Space Market Model
Space Industry Input-Output Model

Preface

This research was conducted under the auspices of the Research Institute for Computing and Information Systems by Robert F. Hodgin, Associate Professor of Economics and Finance, and Roberto Marchesini, Associate Professor of Accounting, both at the University of Houston-Clear Lake, in support of the Space Market Model research project. Overall technical direction was provided by Peter C. Bishop, Director of the Space Business Research Center, at the University of Houston-Clear Lake.

Funding has been provided by the Mission Planning and Analysis Division, NASA/JSC through Cooperative Agreement NCC 9-16 between NASA Johnson Space Center and the University of Houston-Clear Lake. The NASA technical monitor for the activity was Harry Erwin, manager of the Technology and Commercial Projects Office, NASA/JSC.

SPACE MARKET MODEL

SPACE INDUSTRY INPUT-OUTPUT MODEL

A report submitted
in accordance with requirements
of RICIS Research
Activity IM.1A

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March 1987

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I. INTRODUCTION

The goal of the Space Market Model (SMM) is to develop an information resource for the space industry. The SMM is intended to contain information appropriate for decision making in the space industry. As stated in the original research proposal, the objectives of the SMM are to:

1. Assemble information related to the development of the space business,
2. Construct an adequate description of the emerging space market,
3. Disseminate the information on the space market to forecasters and planners in government agencies and private corporations,
4. Provide timely analyses and forecasts of critical elements of the space market.

The first two objectives clearly indicate the need for data gathering and model building for the space industry. The last two objectives suggest how the transformed data are to be used by various agents in the economy.

This submission of the SMM report is mainly concerned with model building. The task is to develop a model of market activity capable of transforming raw data into useful information for decision makers and policy makers dealing with the space sector. The report proceeds first by describing the essential elements of an input-output (I-O) model in general. Section II discusses how the I-O structure can be modified to accommodate the space industry. Two versions are suggested. The first is a separate space industry I-O model linked generally to the rest of the economy. The second model version suggests full integration of the space sector with the national I-O model.

The final section provides insights to opportunities and barriers for both I-O model versions, summarizes the major points and argues for the fully integrated I-O model version.

II. ECONOMIC INPUT-OUTPUT MODELS

A model, in general, is a representation of actual phenomena in order to explain, predict, and control activity. In economic analysis these three functions are identified with structural analysis, forecasting, and policy evaluation, respectively.

The Leontief open, static input-output model rests on the theory of production and is designed to show the structural interdependence among sectors in an economy. The basic table of the input-output system is the transactions table. This table relates the inputs from all industries to the purchases by all other industries. The number of processing sectors depends both on the purpose of the table as well as on the availability of data. The transactions table reveals intermediate goods relationships among all industry sectors as well as sector relationships to final demand for the goods. See Table 1 for a complete schematic of a transactions table.

All input-output models rest on a series of assumptions. The most important of these are:

1. Each commodity is supplied by a single industry or sector of production.
2. The inputs purchased by each sector are a function of the level of output of that sector.
3. The total effect of carrying several types of production is the sum of the separate effects.

The major quadrants of the transactions table in Table 1 deserve brief explanation. Quadrant I is labeled the processing sector. It captures the inter-industry transactions. In general, the X_{ij} term shows the sales by the i^{th} sector, on the left, to the j^{th} sector, at the top. Quadrant II comprises the final demand sector. Each column records the volume of sales to final purchasers by descriptive category. Quadrant III (a part of Quadrants II and IV) represents the outputs of Quadrant IV that are used as inputs to Quadrant II. In total, for the system to balance, the sum of the row totals of the payments sector must equal the sum of the column totals of the final demand sectors.

TABLE 1

INTER-INDUSTRY TRANSACTIONS TABLE

Sector Producing \ Sector Purchasing		Intermediate Goods and Services	Final Demand					Total Gross Output
			I	H	C	G	E	
Processing	1	$X_{11} \ldots X_{1j} \ldots X_{1n}$	I_1	H_1	C_1	G_1	E_1	X_1
	2	.						
	.	.	(Quadrant II)					
		$X_{i1} \ldots X_{ij} \ldots X_{in}$	I_i	H_i	C_i	G_i	E_i	X_i
	.	. (Quadrant I)						
	.	.						
	n	$X_{n1} \ldots X_{nj} \ldots X_{nn}$	I_n	H_n	C_n	G_n	E_n	X_n
Payments	I	I_1 I_j I_n						I
	H	H_1 H_j H_n						H
	D	D_1 D_j D_n	V_I	V_H	V_C	V_G	V_E (Quadrant III)	D
	G	G_1 G_j G_n						G
	M	M_1 M_j M_n (Quadrant IV)						M
Total Gross Outlays		X1 Xj Xn	I	H	C	G	E	X

I = Inventory | G = Government
H Households | E = Exports
C = Gross Private Capital Formation | M = Imports

As described, the transactions table is a complete and detailed accounting system for an economy, typically for a year's period. Since the data are usually quite disaggregated, it reveals much more than the conventional national income accounts for an economy.

To be analytically useful, a table of technical coefficients must be constructed. Using the processing sector only, the technical coefficients are constructed in such a way that they estimate the direct purchases by each sector from every other sector per dollar of output. See the Mathematical Appendix for details. If the technical coefficients remain stable from year to year or if they can be amended on the basis of new information, it is possible to calculate the amount of direct purchases required from each industry along the left-hand side of Table 1, as a result of a change in the output of one or more of the industries listed on the top of Table 1.

Technical coefficients can change over time for three reasons:

1. Technical knowledge changes,
2. Relative prices change,
3. The organization of establishments changes, i.e., there is increased or decreased sub-contracting due to changes in the operational definitions of the sectors.

The table of technical coefficients, showing "first round" effects of a change in output, is also the basis for a general solution in which both direct and indirect effects on output of all industries in the processing sector can be determined.

Lastly, the true power of the Leontief structure is revealed when the model is solved generally for both direct as well as indirect effects of a change in industry sales to final demand changes. Here, estimates of both employment and income multiplier impacts can be seen.

Modification of the I-O construct, which was originally a nationally oriented schema, to a regional or even an industrial context is possible. Trade-offs exist concerning the difficulty of data collection, cost of model construction and resulting accuracy of the sectoral relationships. These issues will be discussed in the following sections.

