinery and equipment	354



<u>Industry number and industry title</u>	<u>Related SIC codes (1957 edition)</u>
48. Special industry machinery and equipment	355
49. General industrial machinery and equipment	356
50. Machine-shop products	359
51. Office, computing and accounting machines	357
52. Service industry machines	358
53. Electric transmission and distribution equipment, and electrical industrial apparatus	361, 362
54. Household appliances	363
55. Electric lighting and wiring equipment	364
56. Radio, television, and communication equipment	365, 366
57. Electronic components and accessories	367
58. Miscellaneous electrical machinery, equipment, and supplies	369
59. Motor vehicles and equipment	371
60. Aircraft and parts	372
61. Other transportation equipment	373, 374, 375, 379
62. Professional, scientific, and controlling instruments and supplies	381, 382, 384, 387
63. Optical, ophthalmic, and photographic equipment and supplies	383, 385, 386
64. Miscellaneous manufacturing	39 (exc. 3992)
Transportation, communication, electric, gas, sanitary services:	
65. Transportation and warehousing	40, 41, 42, 44, 45, 46, 47
66. Communications, except radio and television broadcasting	481, 482, 489
67. Radio and TV broadcasting	483
68. Electric, gas, water, and sanitary services	49
Wholesale and retail trade:	
69. Wholesale and retail trade	50 (exc. manufacturers sales offices), 52, 53, 54, 55, 56, 57, 58, 59, pt. 7399

Table 2 (cont'd)

<u>Industry number and industry title</u>	<u>Related SIC codes (1957 edition)</u>
Finance, insurance, and real estate:	
70. Finance and insurance	60, 61, 62, 63, 64, 66, 67
71. Real estate and rental	65 (exc. 6541 & pt. 6561)
Services:	
72. Hotels and lodging places; personal and repair services, except automobile repair	70, 72, 76 (exc. 7694 & 7699)
73. Business services	6541, 73 (exc. 7361, 7391, & pt. 7399), 7694, 7699, 81, 89 (exc. 8921)
74. Research and development	--
75. Automobile repair and services	75
76. Amusements	78, 79
77. Medical, educational services, and nonprofit organizations	0722, 7361, 80, 82, 84, 86, 8921
Government enterprises:	
78. Federal government enterprises	--
79. State and local government enterprises	--
Imports:	
80. Gross imports of goods and services	--
Dummy industries:	
81. Business travel, entertainment, and gifts	--
82. Office supplies	--
83. Scrap, used and secondhand goods	--
Special industries:	
84. Government industry	--
85. Rest of world industry	--
85. Household industry	--

TABLE 3

OCCUPATIONAL MANPOWER CATEGORIES

Professional Technical, Kindred

Engineers, Technical

Engineers, Aeronautical

Engineers, Chemical

Engineers, Civil

Engineers, Electrical

Engineers, Industrial

Engineers, Mechanical

Engineers, Metallurgy, etc.

Engineers, Mining

Other Engineers, Technical

Natural Scientists

Chemists

Agricultural Scientists

Biological Scientists

Geologists, Geophysicists

Mathematicians

Physicists

Other Natural Scientists

Technicians, Except Medical, Dental

Draftsmen

Surveyors

Air Traffic Controllers

Table 3 (Cont.)

Radio Operators

Technicians, Other

Medical, Other Health Workers

Dentists

Dietitians, Nutritionists

Nurses, Professional

Optometrists

Osteopaths

Pharmacists

Physicians and Surgeons

Psychologists

Technicians, Medical, Dental

Veterinarians

Other Medical, Health Workers

Teachers

Teachers, Elementary

Teachers, Secondary

Teachers, College

Teachers, Other

Social Scientists

Economists

Statisticians and Actuaries

Other Social Scientists

Table 3 (Cont.)

Other Professional, Technical and Kindred

Accountants and Auditors

Airplane Pilots, Navigators

Architects

Workers in Arts, Entertainment

Clergymen

Designers, Except Design Draftsmen

Editors and Reports

Lawyers and Judges

Librarians

Personnel and Labor Relations Workers

Photographers

Social and Welfare Workers

Professional, Technical, Kindred, Nec.\*

Managers, Officials, Proprietors

Conductors, Railroad

Creditmen

Officers, Pilots, Engineers, Ship

Postmasters and Assistants

Purchasing Agents

Managers, Officials, Proprietors, Nec.\*

Clerical and Kindred Workers

Stenos, Typists, Secretaries

Office Machine Operators

Table 3 (Cont.)

