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ABSTRACT

This documentation presents an input-output model which has been modified to include the environmental impact of economic operation. In lieu of market prices for the environmental factors, trade-offs with regional income and employment are estimated for use in regional planning. The program is written in FORTRAN IV with single precision for the IBM 360/65 system. The example data has been set-up to contain five endogenous sectors and three exogenous sectors (including households). The data are then compressed to three endogenous sections. (Author/BL)

Department of Agricultural Economics and Rural Sociology 1973

Departmental Program and Model Documentation

ECONOMIC AND ECOLOGICAL INPUT-OUTPUT MODEL

73-2

The Texas A&M University System
The Texas Agricultural Experiment Station
J. E. Miller, Director, College Station

Economic and Ecological Input-Output Model

Agricultural Economics
Program and Model Documentation
73-2

by

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and

Lonnie L. Jones

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General Abstract

This documentation presents an input-output model which has been modified to include the environmental impact of economic operation. In lieu of market prices for the environmental factors, trade-offs with regional income and employment are estimated for use in regional planning. The program is written in FORTRAN IV with single precision for the IBM 360/65 system. The example data has been set-up to contain five endogenous sectors and three exogenous sectors (including households). The data is then compressed to three endogenous sectors.

PURPOSE AND GENERAL CAPABILITIES OF THE PROGRAM

Input-Output is a well known analytical tool which is particularly well suited for gaining information on the economic aspects of environmental quality and resource use. These economic aspects concern trade-offs between levels of pollution or resource use and levels of output, income, and employment in the economy. When an environmental sector is added to the I-O matrix, these trade-offs may be estimated by using interdependence coefficients and the multiplier concept normally incorporated in input-output models. The purpose of this documentation is to provide information about a computer program (ECON-ECOL) that allows an analysis of economic and environmental data via the input-output approach by estimating interrelationships and multipliers which link the economy with its demand for resources and its supply of pollutants.

The details of the program's operation are described in later sections, but a statement of the general aspects of the program is useful as an introduction. The program links the environmental factors with the economic sectors by expressing resources as inputs per dollar of output and pollutants as production by-products per dollar of output. Environmental factors are introduced into the input-output model as L sectors of positive environmental imports (resource inputs) and K sectors of negative environmental imports (exported pollutants). The result is a MXN (where M = K + L) environmental matrix. The data in this matrix are converted to quantities per unit of output (production coefficients) for each economic sector. This yields a more complete production function for each economic sector of the model.

Once formed, the env[illegible] coefficient matrix is post multiplied by the inverse of the economic processing matrix. The resulting matrix contains environmental-output (E-O) multipliers that indicate the direct and indirect effects of economic production on the environment. By using the

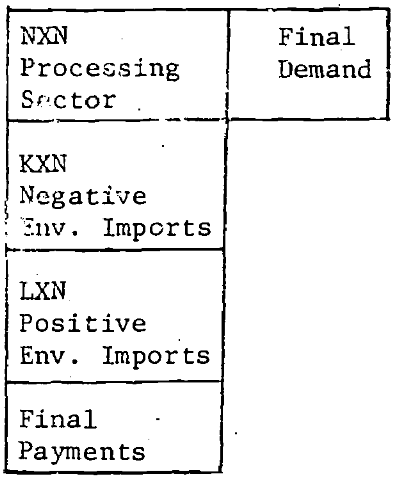


FIGURE 1

inverse of a processing sector containing households, the induced environmental effect is incorporated in the E-O multipliers. Finally, by combining the elements of the E-O matrix with appropriate income and employment data, environmental trade-offs in terms of dollars of income and/or levels of employment are generated.

The program is written to provide maximum information and flexibility and to be relatively inexpensive with respect to computer operation. The information provided as output includes multipliers calculated with households both exogenous (type I) and endogenous (type II). The flexibility provides for any size matrix up to 95 x 95 for the complete I-O model, up to 90 x 90 for the processing sector, and up to 25 environmental factors. The environmental factors can be either pollutants or resources or both. A compression subroutine allows a large model to be aggregated to as small a matrix as is desired. Other options allow for deleting the employment vectors or for operating simply as an I-O model excluding the environmental analysis.

USER DOCUMENTATION

The use of the various options of the ECON-ECOL program results in differing data requirements, arrangements, and coding. The use of the option COMPRESS calls for a slight alteration in the way in which information is presented to the computer. Information on data requirements and the arrangement of data relative to the main program is presented here as if the program's full capabilities are to be used.

Data Requirements

Assuming that an analysis including employment-environmental relationships is desired, data is needed for two matrices and two vectors. The matrices are for economic data on each industry's sales and purchases and environmental data on resources required and pollutants produced by each industry listed in the processing sector of the I-0 model. The two vectors consist of employment totals for each industry and a list of names for the industries and environmental factors that constitute the production function.

Economic Data

It will be assumed that the user is familiar with the data requirements of the economic sector of this input-output model. Therefore, the only discussion of this topic will center on level of aggregation for each sector. This topic will be taken up later.

Environmental Data

The environmental data must contain environmental inputs for each industry of the processing sector expressed as positive quantities, and pollutants expressed as negative quantities. The number and type of these positive and negative environmental factors depends on existing definitions of pollutants, data availability, and the user's analytical interests. The environmental data should conform to the economic data in terms of industrial classification, production period, etc. However, unlike the economic data that is expressed in dollars, resources and/or pollutants may be expressed in any appropriate units (e.g. tons, gallons, acre feet). Differing units may be used within the same environmental matrix.

Employment Data

Employment totals for each of the industries within the processing sector are used to calculate environmental-employment trade-offs as well as the standard I-O employment multipliers.

Row Names

For print-out purposes row names for the economic and environmental matrices are needed. The economic row names include processing industries, households, and final purchases. Names for final demand sectors are not needed as they are listed as columns which are numbered rather than named. Environmental row names contain designations for each resource and each pollutant for which data has been collected.

Each of the above data items may be thought of as separate data decks in the program. Hereafter, they are referred to as ECON for the economic data, RES (resources) for the positive and negative environmental data, EMPLOY for employment, and NAME for row name vector.

Control Cards

The final data category contains control and option cards. The options desired are listed on one computer card, called the option card (designated

OPT). The options available are for environmental analysis, employment-environmental analysis, and compression of original data. If the environmental analysis is excluded, resource and pollutant data is not needed, and the program will perform a standard Input-Output analysis. This analysis results in output multipliers, type I & II income multipliers, and if desired, employment multipliers. Employment multipliers for the economic sectors and the environmental sectors can be excluded via the second option. Through the compression option it is possible to reduce the matrix constructed from the original data collection to as small a size as is desirable. The result will be a reduced economic and resource matrix with a correspondingly shortened employment vector.

The control card SIZE specifies the size and degree of partitioning of the matrix that is to be used in the analysis for that particular computer run. The size of the matrix refers to the entire transaction table. The partitioning consists of separating and finding subtotals for the processing matrix, the value added vectors, and the import vectors.

The final set of control cards are used only if subroutine compress is called. These cards describe which rows and columns are to be aggregated and the position of the resulting rows and columns in the reduced matrix. These control cards, then, constitute another data "deck" and will be designated MOVE.

Generalized Job Stream

The control card, option card, and data decks are combined with the main program as illustrated in Figure 2.

GENERAL JOB STREAM

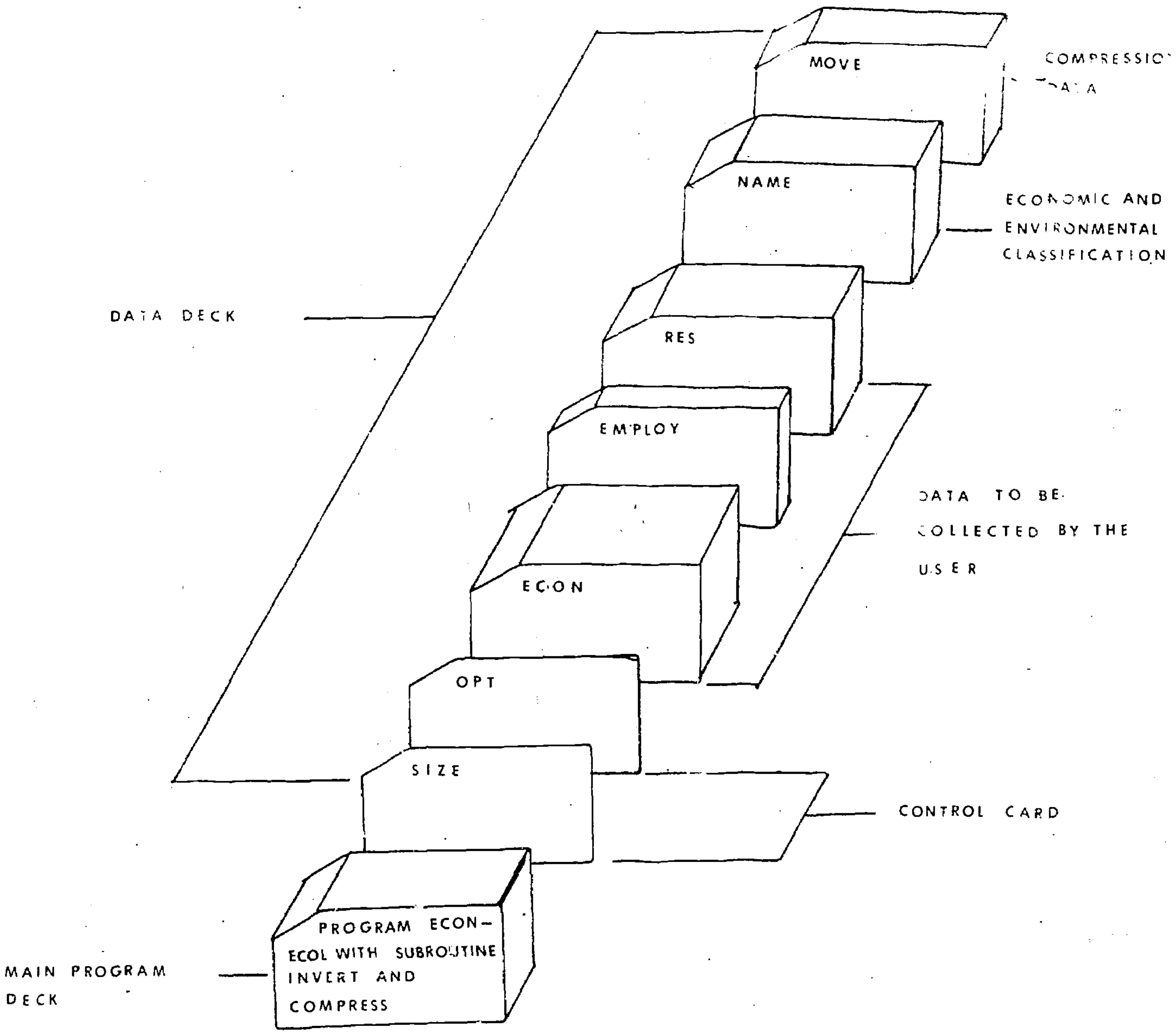


FIGURE 2

Data Coding

Industrial Classification

The level of aggregation for which the data is collected depends on the industry classification. This classification also determines the size of the matrices to be used. This program is written in general terms so that any size matrices can be used that are less than or equal to the maximum specified in the dimension statements. These limits consist of 95 x 95 for the I-O transaction table, 89 x 89 for the processing sector without households, and 25 x 100 for the resource matrix. Larger or smaller limits can be used but it will be necessary to change several cards in the program. This information can be found in the section describing the technical details of the program itself.

