8-2020

Input-Output Analysis: A Primer, 2nd ed.

Randall W. Jackson
West Virginia University

The Web Book of Regional Science

Sponsored by

Input-Output Analysis: A Primer

Second Edition

By

Randall W. Jackson

Director

Regional Research Institute

West Virginia University

Originally Published: September 20, 1993

Updated: August, 2020

Editor: Randall Jackson
Director, Regional Research Institute
West Virginia University

The Web Book of Regional Science is offered as a service to the regional research community in an effort to make a wide range of reference and instructional materials freely available online. Roughly three dozen books and monographs have been published as Web Books of Regional Science. These texts covering diverse subjects such as regional networks, land use, migration, and regional specialization, include descriptions of many of the basic concepts, analytical tools, and policy issues important to regional science. The Web Book was launched in 1999 by Scott Loveridge, who was then the director of the Regional Research Institute at West Virginia University. The director of the Institute, currently Randall Jackson, serves as the Series editor.

When citing this book, please include the following:

Jackson, R.W. (2020). *Input-Output Analysis: A Primer.* WVU Research Repository, 2020.

Contents

PREFACE

The need for regional economic development planning is becoming increasingly apparent to government officials and to the general public. One need only look as far as the rising number of local development commissions of various types to be convinced of the trend. The concern for economic development issues unfortunately tends to outstrip expertise in methods of regional economic analysis.

Economic development issues are widely varied and often interrelated. Traditional frameworks such as the export base model cannot adequately deal with the growing complexities of the modern regional economy. The apparent sophistication of more complex models is often unnecessarily discouraging to the development planner. The analytical power of such models is, as a consequence, unnecessarily underutilized. The purpose of this brief monograph is to strip the mask of sophistication away from one of these models, the input-output (IO) model, in an attempt to make it a more accessible tool. The IO modeling framework requires a certain level of mathematical notation, but I have attempted to keep the maths to a minimum and to provide thorough non-mathematical description in the accompanying text.

This first version of this document was written in 1985 at the request of the Illinois Department of Commerce and Community Affairs in an attempt to fill the need for a less technical, less mathematically demanding introduction of input output modeling and analysis to planners and local decision-makers. It was revised and re-purposed largely as a classroom instructional resource in 1995 when the author was an associate professor of geography at The Ohio State University. There has been some minor editing for clarity, but the overall presentation remains largely unchanged from the original.

In the decades since the first version, national and regional input-output modeling theory and applications have proliferated in the literature, and have found wide-spread adoption and use both within the United States and internationally. IO continues to fill its traditional role in economic impacts assessment, and it is increasingly popular in applications to environmental modeling, water use and embodiment in trade, global value chains, and industrial cluster analysis, to name just a few.

Interested readers will have no difficulty finding additional resources to fill in and fill out the presentation in this document. Indeed, a very good place to start, given free access to electronic document downloads, is the Regional Research Institute's Web Book of Regional Science, hosted on The Research Repository at the West Virginia University, where this and other documents will be permanently housed. The Web Books by Geoffrey Hewings and William Schaffer are particularly relevant to this topic. We invite you to browse not only the Web Books, but also the numerous Working Papers, Resource, and Technical Documents housed there.

Randall Jackson, Regional Research Institute Director
Web Book of Regional Science Editor
2002 - present

1 INTRODUCTION - WHAT IS OUTPUT ANALYSIS?

Input-output analysis is the name of a particular approach to studying economic interaction. It is a technique for economic analysis based on a modeling framework that accounts for all of the business transactions in an economy for a period of time. The economy under study can be a national economy, a multi-state, state, or multi-county regional economy. Smaller regions are usually not appropriate for reasons that will soon become clear.

Input-output (IO) analysis can be used in a number of ways, all of which tend to improve the understanding of how industries in an economy are interrelated. Industries contribute to economies in five primary ways:

1. They contribute to income (through wages, salaries, profits and other payments).
2. They purchase inputs from other industries.
3. They supply inputs to other industries.
4. They supply their output to non-industrial consumers.
5. They pay taxes.

As its name suggests, the IO accounting framework describes and depicts the input and output relationships of all industries in an economy. The utility of the IO framework is manifold. Most immediately, the inter-industry transactions table, or input-output matrix, describes the direct sales and purchases relationships among industries. The framework, in its several forms, is useful for assessing the impacts of changes in economic activity within or outside a region and for targeting industries for retention or recruitment policies. These and other uses will be discussed in this monograph.