Other Clerical, Kindred Workers

Accounting Clerks

Bookkeepers, Hand

Bank Tellers

Cashiers

Mail Carriers

Postal Clerks

Shipping, Receiving Clerks

Telephone Operators

Clerical and Kindred, Nec.\*

Sales Workers

Craftsmen, Foremen and Kindred

Construction Craftsmen

Carpenters

Brickmasons and Tile Setters

Cement, Concrete Finishers

Electricians

Excavating, Grading Machine Operators

Painters and Paperhangers

Plasterers

Plumbers and Pipefitters

Roofers and Slaters

Structural Metalworkers

Table 3 (Cont.)

Foremen Nec.\*

Metalworking Crafts Except Mechanics

Machinists and related

Blacksmiths, Forgemen, Hammermen

Boilermakers

Heat Testers, Annealers

Millwrights

Molders, Metal, Except Coremakers

Patternmakers, Metal, Wood

Rollers and Roll Hands

Sheet Metal Workers

Toolmakers and Diemakers

Printing Trades Craftsmen

Compositors, Typesetters

Electrotypers, Stereotypers

Engravers Except Photoengravers

Photengravers, Lithographers

Pressmen, Plate Printers

Transport and Public Utility Craftsmen

Linemen and Servicemen

Locomotive Engineers

Locomotive Firemen

Mechanics and Repairmen

Airplane Mechanics and Repairmen

Motor Vehicle Mechanics

Table 3 (Cont.)

Office Machine Mechanics

Radio and TV Mechanics

Railroad and Car Shop Mechanics

Other Mechanics and Repairmen

Craftsmen and Kindred

Bakers

Cabinetmakers

Cranemen, Derrickmen, Hoistmen

Glaziers

Jewelers and Watchmakers

Loom Fixers

Opticians, Lens Grinders

Inspectors, Log and Lumber

Inspectors, Other

Upholsterers

Craftsmen and Kindred Nec.\*

Operatives and Kindred Workers

Drivers and Deliverymen

Drivers, Bus, Truck, Tractor

Deliverymen and Routemen

Transportation and Public Utility Operatives

Brakemen and Switchmen, Railroad

Power Station Operators

Sailors and Deckhands



Table 3 (Cont.)

Semiskilled Metalworking Occupations

Furnacemen, Smeltermen, Pourers

Heaters, Metal

Welders and Flame Cutters

Assemblers, Metalwork, Class A

Assemblers, Metalwork, Class B

Inspectors, Metalwork, Class B

Machine Tool Operators, Class B

Electroplaters

Electroplaters Helpers

Semiskilled Textile Occupations

Knitters, Loopers, Toppers

Spinners, Textile

Weavers, Textile

Sewers and Stitchers, Manufacturing

Other Operatives and Kindred

Asbestos, insulation workers

Attendants, auto service, parking

Blasters and Powdermen

Landry, Dry Cleaning Operatives

Meat Cutters, Except Meat Packing

Mine Operators, Laborers, Nec.\*

Operatives and Kindred, Nec.\*

Table 3 (Cont.)

Service Workers

Private Household Workers

Protective Service Workers

Firemen

Guards, Watchmen, Doorkeepers

Police, Other Law Enforcement Officials

Food Service Workers

Bartenders

Cooks, Except Private Household

Counter and Fountain Workers

Waiters and Waitresses

Other Service Workers

Airline Stewards, Stewardesses

Attendants, Hospital and Other Institutional

Charwomen and Cleaners

Janitors and Sextons

Nurses, Practical

Service Workers, Nec. \*

Laborers, Except Farm and Mine

Farmers and Farm Workers

\*Nec.: Not elsewhere classified

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## APPENDIX

### Formal Statement of the Basic Theoretical Model

#### Notation

- $j$ : Number of industrial categories.
- $u$ : number of economic activity categories.
- $k$ : number of occupational employment categories.
- $y$ : a  $j$ -by-1 vector giving the industrial requirements of final demand.
- $g$ 's:  $j$ -by-1 vectors showing the industrial requirements of the relevant national economic programs.
- $a$ 's: percentages of total national expenditures devoted to the corresponding economic activities.
- $L$ : a (partitioned) Leontief matrix.
- $Z$ : a  $j$ -by- $j$  matrix indicating intermediate product flows.
- $w$ : a 1-by- $j$  vector showing the values added in each industrial category.
- $x$ : a  $j$ -by-1 (total) output vector whose elements are  $x_1, x_2, \dots, x_j$ .
- $d$ : a  $j$ -by-1 vector of ones.
- $X$ : a  $j$ -by-1 diagonal matrix whose diagonal elements are the elements of the vector  $x$ .
- $A$ : a  $j$ -by- $j$  matrix of input-output coefficients indicating the source and quantity of inputs to each industrial category per specified dollar amount of output from that category.
- $I$ : an identity matrix of order  $j$ .
- $P$ : a  $j$ -by- $u$  activity-industry matrix showing the industrial requirements of the economic activity categories.
- $q$ : a  $u$ -by-1 vector indicating the distribution of national expenditures among the economic activity categories.
- $F$ : a  $j$ -by- $j$  diagonal matrix of employment-output ratios.