III. AN INPUT-OUTPUT MODEL FOR THE SPACE INDUSTRY

A. Version I

The SMM is intended to capture, as much as possible, the economic behavior of the space industry. This goal is carried out by:

1. Defining what constitutes the space industry,
2. Identifying the participants in this industry,
3. Classifying products, inputs, revenues, costs, and overall economic activity of these agents.
4. Determining the major economic variables which affect the decision making process of the participants in the space industry.

In essence, the first step is to develop a structural analysis of the space sector which serves as the foundation for subsequent forecasting and policy evaluation. Two potential approaches will be discussed. The first deals with constructing a transactions matrix for the space industry and broadly linking it with the rest of the economy. The second suggests full integration of the national I-O model with the original and some newly created space related SIC coded industries and products.

TABLE 2

SAMPLE SPACE MARKET I/O STRUCTURE

Sector Producing \ Sector Purchasing		1	2	3	4	5	6	7	Final Demand I	C	G	D	E	T
Terrestrial Comm. Network		X_{11}			X_{1j}			X_{1n}	I_1	C_1			E_1	X_1
Launch Facilities Launch Vehicles Payload Integration		X_{i1}	I		X_{ij}			X_{in}	I_i	C_i		II	E_i	X_i
Remote Sensing Comm. Satellites Material Processing		X_{n1}			X_{nj}			X_{nn}	I_n	C_n			E_n	X_n
Payments	I_d	I_{d1}			I_{dj}			I_{dn}						I_d
	A	A_1			A_j			A_n						A
	D	D_1	IV		D_j			D_n			III			D
	G	G_1			G_j			G_n						G
	M	M_1			M_j			M_n						M
TOTAL GROSS OUTLAYS		X_1			X_j			X_n	I	C	G	D	E	X

I = Invent. Accumulation
C = Gross Private Capital Formation
G = Government
D = Other Domestic Sectors

E = Exports
T = Total Gross Output
I_d = Inventory Depletion
A = Depreciation

M = Imports

Although the effort involved in constructing an I-O table is extraordinary, the results are fairly easily interpreted. For illustrative purposes, Table 2 represents a possible I-O table for the SMM as it may be used to identify the main sectors which comprise it. This version assumes a processing sector for the space industry only.

The upper left-hand quadrant is labeled the processing sector and contains industries producing goods and services. For the SMM, this sector of the table includes only space and space-related industries. An industry or sector is defined as one consisting of one or more establishments producing a homogeneous product or providing a single type of service. This ideal approach is compromised, however, by practical considerations. Disclosure rules might require the aggregation of enterprises with different characteristics. SIC classification requirements would be used to assign establishments to appropriate industry sectors. In this approach, the classification of all establishments is done by using their main product classification.

In Table 2, reading across each row, the sales by the sector at the left to each of the sectors at the top are given in dollar terms. Reading down each column one observes the purchases by the sector at the top from each of the sectors listed at the left. The general term x_{ij} shows the sales by the i^{th} sector, at the left, to the j^{th} sector, at the top.

The quadrant labeled "Final Demand" constitutes the final demand sector. It shows final sales by each of the sectors at the left to the various components of final demand (C, I, G, X), the general link to the rest of the economy.

The third quadrant records the sales of primary factors to final users, while Quadrant IV is referred to generally as the payment sector. It shows the inputs from the Government, Depreciation, and Imports to each of the columns to the top of the table. Finally, Total Gross Outlays and Total Gross Output (last row and column) show that total sales to all sectors must equal total purchases by all sectors as an accounting identity.

The application of I-O analysis to the SMM demands some modifications to the basic model. First, the space sector represents one of the many producing sectors of the economy. In a national I-O table, products of the space sector would be reported under manufacturing, transportation, and so on. If all space and space-related products would be reclassified, we would derive only two vectors (row and column). The aggregation would be so severe as to make the sector meaningless. A better approach, still consistent with the assumptions of the I-O table, is to define each commodity (or commodity group) supplied by a single industry or sector of production.

It is possible, then, to separate space activities by major products or areas. Remote sensing of land areas, communication satellites, and launch vehicles are some examples. These activities would represent the cells in Quadrant I. The Final Demand sector would be represented by Inventory Accumulation, sales to Gross Private Capital Formation, Government, other Domestic sectors, and Exports (I, C, G, D, E).

The cells in Quadrant IV, the payments sector, would be constituted as:

I = Inventory Depletion

A = Depreciation

D = Domestic (other sectors)

G = Government

M = Imports

Within this framework it is possible to capture the production activities of the space industry and also to determine the effects of a change in final demand on space producing sectors. The transactions table as modified in this context, is a description of the structure of the space industry. It can be thought of as a complete and detailed accounting system for the space sectors.

Some important classification questions arise here. Within the space industry it is important to distinguish between those sub-sectors which are intermediate to other space industries and those that provide service and product to other non-space industries. As space products and services are classified according to SIC standards, these production relationships should become clear and a properly integrated transactions table can be constructed. Table 2 above is simply a first assessment as to the proper space sub-industry relationships.

Regrettably, this particular modification of an I-O model linking the space industry to the rest of the economy lacks much useful detail. Specifically, it excludes the space industry linkages to all other industries. As it stands, the construct serves as a good description of the space industry in relative isolation. How the industry is generally affected by changes in demand from the other broadly defined sectors can be assessed but no inter-industry details can be revealed.

B. Version II

Full integration of the space industry with the national I-O model is also possible. Of the six sectors identified as part of space-related activities, three of them are new activities for which no equivalent SIC classification and no equivalent sectors in the U.S. I-O model currently exist. The three are: Launch Facilities, Remote Sensing Services and Materials Processing Services.

The three remaining sectors represent activities for which SIC codes and sectors in the U.S. I-O model do exist. These sectors do not raise any serious problems for integrating the space industry with the full national model. The three sectors and related SIC categories are: Launch Vehicles (3761—Guided Missiles, Space Vehicles), Sattelites (3663—Radio and TV Communication Equipment) and Terrestial Communications (4811—Telephone communication).