Economic and Resource Format

The collected data must be coded so that they can be read by the computer. The economic and environmental data are presented in the same form. Each quantity to be placed in a matrix is accompanied by the row and column number which designates its position in the matrix. Each data card will have four data points. Each data point will consist of three numbers. These numbers are row, column, and data value. The exact format is specifed as 4(2I3, F12.3).

	Card Item	Card Column	Format
1)	Row number	1-3	I3
2)	Column number	4-6	I3
3)	Datum value	7-18	F12.3
4)	Row number	19-21	I3
5)	Column number	22-24	I3

	Card Item	Card Column	Format
6)	Datum value	25-36	F12.3
⋮		⋮	⋮
10)	Row number	55-57	I3
11)	Column number	58-60	I3
12)	Datum value	61-72	F12.3

This arrangement of data is repeated on as many additional cards as needed.

Data Arrangement

Zeroes need not be coded since all matrices are filled with zeroes initially and whatever cells are not filled with data will automatically register as zero. An additional aspect of this feature is that the order of the data within the decks ECON & RES is unimportant. Each deck could be shuffled and the row and column designation will insure proper placement of the quantity.

There are only two restrictions on the arrangement of the data. First, the households sector must be the vector immediately following the processing matrix. This facilitates bringing households inside the processing sector for estimating type II multipliers. It is, therefore, necessary for the household row and column total to be balanced. Second, all value added sectors must be grouped together and preceed a similar grouping of the import sectors. These groupings are necessary because of the feature that partitions the transaction table and presents row sub-totals for each of the groups mentioned.

Pollutants are treated as negative resources. Therefore, each pollutant quantity should be punched as a negative number. The last card in deck ECON and deck RES must be -99 starting in column one. This tells the computer that the last card in that deck has been read.

Employment Format

Employment totals are placed six to a card. Each figure is right justified in a ten space field beginning in column one. As many cards as are necessary may be used.

Item	Card Column	Format
Card 1		
1. Employment total sector 1	1-10	I10
2. Employment total sector 2	11-20	I10
⋮	⋮	⋮
6. Employment total sector 6	51-60	I10
Card 2		
1. Employment total sector 7	1-10	I10
2. Employment total sector 8	11-20	I10
⋮	⋮	⋮
6. Employment total sector 12	51-60	I10

Row Name Format

Row names are punched one to a card. The first three spaces contain the row number. The next three spaces are left blank, and the names are then placed anywhere within a twelve character field. This is done for both economic sectors and environmental categories.

Item	Card Column	Format
Card 1		
1. Row number	1-3	I3
2. Row name	7-18	3A4
Card 2		
1. Row number	1-3	I3
2. Row name	7-18	3A4

Control Card Format, SIZE

Control cards SIZE and OPT have the appropriate numbers right justified in fields of five spaces each. The first card, SIZE, contains four numbers relating to the economic matrix being used for analysis. These numbers are the size of the transaction table (NN), the number of the last row of the processing sector (NP), the number of the last row of the value added sector (NV), and the number of the last row of the import sector (NI).

Item	Card Column	Format
1. NN	1-5	I5
2. NP	6-10	I5
3. NV	11-15	I5
4. NI	16-20	I5

Control Card Format, OPT

The option card contains three numbers. The first (MN) is for the environmental analysis. If environmental multipliers are being calculated MN = the number of environmental categories (positive & negative) that are being used. If no environmental analysis is desired MN = 0. The second number (LAB) indicates the length of the original (i.e., noncompressed) employment vector. If no employment data is present LAB = 0. The last number (NCOMP) indicates whether the matrix to be analyzed is a compressed version of the data being read in. If compression is desired, NCOMP = the number of times that several sectors are being compressed into one. If subroutine compress is not required, then NCOMP = 0.

Option Card Format

Item	Card Column	Format
1. Environmental Option (MN) MN = 0 deletes option MN = number of environmental sectors calls option	1-5	I5
2. Employment option (LAB) LAB = 0 deletes option LAB = number of processing sectors calls option	6-10	I5
3. Compression Option (NCOMP) NCOMP = 0 deletes option NCOMP = number of compressions within matrix calls option	11-15	I5

If NCOMP $\neq$ 0, the size of the matrix being used for analysis is smaller than the matrix being read in. Therefore, the data on card SIZE (NN, NP, NV, NI) refer to the compressed matrix and are smaller than they would be if compression were not desired.

Control Card Format, MOVE

The last set of data cards (deck MOVE) provide the information needed by the compression subroutine. The information consists of the size of the transaction matrix being read (since compress is being called, this number is larger than its counterpart on control card SIZE) and a vector of numbers in groups of three which states the destination, origin, and range of each compression.

Only adjacent sectors can be aggregated, and while some column and row numbers will change, the sequence must be maintained. The first group of sectors which are aggregated are placed in the row and column which the first sector of that group occupied. The unaggregated sectors between the first and second compression will automatically be moved over, and the sum of the second group of aggregated sectors will be placed in the following row and column. The information presented in the compression vector, then, is (1) the number of the new column (row) which contains the aggregated sectors of the initial compression, (2) the number of the first sector in the group to be added (i.e., the starting position of the compression) and (3) the number of the last sector of the group (i.e., the end of that particular compression). Similar information is given for each compression. One compression includes summation of both columns and rows.

The data for subroutine COMPRESS are right justified in adjacent fields, containing five columns each. The first field begins in column one. The first card contains the size of the transaction matrix being read in and as many as four groups of compression data. If more than four compressions are desired the information is coded on subsequent cards as needed. All additional cards contain only the four groups of three numbers.

Move Format

	Card Item	Card Column	Format
Card 1			
1.	Dimension of matrix read in Dimension = N for an NxN matrix	1-5	I5
2.	Column (Row) number of position of aggregate vector	6-10	I5
3.	First column (Row) of group to be aggregated	11-15	I5
4.	Last column (Row) of group to be aggregated	16-20	I5
5.	Column (Row) number of position of aggregate vector	21-25	I5

Move Format (continued)

	Card Item	Card Column	Format
6.	First column (Row of group to be aggregated	26-30	I-5
⋮		⋮	⋮
13.	Last column (Row) of group to be aggregated	61-65	I-5

Card 2

1.	Column (Row) number of position of aggregated vector	I-5	I-5
2.	First column (Row) of group to be aggregated	6-10	I-5

When COMPRESS is used the row names in NAME correspond to the aggregated sectors rather than the original sectors.

Example Code Sheets

Examples of the coding procedures are presented in the following code sheets. The data used are from a problem run as an illustration of the program's use and output.

DATA PROCESSING CENTER

TEXAS A & M UNIVERSITY

PROBLEM: DATA for ECON-ECOL

PROGRAMMER:

PAGE OF

DATE

FORTRAN STATEMENT

Economic data is coded as follows:

FORMAT (4(2I3, F12.3))

Row	Column	Amount	Row	Column	Amount	Row	Column	Amount	Row	Column	Amo
1	1	100.000	1	2	50.000	1	4	500.000	1	5	20
1	6	500.000	1	7	500.000	1	8	650.000	2	2	7
Set 1			Set 2			Set 3			Set 4		

Continue until all data for ECON is coded.

End ECON data with one card coded as follows:

-99

Environmental data is coded as follows:

FORMAT (4(2I3, F12.3))

Row	Column	Amount	Row	Column	Amount	Row	Column	Amount	Row	Column	Amo
1	1	-500.000	1	2	-2000.000	1	4	-800.000	1	6	-20
3	1	1700.000	3	2	1600.000	3	3	1100.000	3	5	50
Set 1			Set 2			Set 3			Set 4		

Continue until all data for RES is coded.

End RES data with one card coded as follows:

-99

Employment data is coded as follows:

FORMAT (6F10.0)

476	200	400	25	300	

Continue until all data for EMPLOY is coded

No special card is needed to end this section.

DATA PROCESSING CENTER — TEXAS A & M UNIVERSITY — FORTRAN STATEMENT

PROBLEM: DATA for ECON-ECOL

PROGRAMMER:

Row names are coded as follows:

FORMAT (I3, 3X, 3A4)

Row #	Blank	Row Name
1	X	AGRICULTURE
2	X	MINING

Continue until all data for NAME is coded.

No special card is needed to end this section.

Control cards are coded as follows:

FORMAT (6I5)

NN	NP	NV	NI
6	3	5	6

SIZL (1 card)

MN	EMPLOY	NCOMP
3	3	2

OPT (1 card)

Compression data is coded as follows:

FORMAT (13I5/, 12I5)

NO	Destination Start		End	Destination	Start	End
8	1	1	2	3	4	5

Continue until all data for MOVE is coded.

No special card is needed to end this section.

Complete Job Stream

Control cards for the computer system consist of a job card, a class card, and supporting JCL cards. At maximum a computer run with this program should not exceed 3 minutes, 5000 lines, or require more than 320K for storage space. It is possible that for smaller data sets smaller parameters may be desired in order to achieve faster turn around.

