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Regional Planning and Mathematical Models

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REGIONAL PLANNING AND MATHEMATICAL MODELS

by

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The purpose of this paper is to explain the multiregional input-output (MRIO) model; to show its links with other interregional models; and to discuss its usefulness--present and potential--as an accounting tool, a policy analysis tool, and a planning tool. It is thus a powerful tool for economic analysis. But as with all economic techniques, it can be used to solve the wrong problems, used in a misguided way to solve the right problems, or even worse, used correctly to solve the right problem, but in a sterile economic environment with no links to the social, political, and physical aspects of the problem. With careful use of the MRIO model, however, these pitfalls can be avoided, and it is not within the purpose of this paper to elaborate further on this subject.

The scope of this paper must necessarily be limited, so it is basically descriptive, centering on the MRIO data and model and their uses. This model was formulated in the late 1960s and was first implemented in 1968, but the origin of interregional input-output models dates back to the early 1950s. Recently another technique--regression analysis--has been proposed as the central core of interregional models. Another technique of analysis, linear programming, is often used with interregional models. Because the emphasis in this paper is on the structural economic relationships of an economy and because the linear programming technique is generally employed in relationship with input-output models, it is not treated as a separate category here.

In the following historical survey, discussion will be limited to interregional models that use data for all industries in the economy. Regional models used for an analysis of a single area, say West Virginia, and interregional models used for an analysis of a single commodity or industry, say coal, are therefore excluded. The term "econometric" will be used to designate models based primarily upon regression analysis techniques, and the term "input-output" will be used for models based mainly upon input-output techniques. This separation is made only for convenience in referencing, since, strictly speaking, an input-output model is often classified as a specific type of econometric model, and both techniques are incorporated into many interregional studies. Although only interregional models are discussed, the same techniques of analysis are frequently used for regional models; the literature review may therefore also be relevant for regional analysts.

A BRIEF HISTORY OF INTERREGIONAL MODELS

The literature on interregional models, especially input-output models, is limited, but rather well documented. Useful surveys have been published by Kerr and Williamson [30], Meyer [37], Miernyk [40], Riefler [55], and Tiebout [63]; and bibliographies by Bourque and Cox [2] and Giarratani, Maddy, and Socher [15], though limited to the United States, are also available. Glickman, in his 1974 article--which was not intended as a survey article--does provide useful documentation on regional econometric models [16]. Two other references that are valuable to analysts working with interregional models are a short article by Kendrick [29] and the book on input-output analysis by Richardson [54].

Of the two types of interregional models specified earlier, interregional input-output models were the first to be formulated. Isard in 1951 [27] and Leontief in 1953 [34] first set forth a theoretical framework for a set of interregional input-output accounts. Simultaneously, Chenery was gathering data to implement a two-region model for Italy [5], and Moses was at work on the empirical information required for a three-region model of the United States [46]. In addition to the two interregional studies conducted by Moses in the 1950s, one of which was a linear programming model [45], only a few studies have been made in the United States in which the interregional input-output models have actually been implemented for all regions of the country. Greytak implemented the Chenery-Moses model for 19 regions, with Appalachia and the Ozarks given in detail [19], and again for eight regions, combinations of the 50 states [20]; and the National Planning Association conducted an interregional study for New York state and the rest of the United States [62]. The Harris [24] and Polenske [50] models, which were both implemented in the late 1960s, will be discussed later.

The theoretical framework, the methods of data assembly, and the techniques used to implement interregional input-output models for a subarea in the United States, however, are often very similar to those employed when all regions are included in the study. For this reason, a few of these studies should be cited. Interregional models of specific U.S. regions have been developed for a variety of economic contexts, ranging from general economic development to particular topics, such as water resources, transportation, and agriculture. Examples of general economic analysis studies are those by Riefler and Tiebout for California and Washington [56]; Henderson and Krueger for the Upper Midwest [25];

Lee, Moore, and Lewis for three regions in Tennessee [33]; and Grubb for nine regions in Texas [21]. Examples of water-resource interregional models are the research of Miernyk [39] and Udis [64] for the Colorado River Basin; Hamilton, et al. for the Susquehanna River Basin [22]; Davis for the West [9]; the U.S. Army Corps of Engineers for the North Atlantic region [61]; and the recent study by Kim, Park, and Kwak for the Arkansas River [31]. The use of interregional models for transportation is illustrated by the CONSAD study of the Northeast Corridor [6] and the recent study of ConRail conducted by Jack Faucett Associates, Inc. [11], while the Carter and Ireri study for California and Arizona [4] is an example of the use of an interregional model for agriculture.