In order to deal with the three sectors not currently included, they must be precisely defined and the technical coefficients estimated. The sectoring in the U.S. model must be used to permit proper integration. This is an important rule to follow. As long as the sectors are defined along SIC bounds, the issue is not a difficult one. A set of transformation rules between the U.S. model and the space model should be delineated which would relate the two.

The SIC code defines an industry class according to both output and production characteristics with some recognition given to inter-industry relationships in more heterogeneous classes. At the three and four digit SIC level, production characteristics tend to dominate even though the definitions are given by descriptions of output. Hence, similar production processes are grouped accordingly.

The three sectors which are not currently included in the SIC code or the U.S. I-O model can potentially be quantified through NASA or NASA related sources of data if no national security issues arise. The same problems of data collection and processing exist here as with field data collection. These are:

a. Purchases are not organized or identified by industry of origin.

b. Industry detail has been lost in compiling accounting aggregates.

c. The amount of raw, hard copy data is very large which makes it available only through a sampling process with difficult sampling design problems attending the situation.

d. Personnel in the organization may not be cooperative for a variety of reasons. A major reason is that they are suspicious of anyone wandering through the raw accounting records of their organization.

e. Data generated by interviews is usually given at too high a level of aggregation. In order to avoid that problem, multiple interviews are required.

A possible alternate source of data may be available through the Input-Output Division of the Bureau of Economic Analysis. Either the work sheets or the individual returns of the establishments obtained from the Bureau of the Census could be quite useful. However, in order to gain access to such records, researchers must be certified as Census Officers and are subject to certain legal restrictions on disclosure and Census Bureau rules must be followed on the project.

Introducing these new sectors into the model also requires adjusting the technical coefficients of purchasing sectors in the U.S. I-O model. To relfect current technology, information would have to be obtained from the Input-Output Division of the Bureau of Economic Analysis about how they handeled these purchases in the latest U.S. model. From this information and data from the worksheets, appropriate adjustments in the purchasing sector coefficients could be made.

As to the three sectors that are already included in the U.S. I-O model, the major problem is that the SMM project may require breaking out specific activities from the U.S. sectors and setting up new sectors. If this is true, then the same data collection and processing problems exist that are discussed above.

The effect of the above activities on the technical coefficients of the current sectors would have to be removed. This task is not impossible once technical coefficients for the space sector have been estimated. The additional information required would be the shipments of the space sector. These data combined with the shipments of the original sector could be used as weights to remove the influence of the space sector. Also, the coefficients of the purchasing sectors in the U.S. model would have to be divided between the new sectors. This would likely involve only a few sectors and would have to be based upon technical or field data. Finally, if the base year of the U.S. I-O model is different from the data collection year, adjustments should be made for changes in relative prices between the base year and the data collection year. On the more positive side, dividing up the U.S. I-O model would not be necessary if there were evidence that differences between the U.S. and space industry sectors were very small. It is not unlikely that such could be the case.

Space sector industries do represent some new establishments which are subject to rapid changes in technical knowledge until they mature. This illustrates a special case of changing technical knowledge which is related to increased experience with new processes (a learning curve phenomenon). Although perhaps difficult to handle in the early versions of a space I-O model, approximation techniques do exist.

The final result would be a new version of the U.S. I-O model showing the space industry fully integrated in enhanced detail. As a result, effects of changes in final demand could be assessed on each industry both directly and indirectly. That is, the space-related industries would be completely linked both to their own companion space sub-industries and to all other existing industries as well.

IV. SUMMARY AND CONCLUSIONS

This report has presented discussions on economic input-output models in general, the prospects for conforming the space industry to such a structure and the possibilities for how integration with the national I-O model might be accomplished. It was seen that the Leontief static, open input-output model was predicated on the theory of production. The construct permits a detailed accounting of product flows between and among industries. Additionally, the model allows an assessment of the dollar impact on the industrial structure from a change in final demand.

It was also seen that the space industry could be assessed to conform to the input-output construct in at least two ways. The first method was to build a processing sector table for all space-related industries and thereby reveal their interrelationships. These space sectors could then be linked to broad sectors of the economy. The principle drawback of this appraoch is that the desired detail of space-related industries with all other industries taken separately is obscured.

The alternative approach, suggesting full integration of the space sector with the national I-O model, provides much richer detail but requires a concomitant amount of effort. However, none of the difficulties are insurmountable. Among the most prominent issues are those concerning data collection, data processing, access to sensitive governmental data sources, the estimation of technical coefficients and the potential for restructuring some national I-O model sectors to conform to space sector definitional needs. Methods exist to manage all issues. The questions of time, cost and eventual usefulness of the results must be brought to bear before a final decision on the preferred method can be made.

Essentially, the troublesome issues fall into two areas: accuracy, especially of the technical coefficients, and base data requirements. The first issue recognizes that technical coefficients change over time, especially for those sectors where rapid technological changes take place. New information is required constantly to update the coefficients. The second issue relates that unless a transformation table exists or one can be constructed, then any linkage with the national I-O model is precluded.

Given the magnitude of the project, during Phase II of the SMM development the major tasks to be carried out would be as follows:

1. Final definition of the space sectors. Presently, four infrastructure sectors have been identified. They are:
   - Terrestrial Communication Network,
   - Launch Facilities,
   - Launch Vehicles,
   - Payload Integration and End-user Sectors.

   Also, three end-user sectors have been identified. They are:
   - Remote Sensing,
   - Communication Satellites,
   - Material Processing.
2. Idenification of all the participants of each sector (1 above.)
3. Development of the appropriate instruments(s) to obtain the information necessary to the construction of the transactions table. (An initial effort has been made along these lines with the "Economic Census of Satellite Remote Sensing Survey").

Task 3, above, remains the crucial point in the development of the table. If inadequate responses are received from the industry participants or official source data are unavailable, the construction of the fully integrated transactions table would not be possible.