The program is written for Fortran G. Due to core requirements it cannot be run on the special superfast compilers such as WATFIV. JCL cards used with the program are indicated in the complete job stream (figure 3).

Output

The results of this program contain matrices presenting standard results of input-output analysis (i.e., transaction matrix, direct coefficients, and inverses with and without households), vectors of income and employment multipliers, and vectors of environmental multipliers.

The environmental multipliers present the trade-offs between the environmental factors and output, income, and employment. In addition, resource-resource multipliers are presented which show the total amount of resource use in the region for a unit increase in its usage by each industry.

With the exception of transaction table all output is self-explanatory. A possible source of confusion is the numbered columns of this matrix. Within the processing section the columns correspond to the named rows. However, since final demand categories can be different from final payments, the column designations must be kept track of separately by the analyst. Finally the last two columns contain respectively sub-totals of the processing sectors and the total of the entire row.

COMPLETE JOB STREAM

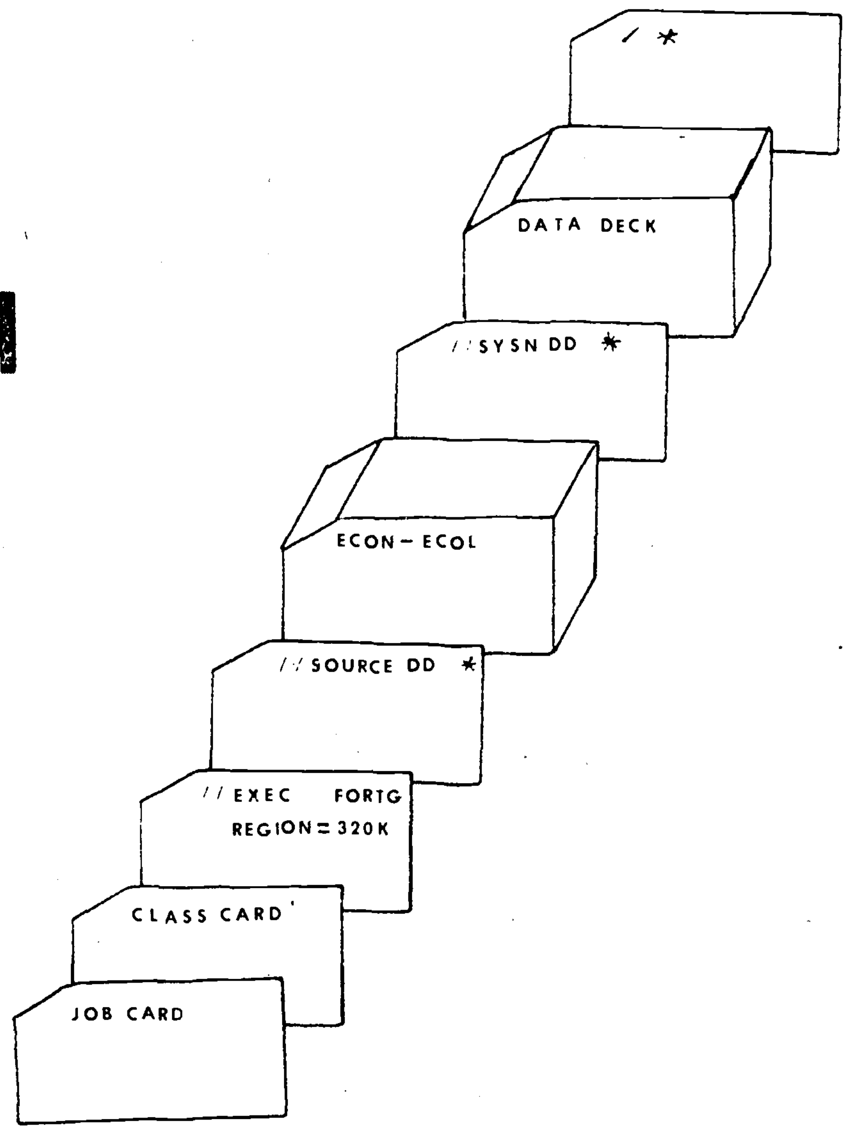


FIGURE 3

Example Problem

The following is output from a sample set of data. The data is from an 8 x 8 transaction matrix which has been reduced, via COMPRESS, to 6 x 6. It should be noted that it is impossible to get output of data before and after compression on the same computer run (i.e., NCOMP cannot = 0 and ≠ 0 at the same time). What follows is the combination of two runs for example purposes.

The environmental factors consists of two pollutants and one resource.

ORIGINAL ECON DATA

	1	2	3	4
1. AGRICULTURE	100.000	50.000	0.0	500.000
2. MINES	0.0	75.000	225.000	200.000
3. CONST-MANUF	200.000	200.000	100.000	0.0
4. UTILITIES	300.000	0.0	300.000	250.000
5. COMMERCE	200.000	300.000	400.000	500.000
6. HOUSEHOLDS	300.000	500.000	275.000	250.000
7. GOVERNMENT	700.000	375.000	100.000	100.000
8. IMPORTS	200.000	300.000	0.0	300.000

	5	6	7	8
1. AGRICULTURE	200.000	500.000	500.000	650.000
2. MINES	300.000	750.000	0.0	250.000
3. CONST-MANUF	800.000	100.000	0.0	0.0
4. UTILITIES	500.000	400.000	0.0	350.000
5. COMMERCE	100.000	400.000	400.000	0.0
6. HOUSEHOLDS	400.000	0.0	225.000	0.0
7. GOVERNMENT	0.0	0.0	0.0	0.0
8. IMPORTS	0.0	300.000	0.0	0.0

TRANSACTION TABLE — COMPRESSED OUTPUT

	1	2	3	4
1.AGRI-MINES	225.00	225.00	1200.00	1250.00
2.CONST-MANUF	400.00	100.00	800.00	100.00
3.UTIL-COMM	800.00	700.00	1350.00	800.00
INT. PURCHASES	1425.00	1025.00	3350.00	2150.00
4.HOUSEHOLDS	1300.00	275.00	650.00	0.0
5.GOVERNMENT	1075.00	100.00	100.00	0.0
VALUE CREATED	2375.00	375.00	750.00	0.0
6.IMPORTS	500.00	0.0	300.00	300.00
TOTAL IMPORTS	500.00	0.0	300.00	300.00
COLUMN TOTALS	4300.00	1400.00	4400.00	2450.00

TRANSACTION TABLE (continued)

	5	6	(Sub-total) 7	(Total) 8
1.AGRI-MINES	500.00	900.00	1650.00	4300.00
2.CONST-MANUF	0.0	0.0	1300.00	1400.00
3.UTIL-COMM	400.00	350.00	2850.00	4400.00
INT. PURCHASES	900.00	1250.00	5800.00	10100.00
4.HOUSEHOLDS	225.00	0.0	2225.00	2450.00
5.GOVERNMENT	0.0	0.0	1275.00	1275.00
VALUE CREATED	225.00	0.0	3500.00	3725.00
6.IMPORTS	0.0	0.0	800.00	1100.00
TOTAL IMPORTS	0.0	0.0	800.00	1100.00
COLUMN TOTALS	1125.00	1250.00	0.0	0.0

ROW SUM = 14925.0000 COLUMN SUM = 14925.0000

	1	2	3	4
1. SULFIDES	-2500.00	0.0	-800.00	-200.00
2. BOD	-300.00	-100.00	-425.00	0.0
3. WATER REQ	3300.00	1100.00	500.00	2000.00

EMPLOYMENT VECTOR

1.	675.00
2.	400.00
3.	325.00

DIRECT REQUIPEMENTS (Econ technical coefficients)

	1	2	3
1. AGRI-MINES	0.05233	0.16071	0.27273
2. CONST-MANUF	0.09302	0.07143	0.18182
3. UTIL-COMM	0.18605	0.50000	0.30682
4. HOUSEHOLDS	0.30233	0.19643	0.14773
5. GOVERNMENT	0.25000	0.07143	0.02273
6. IMPORTS	0.11628	0.0	0.06818
COLUMN TOTALS	1.00000	1.00000	1.00000

INTERDEPENDENCE TABLE

	1	2	3
1. AGRI-MINES	1.23319	0.55276	0.63018
2. CONST-MANUF	0.21932	1.35235	0.44100
3. UTIL-COMM	0.48918	1.12382	1.92986
COLUMN TOTALS	1.94169	3.02893	3.00104

DIRECT REQUIREMENTS (Econ technical coefficients)

	1	2	3	4
1. AGRI-MINES	0.05233	0.16071	0.27273	0.51020
2. CONST-MANUF	0.09302	0.07143	0.18182	0.04082
3. UTIL-COMM	0.18605	0.50000	0.30682	0.32653
4. HOUSEHOLDS	0.30233	0.19643	0.14773	0.0
5. GOVERNMENT	0.25000	0.07143	0.02273	0.0
6. IMPORTS	0.11628	0.0	0.06818	0 12245
COLUMN TOTALS	1.00000	1.00000	1.00000	1.00000

INTERDEPENDENCE TABLE

	1	2	3	4
1. AGRI-MINES	2.00425	1.49851	1.51822	1 57948
2. CONST-MANUF	0.49906	1.69546	0.76318	0.57303
3. UTIL-COMM	1.32148	2.14468	2.88843	1.70492
4. HOUSEHOLDS	0.89918	1.10290	1.03561	1.84194
COLUMN TOTALS	4.72396	6.44155	6.20544	5.69937

INCOME MULTIPLIER TYPE I

1	1.6147
2	3 0483
3	3.8059

INCOME MULTIPLIER TYPE II

1	2.9742
2	5.6148
3	7 0103
4	1.8419

EMPLOYMENT MULTIPLIERS

	DIRECT EFFECT	TOTAL EFFECT	MULTIPLIER
1	0.15698	0 29238	1.86256
2	0.28571	0.55616	1.94658
3	0 07386	0.36747	4.97499

ENVIR. FACTORS PER DOLLAR OUTPUT

	1	2	3	4
1.SULFIDES	-0.581395	0.0	-0.181818	[illegible]
2.BOD	-0.069767	-0.071429	-0.096591	0.0
3.WATER REQ	0.767442	0.785714	0.113636	[illegible]