Outside of the United States, research has also been focusing more and more on interregional models, both econometric and input-output. The 1953 publication of the Chenery research in Italy was followed by the Wonnacott study of Canadian-American dependence in 1961 [67], a study of Argentina by Brodersohn in 1965 [3], and still later by the publication of the 1960 [41], 1965 [42], and 1970 [43] Japanese interregional tables. Studies are, or will soon be, available for Belgium [66], Canada [26], Colombia [38], France [8], Germany [13], and India [14].

In 1968, at the Regional Science Association meeting in Cambridge, Massachusetts, Morris R. Goldman, Deputy Director of the Office of Business Economics, U.S. Department of Commerce, cautiously lent support to the development of interregional input-output tables [17]. During the past few years, a concerted effort has been made by the staff at the Bureau of Economic Analysis (formerly the Office of Business Economics) to establish the assembly of interregional input-output accounts as a part of their overall input-output program.

At the same 1968 meeting in Cambridge at which Goldman appeared, Lawrence Klein proposed establishing regional econometric models and linking them to a national model [32], his obvious choice being the Wharton Econometric Forecasting Model [10]. Glickman has recently given a valuable account of how Klein's proposed system could be implemented [16]. In his paper, Glickman summarizes current econometric regional models and research. Most are regional, not interregional, models. As far as is known, the industrial detail is severely limited in all the regional or interregional econometric models. The Massachusetts econometric model, developed by Friedlaender, Tresz, and Tresch, for example, while linked to the Data Resources Incorporated national model, contains data for only one region (Massachusetts) and for only the two-digit Standard Industrial Classification (SIC) [12].

Both of the interregional input-output models under discussion at the present meeting were developed in the late 1960s. The multiregional input-output (MRIO) model was first described by this author at the 1968 Geneva International Input-Output Conference, and a paper was published in 1970 [47]; the multiregional, multi-industry (MRMI) forecasting model was described by Harris at the 1969 Regional Science Associating meetings, and a paper was published in 1970 [23]. Four of the main distinctions between the MRIO and MRMI research projects and most of the other interregional research cited are that (1) the MRIO and MRMI projects have been ongoing for ten years or more, (2) the data are available at the state or county level and are specified for three- and four-digit SIC industries, (3) the models have actually been implemented, and (4) the data and models are being used for making policy decisions by federal, state, and local governments, as well as for general research purposes by consulting firms and university research groups. Because an excellent comparison of the two models is being made by Theresa Coulter and should be available soon from the Bureau of Public Roads [7], an extensive comparison is not given in this paper. Rather, only the MRIO model and its actual and potential uses are discussed in detail in the following section.

THE UNITED STATES MULTIREGIONAL INPUT-OUTPUT MODEL

The MRIO model is a comprehensive, multipurpose tool that can be used for systematic studies of many regional economic policies. It provides a consistent framework for describing and analyzing not only the sales and purchases of all industries in every region of the economy, but also the shipments to and from all regions. Because both industries and regions are strongly interdependent, the MRIO model provides a useful way of measuring the direct and indirect effects of variations in economic activities throughout the country. For example, it can be used to show how a purchase in one state generates a chain of transactions affecting industries in many states. If the MRIO framework has been correctly specified, the outputs required from each region in the country and the resulting interregional shipments of all goods needed for that production can be accurately measured. It is an accounting tool, a policy analysis tool, and a planning tool.

The Interregional Accounts and the Model

To implement the model, a set of interregional accounting data were assembled. These consisted of a set of 1963 input-output tables for each of 51 regions (50 states plus the District of Columbia), a set of 1963 regional trade-flow tables for each of 79 goods and services, and a set of 1963 final demands, separated into six major components of the gross regional product.[1] Thus, base-year regional technological, trade, and final demand relationships are completely specified. All these accounting data were assembled according to the 87-industry classification scheme of the Bureau of Economic Analysis and have been made consistent with the published national tables. The six major components of final demand were also projected, based upon data from earlier years, to 1970 and 1980. For the projections, the final demands were made consistent with the national projections published by the Bureau of Labor Statistics.