BIBLIOGRAPHY

BIBLIOGRAPHY

THEORY

Gossling, Allen G. Estimating and Projecting Input-Output Coefficients. Papers testing improvements in the predictive capabilities of the Leontief model (mostly theoretical) and methods to update tables and coefficients. (HB 142E87 Rice)

Hoffenberg, Arrow. A Time Series Analysis of Interindustry Demands. (HB 171.B33 Rice)

Barcharach, Michael. Biproportional Matrices and Input-Output Change. Analysis of Biproportional Input-Output model (matrix problem) setup and solution of problem discussed. (HB74.M3 Rice B232)

Bulmer, Thomas. Input-Output Analysis in Developing Countries. Treatment of applied input-output analysis presented in systematic handbook form. (HC59.7 B85 Rice)

Carter, Anne and Brudy, A. Contributions to I-0 Analysis. Proceeding of conference on I-0 techniques, 1968. Many individual papers on topics such as dynamic analysis, structured change, inter regional analysis, price analysis. (HB21 I64 Rice)

Cheney, Hollis B. Interindustry Economics. A thorough study of I-O analysis starting with models of structural inter-dependence going through applications of interindustry analysis. (HB99.C53 Rice)

Corres, Hector. Integrated Economic Accounting. Includes chapter on macro-accounting statements dealing with real aspects only. (HF5635 C794 UH/CL)

Dorfman and Samuelson. Linear Programming and Economic Analysis 1958. Statical Leontief system from linear programming point of view. (HB71.D6)

Elliot-Jones, M.F. I-O Analysis - A Nontechnical Description 1971. New York Conference Board, simplified introduction to I-O analysis. Data and applications of I-O. Conventions and caveats of I-O. (HD9824.E55 UH/CL)

Farag, Shawki. Input-Output Analysis: Applications To Business Accounting. Basic theory of business accounting and I-O theory. Construction of micro input-output models. (HF5635 F27 UH/UP)

Gerking, Shelby D. Input-Output As a Simple Econmetric Model. Bloomington, Indiana: Institute for Applied Urban Economics, Indiana University. The objective of this work is to show how two-stage least squares may be applied to cross-sectional data in order to obtain 1) consistent estimates of the technical coeeficients and 2) standard errors for these estimates. This estimation technique is applied to survey data from five input-output sectors of the West Virginia economy.

Gerking, S.D. Estimation of Stochustic Input-Output Models 1976. Tests of stahi open I-O model use of the variance to solve problems of I-O anaylsis. Conditions for eliminating 1st order aggregation bias in I-O models. (HB142.G46 UH/UP)

THEORY Continued

Ghosh, Programming and Interregional Input-Output Analysis 1973. An application to the problem of industrial location in India and the use of I-O models to optimize location. (HD58 G45)

Gossling, W.F. (ed). Capital Coefficients and Dynamic Input-Output Models Studies on dynamic input-output systems. (HB142 C30 Rice)

Harris, Curtis C. A Multiregional, Multi-industry Forecasting Model. The author develops a multiregional forecasting model which incorporates industrial coeeficients and a linear programming transportation model. Regional intermediate demand is estimated by applying the technical coefficients to the industry output of each region.

Hatanake, Michio. The Workability of Input-Output Analysis 1960. Special attention paid to various types of error in I-O tables and how to work around them and test for them. (HB71.H38)

Heesterman, A.R.G. Allocation Models and Their Use in Economic Planning 1971. I-O model, inter-temporal allocation in I-O, balance growth frontier, dynamized Leontien model, foreign trade, costing problem, discounted cash flow, increasing returns to scale, distribution of outputs, opportunity cost. (HB74.M3 H347)

Koehler, Whinston and Wright. Optimization Over Leontief Substitution System 1975. Herative method for solving large scale linear programs over Lenotief substituions systems developed and applied. (HB142.K63 Rice)

Leontief and Wassily. Input-Output Economics 1966. Eleven essays between 1951 and 1965 including I-O analysis interregional I-O analysis. (HC106.5 LJ7 Rice)

Miernyk, William H. Long-Range Forecasting With a Regional Input-Output Model: Western Economic Journal Volume 6, No.3 (June 1968: 165-176. The author argues that if one wishes to make interindustry regional forecasts it is necessary to construct the regional transactions table from survey data. The "best practice" technique is discussed as a projection alternative that reflects anticipated changes in technology and trade patterns.

Miernyk, William H. The Elements of Input-Output Analysis 1965. New York Random House. Theory of I-O. General ideas on applications in regional settings and international development. Frontiers of I-O analysis discussed as well as rudiments of I-O mathematics. (HB71M62 UH/CL)

Miyazawa, K. Input-Output Analysis and the Structure of Income Distribution 1976. Introduces inter-relational income multiplier as a matrix to combine I-O analysis with structure of income distribution. Also method to partition off original Leontief inverse in terms of "internal" and "external" matrix multipliers. (HB142. M59 UH/UP)

Monshuma and Michio. Equilibrium Stability and Growth, A Multi-Sectoral Analysis 1964. Stability analysis of Watrus-Leontief system, dynamic Leontief system Von Heumann models. (HB71.M66 Rice)

THEORY Continued

Pleeter, Saul. Economic Impact Analysis, Methodology and Applications 1980. Relationship between I-O models and regional impact analysis, error generation in regional I-O analysis. (HT39.E32 UH/CL)

Richardson, H.W. Input-Output and Regional Economics 1972. Theory Multiplier analysis, inter-regional models. data problems, collection, reduction of data, simplified terms of I-O tables. Applications, economic input analysis, regional forecasting, linear programming urban I-O models. (HB142R5 UH/UP)

Schildenuck, J. Production and Income Relations In The Netherlands 1970. Contains brief description of I-O analysis followed by study of production costs and income in the provinces of the Netherlands. (HC325.S34 UH/UP)

Theil, Henn. System-wide Explorations In International Economics 1980. Input-Output Analysis, and Marketing Research". Input-ouput analysis as an extension of production theory and extension of decision distributions and heirarchies to I-O analysis. (HB135T477 Rice)

Tsukui, J. and Murakam, Y. Turpike Optinality In Input-Output Systems 1979. Theory and application for planning of many aspects of turnpike theory. (HD 82T78)

Vandermeulen, Daniel. Linear Economic Theory 1971. Has a chapter on the Leontief Input-Output system done with linear programming. (HB74.M3 V34)

Yan, C.D. Introduction to I-O Economics. Framework, theoretical implications, problems and practices of I-O techniques. Analysis of tables, regional I-O models. (HB74 M3Y32 UH/UP, Rice)

THEORY WITH APPLICATIONS

Barna, T. The Structural Interdependence of the Economy 1954. Proceedings of an international conference on I-O analysis. Includes papers on methods of analysis, social accounting aspects, national studies. (HB21P5)