ENVIRONMENTAL INTERDEPENDENCE MATRIX

	1	2	3
1.SULFIDES	-0.805911	-0.525704	-0.717265
2.BOD	-0.148953	-0.243712	-0.261873
3.WATER REQ	1.174313	1.614474	1.049428

ENV. SELF MULTIPLIER I

	1	2	3
1.SULFIDES	1.386167***********		3.944956
2.BOD	2.134987	3.411963	2.711154
3.WATER REQ	1.530165	2.054785	9 234970

ENVIRONMENTAL INTERDEPENDENCE MATRIX II

	1	2	3	4
1.SULFIDES	-1.478930	-1.351203	-1.492393	[illegible]
2.BOD	-0.303120	-0.432808	-0.439431	[illegible]
3.WATER REQ	2 814453	3 626207	2.938409	[illegible]

	1	2	3	4
1.SULFIDES	2.543758	***********	8.208161	16.334486
2.BOD	4.344728	6.059314	4.549405	***********
3.WATER REQ	3.667317	4.615172	25.858002	4.115702

ENVIRON - EMPLOYMENT MULTIPLIERS

	1	2	3
1.SULFIDES	-2.756400	-0.945231	-1.951896
2.BOD	-0.509452	-0.438201	-0.712636
3.WATER REQ	4.016418	2.902871	2.855915

TYPE I ENVIRON - INCOME MULTIPLIERS

	1	2	3
1.SULFIDES	-1.650880	-0.877970	-1.275733
2.BOD	-0.305124	-0.407019	-0.465770
3.WATER REQ	2.405537	2.696308	1.866523

TYPE II ENVIRON - INCOME MULTIPIERS

	1	2	3	4
1.SULFIDES	-1.644750	-1.225133	-1.441080	-0.748479
2.BOD	-0.337107	-0.392426	-0.424322	-0.171453
3.WATER REQ	3.130014	3.287876	2.837379	1.224934

PROGRAMMER DOCUMENTATION

The Input-Output model used in this program presents the economy of a particular region as a system of simultaneous linear equations. These equations represent the distribution of each economic sector's output among its purchasers. Purchasers are separated into two main groups, the processing sector and final demand. The system of equations is solved to give the output of industries of the processing sector expressed as a function of the final demand sector. The solution is in the form of coefficients that express the total change in output in each industry for a change in final demand in each industry.

The environmental matrix is formed by expressing resource use in terms of units per dollar of output. When this matrix is multiplied times the above matrix of coefficients, the total change in environmental factors (positive for resource inputs, negative for pollutants) per dollar change in final demand are estimated. Trade-offs between environmental factors and economic variables such as income and employment are estimated by combining relations found in the economic analysis with those derived in the environmental analysis.

Basic Mathematical Model

The following is a mathematical presentation of the model.

Let, $X_i = x_{ij} + \dots x_{in} + y_i \qquad i = 1,2,\dots n \qquad (1)$

where X_i = total output of industry i

x_{ij} = purchase of output from industry i by industry j

y_i = purchase of output from industry i by final demand sectors.

It is assumed that a linear relationship exists between purchases of a sector from other sectors and the level of output by that sector. Since total output equals total purchases, this may be expressed as:

$$x_{ij} = a_{ij}X_j \quad (2)$$

or

$$a_{ij} = x_{ij}/X_j \quad (3)$$

where, X_j = total purchases by sector j.

Substituting (2) into (1) yields the equation,

$$X_i = a_{ij}X_1 + a_{i2}X_2 + \ldots + a_{in}X_n + y_i \quad (4)$$

Data being fed into the program consists of purchases, x_{ij} of equation (1), and is printed out in the data and transactions matrix. The a_{ij} elements of equation (4) are calculated and presented as elements of the Direct Requirements matrix, sometimes referred to as the technical coefficients of production.

By rearranging (4) this system of equation may be written,

$$\begin{aligned} (1 - a_{11})X_1 \quad - a_{12}X_2 - a_{13}X_3 \quad \ldots - a_{1n}X_n &= y_1 \\ a_{21}X_1 - (1 - a_{22})X_2 - a_{23}X_3 \quad - a_{2n}X_n &= y_2 \\ \vdots \\ a_{n1}X_1 \quad - a_{n2}X_2 - a_{n3}X_3 \ldots - (1 - a_{nn})X_n &= y_n \end{aligned} \quad (5)$$

Equation (5) can then be expressed in matrix notation as follows:

$$(I - A)X = Y \quad (6)$$

Inverting the matrix (I - A) yields

$$X = (I - A)^{-1}Y \quad (7)$$

The $(I - A)^{-1}$ represents the matrix of partial derivatives of X with respect to Y (i.e., $\partial X_i/\partial y_j$). Elements of this matrix are commonly referred to as the matrix of interdependence coefficients and represent the change in output of industry i for a change in final demand in industry j.

The environmental data is transformed into resource use (pollution) per unit of output. The relationship of resource use (pollution) and output is assumed to be a linear function also,

$$r_{kj} = b_{kj}X_j \tag{8}$$

where

r_{kj} = amount resource requirement or pollution output

X_j = output of sector j

and b_{kj} = a constant.

The technical coefficients b_{kj} are thus derived from the combination of calculated output and collected resource data as follows,

$$b_{kj} = r_{kj}/X_j . \tag{9}$$

Let R_k = total regional level (positive or negative) of environmental factor K. Thus,

$$\begin{aligned} R_1 &= b_{11}X_1 + b_{12}X_2 + \ldots + b_{in}X_n \\ R_2 &= b_{21}X_1 + b_{22}X_2 + \ldots + b_{2n}X_n \\ &\vdots \\ R_m &= b_{m1}X_1 + b_{m2}X_2 + \ldots + b_{mn}X_n \end{aligned} \tag{10}$$

Again, in matrix notation

$R = BX$

where $R = \begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_m \end{bmatrix}$ $\quad B = \begin{bmatrix} b_{11} & b_{12}\cdots b_{1n} \\ b_{21} & b_{22}\cdots b_{2n} \\ \vdots & \vdots \quad\quad \vdots \\ b_{m1} & b_{m2} \quad\; b_{mn} \end{bmatrix}$ $\quad X = \begin{bmatrix} X_1 \\ X_2 \\ X_n \end{bmatrix}$

Substituting equation (7) from the input-output model into equation (11) yields the environmental-output equation,

$$R = B(I - A)^{-1}Y. \quad (12)$$

For simplicity, let $P = B(I - A)^{-1}Y$ so that equation (12) becomes

$$R = P(Y). \quad (13)$$

The P matrix contains the environmental-output multipliers which express the relation between a change in final demand in a given sector and the total change in a given environmental factor. For resource use (e.g., water, minerals, land) these multipliers are positive and may be interpreted as the total change in the use of the resource within the region per dollar of final demand in a particular sector. For pollutants the multipliers are negative, but their interpretation is the same. A P_{kj} element indicates the total change in environmental factor k per dollar change in final demand in industry j.

Calculation of Multipliers

Environmental-Income Multipliers

The trade-off between environmental factors and income is found by using the total income effect and the resource-output multiplier. The total income effect is usually found as the first step in generating income multipliers. If households are exogenous to the processing sector then the total income effect is

$$(9) \quad Z = W(I - A)^{-1}$$

where Z = a vector of multipliers indicating the change in wages in a sector for a dollar change in output for that sector ($\partial W/\partial y$).

W = the vector of wages paid per dollar of output.

The type I environmental-income multipliers are then found by dividing each environmental-output multiplier by the total income effect of the appropriate sector.

$$R_Z = P_{kj}/Z_j$$

where Z_j = the jth element of vector Z.

R_Z = matrix of environmental-income multipliers

When the households sector is made endogenous to the processing sector, the procedure is similar to the above. However, the vector Z is calculated directly in the inversion process that yields the interdependence coefficients. By using the household row of the inverted matrix, we obtain the type II resource income multipliers. The difference between type I multiplier as described above and type II multiplier is that the induced spending of households is included in the latter.

Environmental-Employment Multipliers

Multipliers for environmental factors and employment interrelations are calculated in the same manner as the type I environmental-income multipliers. In place of the income vector Z, a vector of employment coefficients is used. These coefficients are found by dividing the total employment of a sector by that sector's total output. The resulting vector will then contain elements which are the average number of employees per dollar of output. Total change in employment for the economy is then estimated by the equation,

(10) $E = L(I - A)^{-1}$

where E = the total effect on employment for a dollar change in each industry's output

L = the vector of direct employment coefficients

Then, environmental-employment interrelations are calculated from,

(11) $R_E = {}^{P_{kj}}/E_j$

where R_E = a matrix of multipliers indicating the change in environmental factor usage for a unit change in each industry's employment.

Environmental-Self Multipliers

The relationship between the amount of environmental factors an industry uses (or produces in the case of pollutants) and that which it causes to be used through its purchases of inputs may be similarily estimated from the model. This "environmental-self" multiplier is calculated by dividing the environmental output multiplier for a particular economic sector and environmental category by the corresponding sector's environmental factor use per dollar of output.

That is

(12) $R_R = {}^{P_{kj}}/b_{kj}$

where R_R = a matrix of environmental multipliers relating the total change in regional use of factor k for each unit change in its use in sector j.

PROGRAM DESCRIPTION

The program is written in FORTRAN IV with single precision. The JCL cards presented in the user documentation are for a one step execution available on the Texas A&M University data processing system. Other systems may require a two or three step execution and corresponding JCL.

Routines

MAIN: This routine reads data in, makes the calculations demonstrated in the mathematical model, and prints out the results.

INVERT: This subroutine uses Gaussian Elimination to invert the (I-A) matrix. The (I-A) matrix is placed in storage as DATA and passed to INVERT along with supporting variables and vectors.

Information passed	Received as
DATA	X
L	N
IER	IERR
LL	L
MM	M

COMPRESS: Aggregation of collected data is done by this subroutine as an option. The main routine then does its calculations with the reduced matrices and vectors. Four variables and one vector are passed to COMPRESS. Two matrices and one vector are placed in common with MAIN and COMPRESS and are accessed through BLOCK DATA.