Although national economic accounts are now routinely published for the United States, the lack of consistent sets of regional data and disputes over the conceptual definitions required for the assembly of regional statistics delayed the compilation of regional economic accounts. The set of multiregional data that has been assembled is the most comprehensive that has ever been available for the American economy using a common industrial and regional classification scheme and covering all industries in the economy. For all the data assembly, of course, a considerable amount of research effort was required to assure an internal consistency between the state figures and the national aggregates.

Given the base-year technologies and trade relationships and the 1970 and 1980 final demands, the 1970 and 1980 outputs and interregional trade flows can be calculated using the MRIO model for each of the 51 regions and 79 industries. The customary assumptions of input-output studies regarding the homogeneity of commodities and constant returns to scale have been maintained in the research to date. One of the basic assumptions of the MRIO model, therefore, is that while the technology for a given industry is allowed to vary from region to region, it is assumed to remain

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[1] Work should be starting soon to assemble a set of 1972 MRIO accounting data.

constant over time. The second basic assumption, relating to the trade flows, is that the fraction of total consumption of a particular commodity supplied to a given region from another region will not change over time. Both assumptions are tenable in the short run, especially in a highly industrialized country like the United States, but need to be relaxed for long-term forecasts.

For the projections of regional outputs and interregional shipments, three trade models that use fixed coefficients were initially tested: point estimate gravity, column coefficient, and row coefficient.[2] The first tests of the MRIO model were made using Japanese interregional trade tables for 1960 and 1963. Because the test results indicated that estimates of outputs and interregional trade flows obtained from the column coefficient model were at least as accurate as those obtained from the other two models, the column coefficient model was selected for the implementation of the model using the United States data.[3] Research by Bon [1] indicates that the row coefficient and gravity trade coefficient models will have to be reformulated before they are used in large-scale models.

An obvious alternative to the three transportation models that use fixed coefficients would be a linear programming model, such as the one tested by Moses [45]. In linear programming models, however, crosshauling of commodities cannot occur unless a considerable number of constraints are specified, and actual data on transportation costs are required to implement them. A linear programming model has not been tested within the present

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[2]The comparisons are given in K. Polenske [48]. The gravity model was originally described by W. Leontief and A. Strout [36].

[3]The first empirical testing of the complete multiregional input-output model for the United States is discussed in a report prepared for the Economic Development Administration, U.S. Department of Commerce, by K. Polenske [50].

MRIO model because the aggregate nature of the interregional shipments data does produce crosshauls in the actual data and because consistent sets of transportation cost data would have been extremely difficult and expensive to obtain.

In comparison with the extensive data on transportation costs and other regional data required for a multiregional linear programming model, only a limited amount of actual regional data is needed to implement the fixed column coefficient model. The required sets of regional data are base-year technical coefficients, a_{ij}^{h}, base-year trade coefficients, c_i^{gh}, and a set of final demands, y_i^h, for the given year. When the model is implemented, the outputs, x_i^{go}, and the interregional trade flows, x_i^{gh}, are determined for all regions and industries in the economy.[4] For the United States, for example, estimations of regional outputs and interregional trade flows have been made for 1970 and 1980. The equation system for the column coefficient model is simply:

Trade Coefficient Equation

$$x_i^{gh} = c_i^{gh} x_i^{oh}$$

Equation System in Matrix Form

$$\begin{aligned} \Delta X &= C(\hat{A}\Delta X + \Delta Y) \\ (I - C\hat{A})\Delta X &= C\Delta Y \\ \Delta X &= (I - C\hat{A})^{-1} C\Delta Y \\ \text{or } \Delta X &= (C^{-1} - \hat{A})^{-1}\Delta Y \end{aligned}$$

An important aspect of the role of the MRIO model as an accounting tool is the basis it provides for three rigorous consistency checks. First, the sum of each regional data component in the technology, trade, and final

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[4]The i designates the producing industry, j the purchasing industry, g the shipping region, and h the receiving region. The o indicates a summation over all regions.

demand tables must equal the respective national figure. Second, for the base year the interregional trade flows for each commodity must be consistent with the total regional production and consumption data contained in the regional input-output tables for the respective commodity. Third, when the model is implemented for the base year, estimated outputs must equal actual outputs. The consistency properties of the MRIO model are emerging as one of its strongest aids to planners. As with any well-developed double-counting system of accounts, all components of the accounts must balance.