Boer, Paul M. D. Price Effects in Input-Output Relations: A Theoretical and Empirical Study for the Netherlands 1949-1967. Production functions leading to four generalized linear I-O models. Transformations of 4 to 1 model and application to Netherlands. (HC325.B644 1982)

Brady and Carter (Editors). Input-Output Techniques Proceedings Of Conference 1971 1972. Environmental analysis, population and manpower, foreign trade in national models, multi-regional and multinational systems, prices and financial analysis rectangular systems, changing coefficients, national planning, applied dynamic systems. (HB142.158 UH/UP1971)

Carter, Anne P. Structural Change in the American Economy 1970. Examines data collection through completion of manipulation. Especially geared to coping with change, including industrial specialization and improvements in economic efficiency. (HC106.6.C32 Rice UH/CL)

THEORY WITH APPLICATIONS Continued

Dnel aand Hartog. Limits to the Welfare State 1980. A study in the highly industrialized heart of Western Europe using input-output relations to build a model taking into account growth, pollution abatement and other factor includes theory of variety of form of I-O models. (HC241.1 Rice D67)

Gelink and Gossling, editors. Input Output and Marketing Proceedings of 1977 London Conference and 1979 Toledo Ohio Workshop 1980. A series of papers using I-O subjects including textiles, energy, Scottish Economy, and some theory. (HF5411.I56 1980)

Gossling W.F. (Ed). Input-Output in the United Kingdom 1970. Proceedings of 1968 Manchester Conference. Includes I-O study of construction industry plus studies on I-O statistics, production models, and time trends of I-O coefficients. (HC250.5 I54 UH/UP)

Harmstrom, Floyd and Lund, Richard. Application of An I-O Framework to a Community Economic System 1967. Concepts of I-O model local industry delineation and measurement units. Data collection application. (HB74.M3H33 Rice)

Hungarian I-O Research, 1971 "I-O Techniques: Proceedings of the Second Hungarian Conference on I-O Techniques." Discussion on overall tables and those for select industries in Hungarian economy. Statistical and methodological problems in construction and application of tables. (HB141.H85

Jensen, R.C. Regional Economic Planning-Generation of Regional Input-Output Analysis 1979. Deriving tables with survey and non-survey approaches. GRIT Application to Australia, (Queensland). (HT391.J45)

Langford and Isard. Regional Input-Output Study 1971. A book demonstrating the feasibility of a highly detailed (500-600 sector) regional I-O study (specific study on Philadelphia area). (HC108.P5 18 Rice)

Lee, Tong, Moore, John R. and Lewis, David. Regional and Interregional Hov Analysis 1973. The method and an application to the Tennessee economy. Examines emphirical implementation and statewide model and the inter-regional model. (HC107T3.L42 Rice UH/CL)

Leontief and Wassily. The Structure of the American Economy 1919-1939 1951. The first major application of Input-Output techniques by its developing father. (HC106.3 L3945 Rice)

Leontief, W. Studies in the Structure of the American Economy 1976. Theoretical and emphirical studies in I-O analysis. Static and dynamic theory, extension of I-O techniques to interregional analysis capital structure of American economy, technological structure of cotton textile industry, commercial air transportation in the U.S. (HC106.H342 1976)

Leontief and Wassily. Input-Output Economics (2nd Edition) 1986. Complilation of twenty papers up to 1985. (HB142.L46 Rice)

THEORY WITH APPLICATIONS Continued

Leontief and Wassily. Structure, System, and Economic Policy 1977. A collection of reports, mostly about U.K. economy, including some I-O studies and theory. (HB21.B7)

Mathur and Bhanadivaz. Economic Analysis In Input-Output Framework With Indian Emphirical Explorations 1965. A collection of papers on I-O research in India. (HC435.ZS36)

Polenske and Skolka. Advances in Input-Output Analysis 1976. Proceedings of Vienna Conference 1974. Includes many regional (country) studies also industrial applications: the NFORUM model "the use of I-O analysis in industrial planning", "the use of I-O computer information in programming for chemical processes". (HB142.158 1974 UH/UP Rice)

Polenske, Karen. The U.S. Multiregional Input-Output Accounts and Model 1980. History and documentation of the national analysis. Data sources and estimation procedures used to assemble multiregional I-O accounts. (HC106.7 P643 Rice)

Preston, Ross S. The Wharton Annual and Industry Forecasting Model 1972. Combines econometric model with input-output studies to make a forecasting model, gives decade projections. (HC106.6.P73 Rice)

Rosehelde, Steven. Soviet International Trade in Heckschefohlin Perspective 1973. An input-output study problems of theory, data and computation, emphirical results of factor proportions, compositional trends. (HP362.5R68)

Schaffer, William A. The Use of Input-Output Models for Regional Planning 1976. Lerden Martinus nighoff social sciences division. Logic and construction of I-O Tables. Study of Georgia economy using I-O and some impact analysis and market analysis. (HC107G4.529 UH/CL)

Skolka, J.V. Compilation of I-O Tables- Proceedings, Gouvienx, France, 1981. See photocopy of list of titles. (UH/UP)

Smyshlyacer. Input-Output Modeling-Proceedings Laxenburg, Austria 1984 1985. See list of subjects covered - photocopy. (HB142.1547 UH/UP 1985)

Todaro, Michael P. Developement Planning-Models and Methods 1973. 1) Basic framework of I-O analysis. 2) Application to central economic planning and development planning, uses mostly underdeveloped countries as examples. (HD82,T55 UH/CL)

Treml, Vladimir. Studies in Soviet Input-Output Analysis 1977. Nine studies focused on 1966 I-O tables, which were filled in using estimation techniques. Economy wide applications of I-O planning, transportation. Regional I-O analysis comparison with U.S. I-O information. (HC336.24.58 UH/UP 1977)

U.N. Industrial Development Organization. Proceedings of the Seventh International Conference on I-O Techniques 1984. U.N. global modeling World Bank and Informum-IIASA global models national models, economic growth and structural change. (HB142.158 1979)

THEORY WITH APPLICATIONS Continued

U.M. Industrial Development Org. International Comparasions of Inter-industry Data 1960. Meeting on industrial programming data, 1965, characteristics of national industry data and approaches to international comparisons. (HC142.A4)