Information Passed	Received As
NC	NC
NN	NEW
NO	NO
MN	MN
NVEC	NV

BLOCK DATA: holds matrices DATA and POL and vector EMP in common with MAIN and COMPRESS. DATA contains the $(I-A)^{-1}$ matrix, POL contains the environmental factors, and EMP is the vector of employment totals.

Dimensions and Initial Data Statements

MAIN

The maximum size of the needed matrices and vectors are specified in the dimension statements, and selected ones are initially filled with zeroes by data statements. Matrices DATA and POL and vector EMP are placed on a common card for access by COMPRESS.

INVERT

Matrix X and vectors L and M are dimensioned initially for use in this subroutine.

COMPRESS

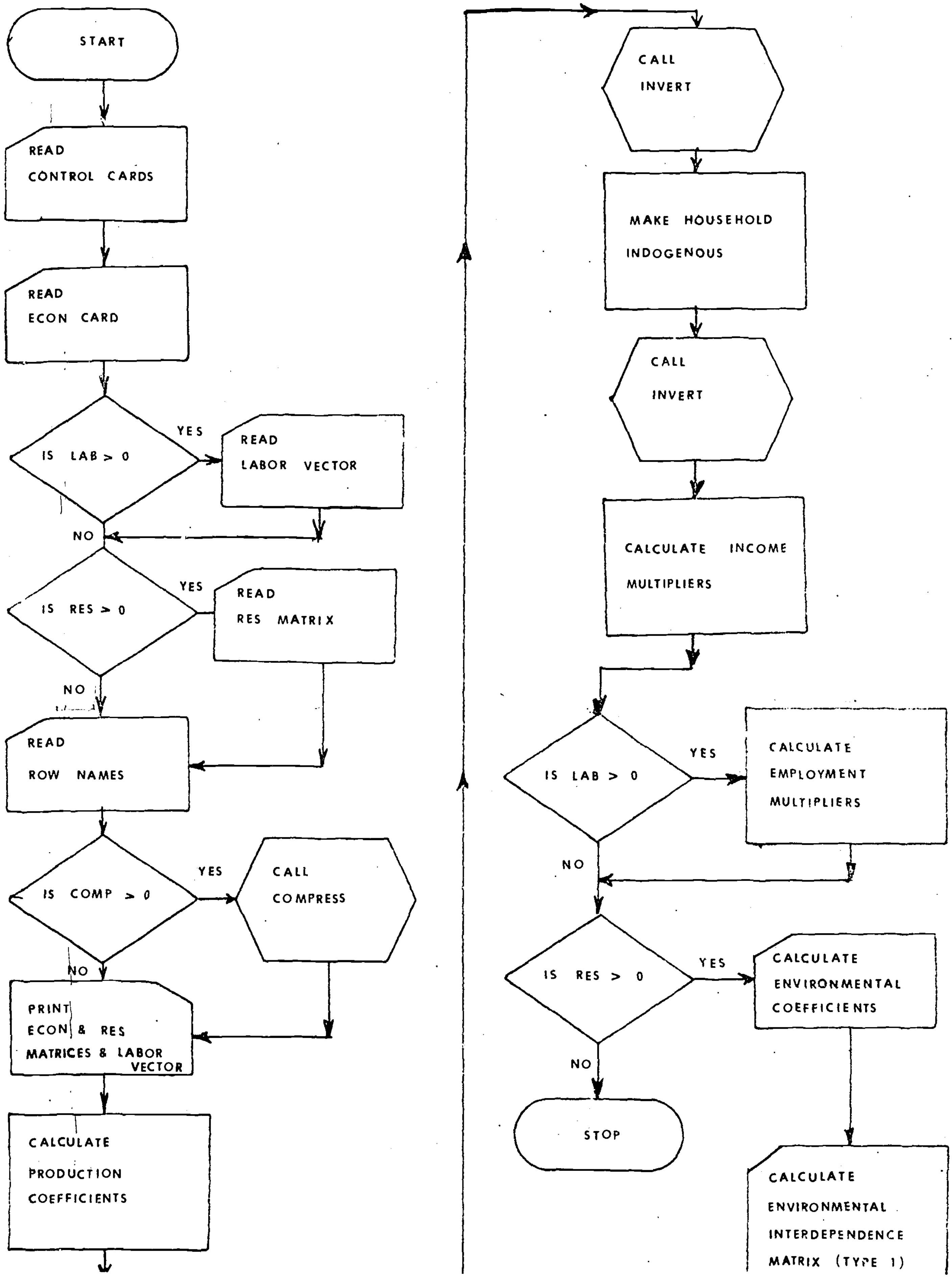
DATA is dimensioned as DATIX. The maximum size of matrix POL and vectors NV and EMP are given. A common statement connects DATIX, EMP, and POL with MAIN.

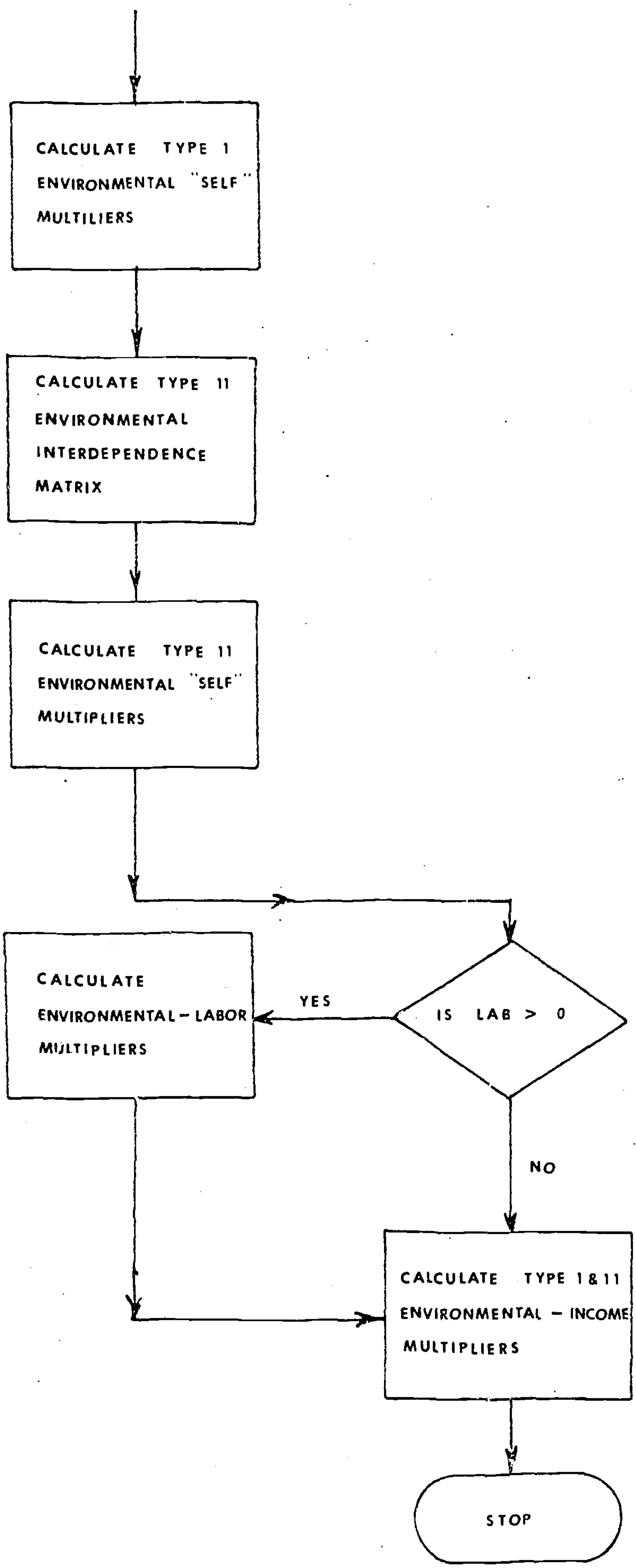
BLOCK DATA

The arrays held in common, DATA, POL, and EMP, are dimensioned and filled with zeroes.

Should it be desired to increase or decrease the maximum size of any matrix or vector, care should be taken to see that all dimension cards containing the array have been properly altered. Also that, if applicable, the proper number of zeroes are placed in the data statement.

FLOW CHART


START
READ CONTROL CARDS
READ ECON CARD
IS LAB > 0
YES
READ LABOR VECTOR
NO
IS RES > 0
YES
READ RES MATRIX
NO
READ ROW NAMES
IS COMP > 0
YES
CALL COMPRESS
NO
PRINT ECON & RES MATRICES & LABOR VECTOR
CALCULATE PRODUCTION COEFFICIENTS
CALL INVERT
MAKE HOUSEHOLD INDOGENOUS
CALL INVERT
CALCULATE INCOME MULTIPLIERS
IS LAB > 0
YES
CALCULATE EMPLOYMENT MULTIPLIERS
NO
IS RES > 0
YES
CALCULATE ENVIRONMENTAL COEFFICIENTS
NO
STOP
CALCULATE ENVIRONMENTAL INTERDEPENDENCE MATRIX (TYPE 1)


CALCULATE TYPE 1 ENVIRONMENTAL "SELF" MULTILIERS
CALCULATE TYPE 11 ENVIRONMENTAL INTERDEPENDENCE MATRIX
CALCULATE TYPE 11 ENVIRONMENTAL "SELF" MULTIPLIERS
IS LAB > 0
YES
CALCULATE ENVIRONMENTAL – LABOR MULTIPLIERS
NO
CALCULATE TYPE 1 & 11 ENVIRONMENTAL – INCOME MULTIPLIERS
STOP