APPENDIX (Cont.)

- $\epsilon$ : a  $j$ -order vector indicating the portion of final demand consumed by each exogenous activity.
- $M$ : a  $j$ -by- $j$  interindustry-employment matrix showing the total employment generated per delivery of a specified dollar amount of output to final demand.
- $T$ : a  $j$ -by- $1$  industry employment vector showing the total employment generated in every industry by a specified distribution of final demand.
- $N$ : a  $j$ -by- $k$  industry-occupation matrix giving the occupational distribution of industry employment in percentage coefficients.
- $T$ : a  $j$ -by- $k$  industry-occupation matrix showing the occupational distribution of total industrial employment.

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Total adjusted net national expenditure is divided among the economic activity categories in a specified manner:

$$(1) \quad y = g_1 + g_2 + \dots + g_u; \quad \sum_i^j y_i = \sum_i^u \epsilon_i \left( \sum_i^j y_i \right); \quad \sum_i^u \epsilon_i = 1$$

An input-output model which represents a complete economic system is usually referred to as a Leontief model, and a convenient way of representing an input-output transaction table is by a partitioned Leontief matrix:

$$(2) \quad L = \left[ \begin{array}{c|c} Z & y \\ \hline w & 0 \end{array} \right]$$

--the zero in the lower right hand corner of the Leontief matrix is present because the non-production accounts of the system are assumed to have been consolidated.

All output is accounted for by either intermediate or final demand:

$$(3) \quad x = Zx + y$$

Relying on a basic assumption of input-output analysis--that inputs vary proportionately with outputs--the technical coefficient matrix,  $A$ , may be obtained by dividing the elements in each column of  $Z$  by the output total in the corresponding row of the transaction table:

$$(4) \quad Z = X^{-1}$$

APPENDIX (Cont.)

Solving equation (4) for Z:

$$(5) \quad Z = AX$$

Substituting the above result into equation (3):

$$(6) \quad x = AXd + y = Ax + y$$

With input-output coefficient matrix A and output vector x, Ax is the vector of input requirements from these outputs; and the vector of net outputs (the quantities available for disposal outside of the production sector) is given by:

$$(7) \quad x - Ax = (I-A)x$$

Interest centers on investigating the effects on employment demands of alternate specified lists of net outputs (final demands or bills of goods). For final demand vector y we have from equations (6) and (7):

$$(8) \quad (I-A)x = y$$

Assuming (I-A) to be nonsingular, x may be solved for directly:

$$(9) \quad x = (I-A)^{-1}y$$

$(I-A)^{-1}$  is the Leontief inverse matrix and from it may be obtained the direct and indirect requirements per specified dollar amount of final demand. To determine the level at which all industries must operate to produce a specified bill of goods, y, equation (9) is solved for x. Premultiplication of the Leontief inverse by a diagonal employment-output ratio matrix yields an interindustry-employment matrix indicating the total employment generated by and in every industry per specified dollar of delivery to final demand:

$$(10) \quad M = F(I-A)^{-1}$$

Postmultiplication of the interindustry-employment table by the final demand vector yields an industry employment vector showing the total employment generated in every industry by a specific bill of goods:

$$(11) \quad m^T = My$$

Premultiplication of the industry-occupation matrix by the diagonal industry employment matrix yields a total industry-occupation matrix indicating the occupational distribution of industrial employment demands generated by a specified bill of goods:

$$(12) \quad N^T = M^T N$$

APPENDIX (Cont.)

Finally, the final demand vector itself can be disaggregated into the product of an activity-industry matrix and an activity-expenditure vector:

$$(13) \quad y = Pq$$

This last step represents a generalization of the system and permits the simulation and analysis of a large number of alternate national priority-expenditure distributions.





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ABSTRACT

This paper summarizes the progress in the development of a large-scale economic and manpower impact model at the Center for Advanced Computation as of July 1971. The first two sections of this report provide the rationale for the model and give a nontechnical description of the methodology and workings of the general system. The third section of this report indicates the type of computerized system which is presently (summer 1971) on-line and available for use in the study of pressing economic and social problems. The fourth section tells of improvements in the model being undertaken and outlines the plans for the development of an expanded system in the near future. Appendices include several tables specifying the economic categories contained in the model, a list of references where additional information pertaining to this model may be obtained, and a mathematical statement of the model.

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