Yamada and Kamm. Theory and Application of Interindustry Analysis 1961. A thorough description of theory with Japanese economy used as an example. (HB71.43 Rice)

APPLICATIONS

Almon, Buildler, Honvitz, and Reimbold. Interindustry Forecasts of the American Economy 1974, 1985. Uses a model that includes input-output tables to make 12 year prediction of our economy. (H106.6N56 Rice)

Boxter, P.F. An Input-Output Matrix for Papua, New Crimea, 1972-1973 1976. Includes reasons for adopting a particular type of input-output matrix. (HC687.P3B36)

Ghosh. 9 Experiments With Input-Output Models 1964. Analysis of the structure of production in post-war Britain by utilizing the I-O tables for 1948. Includes comparison of I-O versus other methods in forecasting ability. (HC256.5G47)

Garrantani. Regional and Interregional I-O Analysis - A Bibliography Annotated 1976. (HT391.G48 UH/UP)

Gillion and O'Neil. An Input-Output Model of Structural Development 1978. A medium term projection exercise on New Zealand economy using I-O model. (HC661.R4H26 Rice)

Gossling, W.F. Input-Output and Throughput-Proceedings of the 1971 Norwich Conference 1971. Utilization of Input-Output technique in studies, mostly regional. (HB142.L66 Rice)

Hargrave, Carolyn Hooper. An Input-Output Study of Louisiana Economy 1971. Some mathematical background and methodology as well as thinking behind paper included. Study on Louisiana economy. (HC107L8H23 UH/CL)

Herenden, Robert A. An Energy Input-Output Marix for the United States, 1963-User guide 1973. Conversion of 1963 tables into energy terms. (HB142.H47 Rice)

Isard, W. Philadelphia Region I-O Study 1966. Highly detailed study of region in order to see effects of new policy implementation. Data collection through use of final table. (HC108 P5I8)

Koutsoyiannis, A. Input-Output Table of the Greek Economy (1960) 1967. Some concepts of data sources and compilation and definitions of sectoral breakdowns. (HC295 K64 UH/UP)

APPLICATIONS Continued

Lamphear, F. and Roesler, T. 1970 Nebraska Input-Output Tables 1971. 1970 I-O tables pluS brief discussion of the interpretation of I-O tables. (HC107.N2 L35 UH/UP)

Leontief, W. and Duchin. The Future Impact of Automation on Workers 1986. An I-O analysis of the future of the labor force. (HD5724.L38 1986)

Lindberg, Carolyn. A Technical Supplement to the Input-Output Study for New Mexico 1986. Describes methods used to construct the 1960 transactions table of the New Mexico Input-Output study of the Bureau of Business Research, University of New Mexico. (HC107.N6 L55 Rice)

Macrakis, M.D. Energy: Demand, Conservation, And Institutional Problems 1974. Includes Use of I-O analysis to determine the energy costs of goods and services. Impacts of new energy technology using generalized I-O analysis. (HD9545.E58 Rice)

Miernyk, William H. Air Pollution Abatement and Regional Economic Development 1974. Use of dynamic input-output model to predict effects of pollution control measures. (HC110.A4 M53 Rice)

Miernyk, William H. Impact of the Space Program on a Local Economy 1967. Effects of space-sector on economy of Boulder using I-O analysis. Discusses analytic framework of sector impact study and definitions and sources of data, then applies model to Boulder, CO economy. (HC108.B66 M4 UH/UP)

Office for Naval Analyses, Holcome, Randall. The Economic Impact of an Interruption in U.S. Petroleum Imports 1975-2000 1974. Analysis done using I-O model of U.S. economy seeing effects of various degrees of interruption of petroleum imports. (HD9502.U52 H638)

Polenskie, Karen R. State Estimates of Technology 1963 1974. Data compiled originally for 1963 multi-regional I-O model. (HC106.6P6)

Ramana, D.V. National Accounts and Input-Output Accounts of India 1969. Study of 195's information including national accounts, transaction models based on accounts (national and I-O) Interpolation of I-O accounts. (HC435.R253 1969)

Rasul, G. Input-Output Relationships in Pakistan, 1954 1964. Presents a construction of an I-O table for Pakistan economy and applications with the table.

Rodgers, John M. State Estimates of Interregional Commodity Grade, 1963 1973. Trade flows presented compiled for use in the multiregional I-O model includes chapter on sources of data on interregional table. (HF3031.R63 Rice)

APPLICATIONS Continued

Strout, Alan. Technological Change and United States Energy Consumption, 1939-1954 1967. I-O analysis of U.S. energy changes, technical change, methodology described. (HD9502.U52 S835 1979 Rice)

Su, Teddy T. The South Carolina Economy, An Input-Output Study 1970. Evaluates gross state product and balance of trade for each industry, 28 sectors. Short introduction, not much info on data collection. (HC107.57 S82 UH/UP)

Tilanus, C.B. Input-Output Experiments, The Netherlands, 1948-65 1966. Time series analysis of input coefficients value forecasts, forecasts of correction of forecasts with more recent data. (HB71.T48 Rice)

Treml, Vladimir. Input-Output Analysis and the Soviet Economy-An Annotated Bibliography 1975. (Z7165.R9 R67)

Treml, Vladimir, Gallik, and Dimitri et al. The Structure of the Soviet Economy Analysis and Reconstruction of the 1966 I-O Table 1972. A detailed discussion of the data and of manipulations done with the original tables. (HC336.23.573 Rice UH/CL)

U.N. Statistical Commission, 1972 Statistical Standards and Studies No 25. Standardized I-O Tables of ECE Countries for Years Around 1959. Some information on data collection and tables for 19 countries and EEC. (HA1107.C6 Rice)

SRI

American Productivity Center, Productivity Indexs computed from BEA and BLS data- updated on 1977 reference year. (SRI 1983/84/85-R2800-1)

Hertet, Thomas. "I-O Analysis for the Indiana Economy" (SRI 1985 2160-1.601)

Technical Publishing Co., Forecasting industrial production and prices, use of input-output method. (SRI C8650-2.105)

Technical Publishing Co., DRI econometric forecast article on industrial production and financial performance through 1984, IO analysis methodology. (SRI 1981 C8650-2.204)