PROGRAM LISTING

```
      REAL MUL1,MUL2
      DIMENSION  DATA(100,100),EMP(100),POL(25,100),
     1NAME(100,4),NAM2(25,4),CTOT(100),RTOT(100),
     2DINT(90,90),PINT(25,90),DTEC(90,90),STOR(25,95),
     3MM(100),NVEC(95),NAME2(1,4),STOR2(100),MUL1(100),
     4II(4),JJ(4),LL(100),DAT2(95,95),MUL2(100),X(4)
      COMMON /DEP/ DATA,EMP,POL
      DATA II/4*0/,JJ/4*0/,X/4*0.0/,NVEC/95*0/
      DATA IER/0/
C     ***********************
C     *  CONTROL  CARD READ *
C     ***********************
      READ (5,5) NN,NP,NV,NI
      READ (5,5) MN,LAB,NCOMP
    5 FORMAT (6I5)
      MNA1=MN+1
      NVA1=NV+1
      NNA1=NN+1
      NNA2=NN+2
      NNA3=NN+3
      NNA4=NN+4
      NNA5=NN+5
      NPA1=NP+1
      NPA2=NP+2
      NPA3=NP+3
C
C     ****************************
C     *   DATA MATRIX IS READ IN *
C     ****************************
C
   10 READ (5,15) (II(I),JJ(I),X(I),I=1,4)
   15 FORMAT(4(2I3,F12.3))
      IF (II(1).EQ.-99) GO TO 25
      DO 20 J=1,4
      K=II(J)
      L=JJ(J)
      IF (K.EQ.0.OR.L.EQ.0) GO TO 20
      DATA (K,L)=X(J)
   20 CONTINUE
      GO TO 10
C
C     ***************************
C     * EMPLCYMENT VECTOR READ *
C     ***************************
C
   25 IF (LAB.EQ.0) GO TO 35
      READ (5,30) (EMP(I),I=1,LAB)
   30 FORMAT (6F10.0)
C
C
C     ********************************
C     *    RES    MATRIX IS READ IN *
C     ********************************
C
   35 IF (MN.EQ.0) GO TO 55
   40 READ (5,45) (II(I),JJ(I),X(I),I=1,4)
   45 FORMAT (4(2I3,F12.2))
      IF (II(1).EQ.-99) GO TO 55
```

```
              DO 50 J=1,4
              IF (II(J).EQ.0.OR.JJ(J).EQ.0) GO TO 50
              K=II(J)
              L=JJ(J)
              POL(K,L)=X(J)
        50    CONTINUE
              GO TO 40
        C
        C     **************************
        C     * READ REGIONS AND TITLES *
        C     **************************
        C
        55    DO 60 I=1,NN
        60    READ (5,65) (NAME(I,J),J=1,4)
        65    FORMAT (I3,3X,3A4)
              IF (MN.EQ.0) GO TO 75
              DO 70 I=1,MN
        70    READ (5,65) (NAM2(I,J),J=1,4)
        75    CONTINUF
        C
        C     *****************************
        C     *  CALL SUBROUTINE COMPRESS  *
        C     *****************************
        C
              IF (NCOMP.EQ.0) GO TO 85
              NC=NCOMP*3
              READ (5,80) NO,(NVEC(I),I=1,NC)
        80    FORMAT (13I5/,(12I5))
              CALL CMPRSS (NC,NN,NO,MN,NVEC)
        85    CONTINUE
        C
        C     *************************
        C     * DATA MATRIX IS PRINTED *
        C     *************************
        C
              DO 95 I=1,NN,9
              K=I+8
              IF (K.GE.NN) K=NN
              WRITE (6,90) (L,L=I,K)
        90    FORMAT ('1',14X,9(10X,I2))
              DO 95 J=1,NN
        95    WRITE (6,100) (NAME(J,L),L=1,4),(DATA(J,N),N=I,K)
        100   FORMAT (I4,',',3A4,2X,9F12.3)
        C
        C     ************************************************************
        C     * TOTALS & SUBTOTALS OF COLUMNS & ROWS                      *
        C     *          CALCULATE  PRINT  &                              *
        C     *                 STORF                                     *
        C     ************************************************************
        C
              SUMR=0.0
              SUMC=0.0
              DO 110 I=1,NN
              RTOT(I)=0.0
              DO 105 J=1,NN
        105   RTOT(I)=RTOT(I)+DATA(I,J)
        110   SUMR=SUMR+RTOT(I)
              DO 120 I=1,NN
```

```
      CTOT(I)=0.0
      DO 115 J=1,NN
115   CTOT(I)=CTOT(I)+DATA(J,I)
120   SUMC=SUMC+CTOT(I)
      DO 121 I=1,NN
      DO 121 J=1,NP
121   DATA (I,NNA1)=DATA(I,NNA1)+DATA(I,J)
      DO 122 I=1,NN
122   DATA (I,NNA2)=RTOT(I)
      DO 125 I=1,NNA2
      DO 123 J=1,NP
123   DATA (I,NNA3)=DATA(I,NNA3)+DATA(J,I)
      DO 124 K=NPA1,NV
124   DATA (I,NNA4)=DATA(I,NNA4)+DATA(K,I)
      DO 125 L=NVA1,NI
125   DATA (I,NNA5)=DATA(I,NNA5)+DATA(L,I)
C
C     **********************************
C     * TRANSACTIONS MATRIX IS PRINTED *
C     **********************************
C
      DO 160 I=1,NNA2,9
      K=I+8
      IF (K.GT.NNA2) K=NNA2
      WRITE (6,126) (L,L=I,K)
      DO 150 J=1,NN
      WRITE (6,145) (NAME(J,L),L=1,4),(DATA(J,N),N=I,K)
      IF (J.EQ.NP) WRITE (6,130) (DATA(L,NNA3),L=I,K)
      IF (J.EQ.NV) WRITE (6,135) (DATA(L,NNA4),L=I,K)
      N1=NP
      IF (J.EQ.NI) WRITE (6,140) (DATA(L,NNA5),L=I,K)
      IF (J.EQ.NI) GO TO 150
126   FORMAT('1 TRANACTION  TABLE'///' ',15X,9(10X,I2))
130   FORMAT(//2X,'INT. PURCHASES ',3X,9F12.2//)
135   FORMAT(//2X,'VALUE CREATED ',3X,9F12.2//)
140   FORMAT(//2X,'TOTAL IMPORTS ',3X,9F12.2//)
145   FORMAT (I4,'.',3A4,2X,9F12.2)
150   CONTINUE
      WRITE (6,155) (CTOT(M4),M4=I,K)
155   FORMAT(//2X,'COLUMN TOTALS',3X,9F12.2//)
160   CONTINUE
      WRITE (6,165) SUMR,SUMC
165   FORMAT('1',' ROW SUM = ',F17.4,5X,'COLUMN SUM =',F17.4)
      DO 170 I=1,NN
      DATA (NNA1,I)=CTOT(I)
170   CONTINUE
C
C     ***************************************
C     * ENVIRONMENTAL MATRIX & EMPLOYMENT   *
C     *       VECTOR IS PRINTED             *
C     ***************************************
C
      IF (MN.EQ.0) GO TO 185
      DO 180 I=1,NPA1,9
      K=I+8
      IF (K.GT.NPA1) K=NPA1
      WRITE (6,175) (L,L=I,K)
175   FORMAT('1',3X,'ENVIRONMENTAL FACTORS',/////15X,
```

```
                    19(10X,I2))
 0119                DO 180 J=1,MN
 0120                WRITE (6,145) (NAM2(J,L),L=1,4),(POL(J,N),N=I,K)
 0121         180    CONTINUE
 0122         185    CONTINUE
 0123                IF (LAB.EQ.0) GO TO 195
 0124                WRITE (6,190) (I,EMP(I),I=1,NP)
 0125         190    FORMAT('1',5X,'EMPLOYMENT  VECTOR',//,(5X,I2,'.',5X,
                    1F10.2))
 0126         195    CONTINUE
              C      DATA  MATRIX  IS  STORED  AS  DAT2
              C
 0127                DO 200 I=1,NNA1
 0128                DO 200 J=1,NNA1
 0129         200    DAT2(I,J)=DATA(I,J)
              C
              C      ********************************
              C      * DIRECT REQUIREMENTS ( 1 &2)  *
              C      *        CALCULATE & PRINT     *
              C      ********************************
              C
 0130         205    CONTINUE
 0131                DO 210 I=1,N1
 0132                CTOT(I)=0.0
 0133                DO 210 J=1,NN
 0134                DATA (J,I)=DATA(J,I)/DATA(NNA1,I)
 0135         210    CTOT(I)=CTOT(I)+DATA(J,I)
 0136                DO 230 I=1,NPA1,9
 0137                K=I+8
 0138                IF (K.GT.N1) K=N1
 0139                M2=K
 0140                WRITE (6,215) (L,L=I,K)
 0141         215    FORMAT('1 DIRECT  REQUIREMENTS'/15X,9(10X,I2))
 0142                DO 220 J=1,NN
 0143         220    WRITE (6,225) (NAME(J,L),L=1,4),(DATA(J,N),N=I,K)
 0144         225    FORMAT (I4,'.',3A4,2X,9F12.5)
 0145         230    WRITE (6,235) (CTOT(M4),M4=I,K)
 0146         235    FORMAT(//2X,'COLUMN TOTALS',3X,9F12.5)
 0147                IF (N1.EQ.NP) GO TO 245
 0148                DO 240 I=1,N1
 0149                DO 240 J=1,N1
 0150         240    DTEC(I,J)=DATA(I,J)
 0151         245    CONTINUE
              C
              C      ***************************
              C      *  INVERT MATRICES 1 & 2   *
              C      ***************************
              C
 0152                L=N1
 0153                M=1
 0154                DO 246 I=1,N1
 0155                DATA (I,I)=1.0-DATA(I,I)
 0156                DO 246 J=1,N1
 0157         246    IF(I.NE.J) DATA(I,J)= -DATA(I,J)
 0158                CALL INVERT (DATA,L,IER,LL,MM)
 0159                IF (IER.NE.0) STOP
 0160                DO 250 I=1,N1
 0161                CTOT(I)=0.0
```

```
0162               DO 250 J=1,N1
0163          250  CTOT(I)=CTOT(I)+DATA(J,I)
              C
              C    *********************************
              C    *   PRINT & STORE INVERSES 1 & 2  *