The model has been used since 1970 for a variety of policy analyses, which will be discussed later. In a number of cases, either through lack of information on particular entries in the accounts or because of speed required to complete a study, errors have unintentionally entered the data system or in a few cases the initial conceptual framework was misspecified. The errors have immediately emerged as the model was implemented. They were usually discovered in one of the three consistency checks just mentioned.

Policy Analyses Using the MRIO Model

Many groups--a partial listing of which is provided in Table 1--have used the MRIO data and model for a variety of regional and interregional policy analyses. Of the studies conducted by other groups, some of the most interesting are the application of the model at the University of Wisconsin to evaluate the regional output, employment, and redistribution effects of a proposed federal income transfer policy [18]; the employment analysis completed for the ConRail Final System Plan [11]; and the employment analysis made for the Arkansas River Project [31]. At the MRIO research project at the Massachusetts Institute of Technology, several

Table 1

USE OF THE MRIO MODEL AND DATA

Federal and State Government Agencies

FEDERAL PREPAREDNESS AGENCY, General Services Administration (formerly part of the Office of Emergency Preparedness, Office of the President), has set up a fully operational version of the MRIO model on the Univac 1108 as the Regional Impact Analysis System (RIAS). This system has been used for an analysis of the SST cut-back of 1971 and a study of the impact of the 1974 coal strike. The staff members of the agency are continuing to cooperate with MRIO staff members in making revisions to the data and model.

CORPS OF ENGINEERS, Institute for Water Resources, Department of the Army, has adapted the model to assess the employment and income impact of construction of the McClennan-Kerr Arkansas River Project.

BUREAU OF ECONOMIC ANALYSIS, U.S. Department of Commerce, evaluated the MRIO model that was submitted to the EDA and worked closely with the MRIO staff at the Institute, giving helpful advice on the 1972 revisions that were made to the model.

ECONOMIC RESEARCH SERVICE, Department of Agriculture (Lansing, Michigan), used the MRIO table for Ohio for an impact study of agriculture.

DEPARTMENT OF BUSINESS DEVELOPMENT, State of Wisconsin (Madison, Wisconsin), used the MRIO data in conjunction with a benefit-cost analysis to evaluate total economic and social benefits in relation to costs of alternative state investments and programs and development opportunities. The input-output model was used to make projections for investment planning in the business community.

Consulting Firms

JACK FAUCETT ASSOCIATES, INC., Chevy Chase, Maryland, used the model for a study of the employment impacts of the Final System Plan (Conrail) for the U.S. Rail Administration.

LOUIS BERGER & ASSOCIATES, INC., East Orange, New Jersey, used the model for a socio-economic study of the Lower Delaware River Basin, sponsored by the National Commission on Water Quality, and are engaging in two other studies, one in northeast New Jersey, to analyze the costs and benefits of the implementation of the Clean Water Act Amendments.

ROBERT REEBIE & ASSOCIATES, Greenwich, Connecticut, used the model for an intermodal freight system study for the U.S. Rail Administration.

PEAT, MARWICK, & MITCHELL, Washington, D.C., used the state-to-state commodity flows to analyze potential rail-truck networks.

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Table 1 (continued) USE OF THE MRIO MODEL AND DATA

TEMPLE, BARKER, & SLOANE, INC., Boston, Massachusetts, used the initial interregional trade flows from the MRIO model to help in making long-range forecasts of commodities transported by the Penn-Central railroad.

DAVID BRADWELL ASSOCIATES, San Francisco, California, used the state MRIO table for Oregon to compare with their estimated state table for Oregon. They are using a regional input-output model to study water-borne and airborne pollutants in the state.

HARBRIDGE HOUSE, Boston, Massachusetts, used the MRIO model to assist in analyzing the impact of the Boston and Maine railroad on the New England economy.

PARSONS, BRINCKERHOFF, QUADE, & DOUGLAS, New York, New York, used the interregional trade flow portion of the MRIO data for an in-depth analysis of commodity shipments through the East-West gateway in St. Louis.