Moskal, Brian. Federal expenditures on public works, and benefit analysis by type of project. (SRI 1983 C7000-3.408)

ASI

Block, Harvey, "Economic Imput of Social Service Expenditures. Uses I-O analysis to assess various aspects of social services. (ASI 1981 4008-51)

Briggs, Hugh, "Input-Output Analysis of Maines' Fisheries" Includes 5 tables showing estimated gross output, in-state income and income generated by 14 Maine non-fishing industries. (ASI 1982 2162-1.202)

ASI continued
Bureau of Econ. Analysis, "Detailed Input-Output Structure of the U.S. Economy 1972" Comes in 2 vols. (ASI 1980 2708-17)

Bureau of Economic Analysis, "Introduction to National Economic Accounting" Sources and methodology for 3 methods. 1) National income and product accounts, 2) Capital Finance accounts, 3) I-O analysis of interindustry transaction. (ASI 1985 2706 6.2)

Bureau of Industrial Economics, "Sectoral Implications of Defense Expenditures" I-O study of commerce department and DOD data. 58 defense-intensive manufacturing industries. Effects of changing demand. (ASI 1983 2018-5)

Bureau of Labor Statistics, "Historical and Projected Input-Output Tables of the Economic Growth Project" 100 Industry sectors 1963-90 derived from BES 10 tables for 1963 and 1967. (ASI 1980 6728-19)

Bureau of Labor Statistics, "Methodology for Projections of Industry Employment to 1990" Based on GNP growth and industry demand and output through 1990. (ASI 198 6888-24)

Cartwright, Joseph V., "Rims II Regional Input-Output Modeling System: Estimation, Evluation, and Application of a Disaggregated Regional Imput Model" Describes a model designed to assess the effect of public policies and private commercial activities on the economy of local areas. (ASI 1981 2708-35)

Chung, H.C., "Economic Impact of Maritime Industries on the U.S. Economy 1971-1978 on Interindustry Study" 50 sectors based on BEA benchmark tables for 1972. (ASI 1981 2128-46)

Collins, Keith J., Cotton in the U.S. Economy: An Interindustry Analysis of Internaitonal Trade in Cotton and Textiles" Effects of foreign trade change on I-O model for cotton. (ASI 1983 1508-243)

Coughlin, Peter, "New Structures and Equipment by Using Industries, 1972: Detailed Estimates and Methodology" Report on value of interindustry transactions in new structures and equipment. (ASI 1980 2706-5.25)

Crane, Jane-Ring, "Employment and Employee Compensation in the 1972 I-O Study" Uses 1972 benchmark tables for 496 industries. (ASI 1982 2706-5.28)

Data Resources, Inc., "Importance of Labor Costs in the Value of Selected Grocery Items" Uses DRI I-O Model. (ASI 1980 21768-22.1)

David, Lester A., "Employment Generated by U.S. Exports". Estimates calculated using a 200 sector I-O model using BEA data. (ASI 1983 2048-17)

"Detailed Input-Output Structure of the U.S. economy 1977" Benchmark tables for 1977. (ASI 1984 2708-17)

Epson, Dons, "Some Problems in Measuring Food Assistance Program Impacts on State and Local Economies". Interpretation and application of I-O Analysis focused upon. (ASI 1980 1548-165)

ASI Continued

Galuk, Dimitri, "I-O Structure of the Soviet Economy: 1972" 88 USSR industry sectors. (ASI 1983 2326-9.6)

Goldstein, Harvey, "Occupational Employment Projections for Labor Market Area: An Analysis of Alternative Approaches". Includes I-O model for projecting occupational employment demand. (ASI 1981 6407-55)

Groenewegen, John R., "Agriculture's Role in the Economy of the U.S.". Effects of food and fiber industry activity on U.S. Economy. Selected years 1972-1981. (ASI 1982-1548-194)

Henry, Mark, Schluber, Gerald, "Measuring Backward and Forward Linkages in the U.S. Food and Fiber System". I-O data for 79 industries - final demand for four food and fiber industries. (ASI 1985 15023.504)

House Energy and Commerce Committee, "Selected Economic Effects of the January 1981 Decontrol of the Domestic Crude Oil Prices: An I-O Analysis". Effects on 64 major industry groups. (ASI 1981 21368-5)

"Input-Output Structure of the U.S. Economy, 1977". Data for 85 industries aggregate of 537 industries. Tables of information including consumption and other criterion. (ASI 1984 2702-1.421)

Joint Economic Committee, "Maintaining the Quality of Energy Statistics for Economic and Energy Analysis". EIA Data use in U.S. Input-Output tables. (ASI 1982 23848-161)

Joint Committee Print, "USSR: Measures of Economic Growth and Development 1950-1980". (ASI 1982 23848-163)

Manchester, Allen C. "Agriculture's Links with U.S. and World Economics". Sumary I-O analysis of farm and food sector 1910-1985 selected years. (ASI 1985 1548-279)

National Bureau of Standards, "Economic Effects of Tracture in the U.S.". Report assesses costs of materials fracture in structure and vehicles and related accidents, uses I-O analysis of 1978 data. (ASI 1983 2218-66)

Opyrchal, Anthony, "Economic Significance of the Florida Phosphate Industry: An I-O Analysis". Analysis of economic impact on Florida and U.S. of phosphate industry. (ASI 1981 5608-125)

Penoyar, William E. "Input-Output Profile of the Construction Industry". Presents 1972 benchmark input-output tables showing construction industry production and inputs from other countries. (ASI 1981 2012-1.109)

Radcliffe, Victory. "Material Requirements and Economic Growth- A Comparison of Consumption Patterns In Industrialized Countries". Calculations based on I-O tables from range of international sources data for ceramics, ferrous and non-ferrous metals, polymers, and chemicals. (ASI 1982 5608-134)

ASI Continued

Ritz, Philip M. "Definitions and Conventions of the 1972 Input-Output Study". Methodology and data sources used in constructing the 1972 benchmark I-O tables. (ASI 1980 2706-5.24)

Silverstein, Gerald. "New Structures and Equipment by Using Industries 1977". Uses 1977 benchmark I-O tables, updating for new equipment in 70 user industries. (ASI 1985 2702-1.536)