              C    *********************************
              C
0164               IF (N1.EQ.NPA1) GO TO 260
0165               DO 255 I=1,N1
0166               DO 255 J=1,N1
0167          255  DINT(I,J)=DATA(I,J)
0168          260  CONTINUE
0169               DO 275 I=1,N1,9
0170               K=I+8
0171               IF (K.GT.N1) K=N1
0172               WRITE (6,265) (L,L=I,K)
0173          265  FORMAT('1 INTERDEPENDENCE  TABLE'/15X,9(10X,I2))
0174               DO 270 J=1,N1
0175          270  WRITE (6,225) (NAME(J,L),L=1,4),(DATA(J,M4),M4=I,K)
0176               WRITE (6,235) (CTOT(M4),M4=I,K)
0177          275  CONTINUE
0178               N1=N1+1
0179               IF (N1.EQ.NPA2) GO TO 280
0180               DO 276 I=1,NNA1
0181               DO 276 J=1,NNA1
0182          276  DATA (I,J)=DAT2(I,J)
0183               GO TO 205
              C
              C    ****************************************************
              C    * AT THIS POINT THE STORED MATRICES ARE AS FOLLOWS  *
              C    *   DINT=INVERSE I             DAT2=ORIG ECON DATA  *
              C    *   DTEC=TECH COEFF W/ HH      POL =ORIG RES DATA   *
              C    *   DATA=INVERSE II                                 *
              C    ****************************************************
              C
              C    ******************************
              C    *  INCOME MULTIPLIERS I &II  *
              C    ******************************
              C
0184          280  DO 290 I=1,NP
0185               VALUE=0.0
0186               DO 285 K=1,NP
0187          285  VALUE=VALUE+DINT(K,I)*DTEC(NPA1,K)
0188          290  STOR2(I)=VALUE
              C                                                TYPE I
              C                                         CALCULATE & STORE
0189               DO 295 I=1,NP
0190          295  MUL1(I)=(STOR2(I)/DTEC(NPA1,I))
              C                                                TYPE II
              C                                         CALCULATE & STORE
0191               DO 300 I=1,NPA1
0192          300  MUL2(I)=(DATA(NPA1,I)/DTEC(NPA1,I))
              C                                                     PRINT
              C                                                     I&II
0193               WRITE (6,305) (I,MUL1(I),I=1,NP)
0194          305  FORMAT('1',10X,'INCOME MULTIPLIER'/' ',15X,'TYPE I',
                  1/(6X,I2,6X,F9.4))
0195               WRITE (6,310) (I,MUL2(I),I=1,NPA1)
```

```
      310 FORMAT('1',10X,'INCOME MULTIPLIER'/' ',15X,'TYPE II',
         1/(6X,I2,6X,F9.4))
C
C     ************************************************
C     *   EMPLOYMENT MULTIPLIERS                      *
C     * CALCULATE, PRINT, & STORE IN DATA(NN+4,I)     *
C     ************************************************
C
          IF (LAB.EQ.0) GO TO 340
          DO 315 I=1,NP
      315 EMP(I)=EMP(I)/DAT2(NNA1,I)
          DO 325 I=1,NP
          CTOT(I)=0.0
          VALUE=0.0
          DO 320 K=1,NP
      320 VALUE=VALUE+DINT(K,I)*EMP(K)
      325 CTOT(I)=VALUE
          DO 330 J=1,NP
      330 RTOT(J)=CTOT(J)/EMP(J)
          WRITE (6,335) (I,EMP(I),CTOT(I),RTOT(I),I=1,NP)
      335 FORMAT('1',28X,'EMPLOYMENT  MULTIPLIERS'//13X,
         1'DIRECT EFFECT',9X,'TOTAL EFFECT',9X,'MULTIPLIER',
         2/(10X,I2,3X,F9.5,13X,F9.5,10X,F9.5))
          DO 336 I=1,NP
      336 DATA (NNA4,I)=RTOT(I)
      340 CONTINUE
C
C     **************************************
C     * ENVIRONMENTAL FACTORS PER $ OUTPUT *
C     *CALCULATE PRINT & STORE IN POL(J,I) *
C     **************************************
C
          IF (MN.EQ.0) GO TO 525
          DO 345 I=1,NPA1
          DO 345 J=1,MN
      345 POL(J,I)=POL(J,I)/DAT2(NNA1,I)
          DO 365 I=1,NPA1,9
          K=I+8
          IF (K.GT.NPA1) K=NPA1
          IF (I/2*2.EQ.I) WRITE (6,350) (L,L=I,K)
          IF (I/2*2.EQ.I) GO TO 360
      350 FORMAT (/////15X,9(10X,I2))
          WRITE (6,355) (L,L=I,K)
      355 FORMAT('1ENVIR. FACTORS PER DOLLAR OUTPUT'///15X,
         19(10X,I2))
      360 CONTINUE
          DO 365 J=1,MN
      365 WRITE (6,390) (NAM2(J,L),L=1,4),(POL(J,M),M=I,K)
C
C     ********************************************
C     * ENVIRONMENTAL INTERDEPENDENCE MATRIX     *
C     *         CALCULATE, PRINT,& STORE IN PINT *
C     ********************************************
C
          DO 370 I=1,MN
          DO 370 J=1,NP
          PINT(I,J)=0
          DO 370 K=1,NP
```

```
0232       370   PINT(I,J)=PINT(I,J)+POL(I,K)*DINT(K,J)
0233             DO 395 I=1,NP,9
0234             K=I+8
0235             IF (K.GT.NP) K=NP
0236             IF (I/2*2.EQ.I) WRITE (6,350) (L,L=I,K)
0237             IF (I/2*2.EQ.I) GO TO 380
0238             WRITE (6,375) (L,L=I,K)
0239       375   FORMAT('1 ENVIRONMENTAL INTERDEPENDENCE ',
                1'MATRIX'///15X,9(10X,I2))
0240       380   CONTINUE
0241             DO 385 J=1,MN
0242       385   WRITE (6,390) (NAM2(J,L),L=1,4),(PINT(J,N),N=I,K)
0243       390   FORMAT (I4,'.',3A4,2X,9F12.6)
0244       395   CONTINUE
           C
           C     ***************************
           C     *      ENVIR. MULTIPLIERS  *
           C     *        CALCULATE & PRINT *
           C     ***************************
           C
           C                                                      TYPE I
           C                                          ENVIRONMENTAL MULTIPLIER
           C
0245             DO 400 I=1,MN
0246             DO 400 J=1,NP
0247             IF (POL(I,J).NE.0.0) DAT2(I,J)=(PINT(I,J)/POL(I,J))
0248             IF (POL(I,J).EQ.0.0.AND.PINT(I,J).EQ.0.0) DAT2(I,J)=0.0
0249       400   IF (POL(I,J).EQ.0.0.AND.PINT(I,J).NE.0.0) DAT2(I,J)
                1=1000000
0250             DO 415 I=1,NP,9
0251             K=I+8
0252             IF (K.GT.NP) K=NP
0253             IF (I/2*2.EQ.I) WRITE (6,350) (L,L=I,K)
0254             IF (I/2*2.EQ.I) GO TO 410
0255             WRITE (6,405) (L,L=I,K)
0256       405   FORMAT('1 ENV. SELF MULTIPLIER I '///15X,9(10X,I2))
0257       410   CONTINUE
0258             DO 415 J=1,MN
0259       415   WRITE (6,390) (NAM2(J,L),L=1,4),(DAT2(J,N),N=I,K)
           C
           C                                                 TYPE II
           C                                       ENVIRONMENTAL INTERDEPENDENCE
           C                                          MATRIX   STORE IN DTEC
0260             DO 420 I=1,MN
0261             DO 420 J=1,NPA1
0262             DTEC(I,J)=0.
0263             DO 420 K=1,NPA1
0264       420   DTEC(I,J)=DTEC(I,J)+POL(I,K)*DATA(K,J)
0265             DO 440 I=1,NPA1,9
0266             K=I+8
0267             IF (K.GT.NPA1) K=NPA1
0268             IF (I/2*2.EQ.I) WRITE (6,350) (L,L=I,K)
0269             IF (I/2*2.EQ.I) GO TO 430
0270             WRITE (6,425) (L,L=I,K)
0271       425   FORMAT('1 ENVIRONMENTAL  INTERDEPENDENCE ',
                1'MATRIX II'///15X,9(10X,I2))
  72       430   CONTINUE
  73             DO 435 J=1,MN
```

```
0274     435   WRITE (6,390) (NAM2(J,L),L=1,4),(DTEC(J,N),N=I,K)
0275     440   CONTINUE
         C
         C                                                  TYPE II
         C                                         ENVIRONMENTAL MULTIPLIER
         C
0276           DO 445 I=1,MN
0277           DO 445 J=1,NPA1
0278           IF (POL(I,J).NE.0.0) POL(I,J)=DTEC(I,J)/POL(I,J)
0279           IF (POL(I,J).EQ.0.0.AND.DTEC(I,J).EQ.0.0) POL(I,J)=0.0
0280     445   IF (POL(I,J).EQ.0.0.AND.DTEC(I,J).NE.0.0) POL(I,J)=
              11000000
0281           DO 460 I=1,NPA1,9
0282           K=I+8
0283           IF (K.GT.NPA1) K=NPA1
0284           IF (I/2*2.EQ.I) WRITE (6,350) (L,L=I,K)
0285           IF (I/2*2.EQ.I) GO TO 455
0286           WRITE (6,450) (L,L=I,K)
0287     450   FORMAT('1 ENV. SELF MULTIPLIER II'///15X,9(10X,I2))
0288     455   CONTINUE
0289           DO 460 J=1,MN
0290     460   WRITE (6,390) (NAM2(J,L),L=1,4),(POL(J,N),N=I,K)