BATTELLE NORTHWEST, Richland, Washington, aggregated the 51-region MRIO data to 5 regions and also to 2 regions for use in economic impact analyses in four states: Washington, Idaho, Montana, and Oregon.

<u>Universities</u>

INSTITUTE FOR RESEARCH ON POVERTY, The University of Wisconsin, used the model to evaluate the regional output, employment, and redistribution effects of a proposed federal income transfer policy.

MATHEMATICS AND COMPUTING GROUP, Lawrence Berkeley Laboratory, Berkeley, California, set up a fully operational version of the MRIO model for use in various regional analyses. This group has already used the MRIO data, along with more detailed information, to study water, waste, and general economic projections of growth in California and Nevada.

NOTE: This is only a partial listing of groups that either have used or are presently using the MRIO model and data. Because the data and literature on the model are freely available to the public, only those groups who have conferred directly with members of the MRIO staff can be listed.

analyses of freight transportation have been made, including some preliminary analyses of the interactions between transportation and energy at the regional level, and projections of freight carried on five midwestern railroads. In addition, an exploratory study is being conducted on the use of the MRIO model for making state employment projections. This study, which will be completed by the winter of 1976, is being made by Ruth Rowan for the Massachusetts Division of Employment Security [59].

Because of the wide variation in needs of users, the data and model were specifically designed for adaptability to different policy studies. Complete methodologies of data assembly and information on the data sources used are readily available in published form [52; 53; 57; 58; 60], as are the computer tapes containing the data, and a guide is available to assist users in implementing the model [51]. Additional information on the mathematical properties of the model are contained in a Ph.D. thesis by Bon [1], while some difficulties in adjusting the interregional trade flows to be consistent with the regional input-output tables are investigated by Möhr in his Ph.D. thesis [44].

For general regional economic studies, the MRIO model has four distinct advantages over most previous regional analyses: (1) indirect, as well as direct, repercussions can be measured; (2) gross, rather than just net, shipments of commodities to and from each region can be estimated; (3) all analyses can be made to provide considerable industrial and regional detail while maintaining an internal consistency of all calculations; and (4) the framework can be used to analyze the industrial and regional impact of economic policy decisions for the nation as a whole, and at the same time, economic analysts in each region or group of regions can use the basic results of the calculations to provide controls in their own investigations of economic problems particular to the region or group of regions under study.

Regional Planning

In a recent article in Challenge, Leontief has outlined the need for planning at the national level [35]. In states, economic planning is already being used to assist in developing general economic policies. Research is now beginning by the MRIO research staff on a three-year program funded by the U.S. Department of Transportation and the Economic Development Administration. It will focus on the use of the MRIO and other regional economic techniques for state and regional planning, both general economic planning and freight transportation planning, with particular emphasis on the railroads.

The primary emphasis of the research will be on determining how the MRIO model and related techniques of regional economic analysis can be used at the state level for the planning and evaluation of state economic development policies. The research will focus especially on policies related to transportation and energy and their impacts on employment and income in the regions. To do this, some account must be taken of the social and political, as well as the institutional, frameworks within which regional economic development occurs.

In conducting this research, consideration will be given to section 803 of the Railroad Revitalization and Regulatory Reform Act of 1976, in which it is stated that:

> A State is eligible to receive rail service assistance from the Secretary if--(1) such State has established an adequate plan for rail service in such State as part of an overall planning process for all transportation services in such State, including a suitable process for updating, revising, and amending such plan.

An assessment will be made as to how the MRIO model could form part of the state transportation plan, especially as it provides an important link with the macroeconomic variables affecting a state. It also provides a means of looking at the regional and industrial interactions between transportation and energy.

CONCLUSION

The MRIO model is a very convenient method of determining the indirect effects of a particular policy on an interregional as well as an interindustry basis. As an accounting tool, the consistency checks help the regional analyst to locate errors in the accounts. The model also provides a useful framework for conducting regional policy studies. It is one of a number of regional economic techniques that should be made available to state and regional planning groups. No other method of analysis has been devised to determine indirect effects of specific economic policies in a systematic way. Although the MRIO model is not the only technique that should be used by research groups, it can become a key part of many present regional research efforts.

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