Taylor, Jeffrey R. "Estimating the I-O Tables From Scare Data: Experiences of the U.S. Census Bureau's Center for International Research". Narrative report. (ASI 1984 2546-10.13)

Treml, Vladimir "Domestic Value of Soviet Foreign Trade: Exports and Imports in the 1972 I-O Table". Coefficients of 88 industry sectors. (ASI 1982 2326-9.4)

U.S. Travel Data Center, "Economic Impact of Foreign Visitor Spending in the U.S.". I-O Analysis to determine secondary impacts of tourists, expenditures on total U.S. economy. (ASI 1980 2908-2.6)

Williams, Franklin E. "Input-Output Profile of the Construction Industry for 1977". Uses benchmark 1977 tables. (ASI 1985 2042-1507)

Young, Paula C. "Summary of Input-Output Tables of the U.S. Economy, 1973, 1974, 1975". (ASI 1982 2706-527)

Young, Paul C. "Summary Input-Output Tables of the U.S. Economy, 1976, 1978, and 1979". 85 Industries 1976, 78-79. (ASI 1983 2706-5.29)

Yuskavage, Robert E. "Employment and Employee Compensation in the 1977 I-O Accounts". Estimates of Employment, employment compensation, and productivity by detailed industry. (ASI 1985 2702-1.535)

TEXAS STUDIES

Adams, John. "An Input-Output Study of the Economy of Northeast Texas". I-O model with 74 producing industries. Uses primary data for all but agriculture sector. Analytic and emphirical techniques and results. (HC 107.T42 N652 UH/UP 1972)

George, E.Y. "Upper Rio Grande Valley- Texas 1967 Interindustry Study". (HC 107.T42 U65 UH/UP 1972)

Grubb, H.W. "The Structure of the Texas Economy". Compilation of regional studies. (HC 107.T4 G76)

Hawkings, Charles. "An Input-Output Model of the Southeast Region of Texas". (HC 107.T42 S66 UH/UP 1972)

Mullendore, Ekholme, and Hayaskhi. "An Inter-industry Analysis of the North Central Texas Region". (HC107.T42 N65 UH/UP 1972)

TEXAS STUDIES Continued

Murrel, Joe C. "An I-O Model of the Lower Rio Grande Region of Texas". Uses of I-O tables in relation to historical problems of lower Rio Grande region. (UH107.T42 L68 UH/UP 1972)

Osborn; Mccray. "An inter-industry study of the Texas High Plains: Part 1". (HC 107.T42 H45 1972)

Stern. "Houston-Galveston Regional Input-Output Study for 1967. (HC107.T42 H685 1972)

Vinson, J. "An Input-Output Model of the Low Rolling Plains Region of Texas". (HC107.T42 L69 UH/UP 1972)

Vison, J.R. "An Input-Output Model of the South Central Region of Texas". 1967 base year. Overview of study region, methodology and procedures of analysis. relation between total regional economy and results of this study given. (HC107.T42 S65 UH/UP 1972)

MATHEMATICAL APPENDIX

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Given the following balance equation

$$X_i = X_{i1} + X_{i2} + \ldots + X_{in} + X_f \quad (i = 1 \ldots n) \tag{1}$$

where

X_i = Total Gross Ouput

$X_{i1} - X_{in}$ = Transactions in the endogenous sector.

X_f = Final Demand

Noting that the demand for part of the output of one endogenous sector, X_i, by another endegenous sector, X_j, is a unique function of the level of production in X_j, we have

$$X_{ij} = a_{ij}X_j \tag{2}$$

Substituting equation (2) in equation (1),

$$X_i = a_{i1}X_1 + a_{i2}X_2 + \ldots + a_{in}X_n + X_f \quad (i = 1 \ldots n) \tag{3}$$

rewritten as

$$X_i = \sum_{\substack{j=1 \\ i=1}}^{n} a_{ij} X_j + X_f \tag{4}$$

Technical coefficients are obtained from equation (2) by solving for a_{ij}

$$a_{ij} = \frac{X_{ij}}{X_j} \tag{5}$$

By dividing the entry in each column of the processing sector by the adjusted gross output for that column (total gross output minus inventory depletion) we obtain a matrix of technical coefficints, A, where

* Source: Miernyk, W.H. Input-Output Analysis, N.Y.: Random House, 1965.

$$A = \begin{vmatrix} a_{11} & \dots & a1j & \dots & a1n \\ \cdot & & \cdot & & \\ a_{i1} & \dots & a_{ij} & \dots & a_{in} \\ \cdot & & \cdot & & \\ a_{n1} & \dots & a_{nj} & \dots & a_{nn} \end{vmatrix} \tag{6}$$

Technical coefficients are defined as the direct purchases by each sector from evey other sector per dollar of output. However, in order to measure the direct and indirect effects of changes in sales to final demand, that is, to measure the direct and indirect (intraindustry) requirements, we need to invert a leontief matrix which is defined as (I - A) in which I is the identity and A is the matrix of technical coefficients (6). The new matrix of coefficients showing direct and indirect effects is transposed to obtain $(I - A)_T^{-1}$, designated as R

$$R = \begin{vmatrix} r_{11} & \dots & r_{1j} & \dots & r_{1n} \\ & & & & \\ r_{i1} & \dots & r_{ij} & \dots & r_{in} \\ & & & & \\ r_{n1} & \dots & r_{nj} & \dots & r_{nn} \end{vmatrix} \tag{7}$$

For any <u>new</u> final demand vector inserted into the system we use these coefficients to compute a new table of interindustry transactions as follows

$$\sum_{j=i}^{n} X_{ji}\, r_{ij} = X_i, \text{ then} \tag{8}$$

$$A_{ij}\ X_i^1 = T^1 \qquad (9)$$

Equation (8) shows that we multiply each column of $(I - A)_T^{-1}$ by the new final demand associated with the corresponding row.

Each column is then summed to obtain the new total from output X_i^1. Finally, in equation (9) each column of the table of direct input coefficients is multiplied by the new total output X_i^1 for the corresponding row. The result is the new transaction table T^1 which can be described as the new balance equation.

$$X_i^1 = \sum_{i=1}^{n} a_{ij}(X_j^1) + X_{f*}^1 \quad (i = 1 \ldots n) \qquad (10)$$