         C
         C     ******************************
         C     * COMBINATION MULTIPLIERS    *
         C     *     ENVIRONMENTAL - EMPLOY *
         C     *     ENVIRONMENTAL - INCOME *
         C     ******************************
         C
         C                                       ENVIRONMENTAL - EMPLOYMENT
         C                                                  CALCULATE & PRINT
0291           IF (LAB.EQ.0) GO TO 485
0292           DO 465 J=1,NP
0293           DO 465 I=1,MN
0294     465   STOR(I,J)=PINT(I,J)/CTOT(J)
0295           DO 480 I=1,NP,9
0296           K=I+8
0297           IF (K.GT.NP) K=NP
0298           IF (I/2*2.EQ.I) WRITE (6,350) (L,L=I,K)
0299           IF (I/2*2.EQ.I) GO TO 475
0300           WRITE (6,470) (L,L=I,K)
0301     470   FORMAT('1 ENVIRON - EMPLOYMENT MULTIPLIERS'///15X,
              19(10X,I2))
0302     475   CONTINUE
0303           DO 480 J=1,MN
0304     480   WRITE (6,390) (NAM2(J,L),L=1,4),(STOR(J,N),N=I,K)
0305     485   CONTINUE
         C                                       ENVIRONMENTAL - INCOME I
         C                                                  CALCULATE & PRINT
0306           DO 490 J=1,NP
0307           DO 490 I=1,MN
0308     490   PINT(I,J)=PINT(I,J)/STOR2(J)
0309           DO 505 I=1,NP,9
0310           K=I+8
0311           IF (K.GT.NP) K=NP
0312           IF (I/2*2.EQ.I) WRITE (6,350) (L,L=I,K)
  13           IF (I/2*2.EQ.I) GO TO 500
  14           WRITE (6,495) (L,L=I,K)
```

```
0315          495   FORMAT('1 TYPE I ENVIRON - INCOME MULTIPLIERS'///1EX,
                   19(10X,I2))
0316          500   CONTINUE
0317                DO 505 J=1,MN
0318          505   WRITE (6,390) (NAM2(J,L),L=1,4),(PINT(J,N),N=I,K)
              C
              C                                ENVIRONMENTAL - INCOME II
              C                                          CALCULATE & PRINT
0319                DO 510 J=1,NPA1
0320                DO 510 I=1,MN
0321          510   DTEC(I,J)=DTEC(I,J)/DATA(NPA1,J)
0322                DO 525 I=1,NPA1,9
0323                K=I+8
0324                IF (K.GT.NPA1) K=NPA1
0325                IF (I/2*2.EQ.I) WRITE (6,350) (L,L=I,K)
0326                IF (I/2*2.EQ.I) GO TO 520
0327                WRITE (6,515) (L,L=I,K)
0328          515   FORMAT('1 TYPE II ENVIRON - INCOME MULTIPIERS'///1EX,
                   19(10X,I2))
0329          520   CONTINUE
0330                DO 525 J=1,MN
0331                WRITE (6,390) (NAM2(J,L),L=1,4),(DTEC(J,N),N=I,K)
0332          525   CONTINUE
0333                STOP
0334                END
```

```
      SUBROUTINE INVERT(X,N,IERR,L,M)
C     REAL MATRIX INVERSION SUBROUTINE BY GAUSSIAN
C     ELIMINATION
C
C     THE FOLLOWING CALLING SEQUENCE SHOULD BE USED TO ENTER
C     THE FOLLOWING CALLING SEQUENCE SHOULD BE USED TO ENTER
C     THIS SUBROUTINE .....      X
C            CALL INVERT(X,N,IERR)
C     WHERE
C            X IS THE MATRIX TO BE INVERTED
C            N IS THE ORDER OF X
C            IERR IS AN ERROR FLAG DENOTING SUCCESSFUL OR
C            NON-SUCCESSFUL INVERSION OF X
C
C
C
      DIMENSION X(100,101),L(100),M(100)
C     SEARCH FOR LARGEST ELEMENT IN X
      DO 80 K = 1,N
      L(K) = K
      M(K) = K
      XBIG = X(K,K)
      DO 20 I = K,N
      DO 20 J = K,N
      IF(ABS(XBIG).GE.ABS(X(I,J))) GO TO 20
      XBIG = X(I,J)
      L(K) = I
      M(K) = J
   20 CONTINUE
C     NOW INTERCHANGE ROWS
      IROW = L(K)
      IF(L(K).LE.K) GO TO 35
      DO 30 I = 1,N
      WAIT = -X(K,I)
      X(K,I) = X(IROW,I)
   30 X(IROW,I) = WAIT
C     NOW INTERCHANGE COLUMNS
   35 ICOL = M(K)
      IF(M(K).LE.K) GO TO 45
      DO 40 J = 1,N
      WAIT = -X(J,K)
      X(J,K) = X(J,ICOL)
   40 X(J,ICOL) = WAIT
C     NOW DIVIDE COLUMN BY MINUS PIVOT
   45 DO 55 IC = 1,N
      IF(IC.EQ.K) GO TO 55
      X(IC,K) = X(IC,K)/(-X(K,K))
   55 CONTINUE
C     NOW REDUCE MATRIX
      DO 65 I = 1,N
      DO 65 J = 1,N
      IF(I.EQ.K) GO TO 65
      IF(J.EQ.K) GO TO 65
      X(I,J) = X(I,K)*X(K,J) + X(I,J)
   65 CONTINUE
C     NOW DIVIDE ROW BY PIVOT
      DO 75 JRO = 1,N
      IF(JRO.EQ.K) GO TO 75
```

```
              X(K,JRO) = X(K,JRO)/X(K,K)
       75     CONTINUE
      C       CONTINUE PRODUCT OF PIVOTS AND REPLACE PIVOT BY
      C       RECIPROCAL
              CALL OVERFL(J1)
              CALL DVCHK(J2)
              X(K,K) = 1.0/X(K,K)
              CALL DVCHK(J2)
              IF(J2.EQ.1) GO TO 600
              CALL OVERFL(J1)
              IF(J1.EQ.1) GO TO 600
      C       NOW CONTINUE OVERALL OPERATION
       80     CONTINUE
      C       NOW FOR FINAL ROW AND COLUMN INTERCHANGE
              K = N
      100     K = K - 1
              IF(K.LE.0) RETURN
              I = L(K)
              IF(I.LE.K) GO TO 120
              DO 110 J = 1,N
              WAIT = X(J,K)
              X(J,K) = -X(J,I)
      110     X(J,I) = WAIT
      120     J = M(K)
              IF(J.LE.K) GO TO 100
              DO 130 I = 1,N
              WAIT = X(K,I)
              X(K,I) = -X(J,I)
      130     X(J,I) = WAIT
              GO TO 100
      600     IERR = 1
              RETURN
              END
```

```
      SUBROUTINE CMPRSS(NC,NEW,NO,MN,NV)
      DIMENSION   DATIX(100,100),POL(25,100),NV(35),EMP(100)
      COMMON/DEP/DATIX,EMP,POL
      DO 100 IC = 1,NC,3
      INC = NV(IC)
      IB = NV(IC +1)
      IED = NV(IC +2)
      IMV = NV(IC +3)
      IED2 = NV(IC +4)
      DO 50 I = 1,NO
      SUM = 0.0
      SUMP = 0.0
      DO 40 J = IB,IED
      IF(MN.EQ.0.OR.MN.LT.I) GO TO 40
      SUMP = SUMP + POL(I,J)
   40 SUM = SUM + DATIX(I,J)
      IF(MN.EQ.0.OR.MN.LT.I) GO TO 50
      POL(I,INC) = SUMP
   50 DATIX(I,INC) = SUM
      IF(IED+1.EQ.IED2) GO TO 100
      IA = IED + 1
      IZ = IED2 - 1
      IF(IZ.LT.0) GO TO 100
      DO 80 I = 1,NO
      K = INC + 1
      DO 80 J = IA,IZ
      IF(MN.EQ.0.OR.MN.LT.I) GO TO 70
      POL(I,K) = POL(I,J)
   70 DATIX(I,K) = DATIX(I,J)
   80 K = K + 1
  100 CONTINUE
      IF(IED.EQ.NO) GO TO 25
      DO 20 I = 1,NO
      K = INC+1
      M = IED +1
      DO 20 J = M,NO
      IF(MN.EQ.0.OR.MN.LT.I) GO TO 19
      POL(I,K) = POL(I,J)
   19 DATIX(I,K) = DATIX(I,J)
   20 K = K + 1
   25 IZE = NEW + 1
      DO 30 I =1,NO
      DO 30 J= IZE,NO
      IF(MN.EQ.0.OR.MN.LT.I) GO TO 30
      POL(I,J) = 0.0
   30 DATIX(I,J) = 0.0
      DO 200 IR = 1,NC,3
      INR = NV(IR)
      IB  = NV(IR +1)
      IED = NV(IR +2)
      IMV = NV(IR +3)
      IED2 = NV(IR +4)
      DO 170 J = 1,NEW
      SUM = 0.0
      DO 150 I = IB,IED
  150 SUM = SUM + DATIX(I,J)
  170 DATIX(INR,J) = SUM
      IF(IED+1.EQ.IED2) GO TO 200
```

```
      IA = IED +1
      IZ = IED2 -1
      IF(IZ.LT.0)  GO TO 200
      DO 180 J = 1,NEW
      K = INR + 1
      DO 180 I = IA,IZ
      DATIX(K,J) = DATIX(I,J)
  180 K = K +1
  200 CONTINUE
      IF(IED.EQ.NO) GO TO 125
      DO 120 J = 1,NEW
      K = INR + 1
      M = IED + 1
      DO 120 I = M,NO
      DATIX(K,J) = DATIX(I,J)
  120 K = K+ 1
  125 IZE = NEW + 1
      DO 130 J = 1,NEW
      DO 130 I = IZE,NO
  130 DATIX(I,J) = 0.0
      DO 300 IV = 1,NC,3
      INC  = NV(IV)
      IB   = NV(IV +1)
      IED = NV(IV +2)
      IMV  = NV(IV +3)
      IED2= NV(IV +4)
      SUM =0.0
      DO 240 J = IB,IED
  240 SUM = SUM + EMP(J)
      EMP(INC) = SUM
      IF(IED+1.EQ.IED2) GO TO 300
      IA = IED + 1
      IZ = IED2 - 1
      IF(IZ.LT.0) GO TO 300
      K = INC + 1
      DO 280 J = IA,IZ
      EMP(K) = EMP(J)
  280 K = K + 1
  300 CONTINUE
      IF(IED.EQ.NO) GO TO 225
      K = INC + 1
      M = IED + 1
      DO 220 J = M,NO
      EMP(K) = EMP(J)
  220 K = K + 1
  225 IZE = NEW + 1
      DO 330 J = IZE,NO
  330 EMP(J) = 0.0
  500 CONTINUE
      RETURN
      END
```

```
      BLOCK DATA
      DIMENSION  DATA(100,100),POL(25,100),EMP(100)
      COMMON/DEP/DATA,EMP,POL
      DATA  DATA/10000*0.0/,POL/2500*0.0/,EMP/100*0.0/
      END
```

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