One of the difficulties in presenting material of this sort lies in the fact that there is a great deal of notation and terminology for which an understanding of specific meanings is essential. For this reason, I have chosen to introduce the notation and terminology within the context of a discussion of accounting frameworks, to reduce the definitional interruptions to explanations later on. Those familiar with economics and similar notation may choose to skip this discussion. For others, it will provide an essential vocabulary for understanding the remainder of the paper. Also, for the benefit of those unaccustomed to dealing with symbolic notation, I have included a list of variables and definitions as Appendix A. For the benefit of those who are not technically inclined, I have "starred" certain sections that may be omitted without detracting substantially from an overall appreciation of the utility of the input-output modeling framework. Even in these sections, however, a reading of the introductory paragraphs will increase understanding.

2 ACCOUNTING FRAMEWORKS

The IO framework is, above all else, an accounting framework. An accounting framework is a basic structure designed and defined in such a way as to record and summarize business and other financial transactions. Other accounting frameworks are common and unimposing. Business revenues less the costs of doing business are by definition equal to profits. Consumption dollars plus government expenditures plus export dollars minus import dollars can be used to define gross national product. Basic (export) activity plus residentiary (service) activity can be defined in such a way that their sum is equal to total activity. Many such mathematical definitions fall into the category of accounting frameworks.

The fundamental accounting relationship in the IO framework is that the output used as inputs to industries (intermediate output) plus output for consumption (final demand) is equal to all the output that is produced (gross output) for a given time period (usually one year). There is nothing magical about this relationship. The variables are simply defined in such a way as to make the statement definitionally correct. The components are defined to ensure the condition. The conventional notation for gross output is the symbol X. Since the units of analysis in economic models are usually industries and not firms, we are interested also in gross output by industry, or X_i, where $i = 1, \ldots, n$, and n signifies the number of industries in our classification scheme. Hence, X_3 denotes the dollar value of gross output produced by industry number 3. The total number of industries included in a regional economic model can vary from two through a dozen or so up to hundreds or even thousands. The difference in numbers of industries in a classification scheme reflects the level of detail in the data available for the region and the purpose to which the model will be put.

The level of detail in a classification scheme is also referred to as the level of disaggregation. Greater numbers of industries reflect finer levels of detail and a greater level of disaggregation. In a classification that details only a dozen or so industries, each industry will have a very general name such as "durable goods manufacturing" or "agriculture." More disaggregated schemes may include industries with such names as "scientific instruments" or "processed dairy products." Finely disaggregated data are usually available for large regions (e.g., nations), but the level of detail for smaller regions generally decreases as the size of the region decreases. The "size" of a region here refers more to the amount of economic activity than to geographic extent.

A further distinction is made in the IO framework between the amount of industrial output that is sold to other industries for further processing and that which is sold for final consumption. The notation for this distinction is x_{ij} for output that is sold from industry i to industry j, and Y_i for output that is sold from industry i for final consumption. Final consumption, or final demand, refers to products that will not be reprocessed for resale and that will not be consumed during the accounting period. A drill press purchased for a production facility, for example, is counted as an investment final demand, an expenditure on capital account, but the drill bits that must be replaced on a regular basis as the machine is used count as intermediate purchases, or current account expenditures.

The IO framework is often referred to as an equilibrium model, meaning that when the system is functioning properly, the intermediate and final demand for all products produced by the region's industries will equal the amount that they produce. Restated, the economy operates in such a way as to precisely satisfy (supply) the wants and needs (demands) of the population. When these demands are met exactly, the system is said to be in a state of equilibrium. Final demand equals final consumption in the model, so these terms will at times be used interchangeably and will both be denoted Y_i. Just as gross output for all industries is denoted X, so total final demand will be denoted Y.

Final demand is often split into some number of components, activities or sectors, for accounting purposes. These can include exports, imports (-), government purchases, investments, and household consumption, and they represent the possible destinations for final outputs.[1] Conversely, to account for all of the payments to various sectors in the production process, we include gross operating surplus (essentially profit), payments to government, and payments to households. Figure 1 is a graphic representation of the accounting framework discussed thus far. Because the inter-industry and final demand purchases include those for domestic industries and imports, these accounts are called *imports-ridden*. There are n "from" industries along the left column of the diagram. These are the supplying industries. The payments sectors are nonindustrial sources of supplies and inputs to the n "to," or purchasing industries across the top of the diagram. The payments sectors and final demand sectors are defined to include all non-industry origins and destinations of dollar flows. As an alternative to including imports as a negative entry in final demand, the imports portions of transactions values can be subtracted from the total intermediate and final demands and recorded as a positive entry values in a new payments sector row. These accounts, called *imports-purged*, are shown in Figure 2. Given this imports-purged formulation, the sum of a column of transactions for any industry in the accounting framework equals total gross outlays. Since supply must equal demand in the framework, the sum of all transactions across an industry row will be equal to the sum of all transactions down the corresponding industry column. Hence, corresponding values in the Total Gross Output column and the Total Gross Outlays row are equal. This accounting identity holds for both imports-ridden and imports-purged accounts.[2]

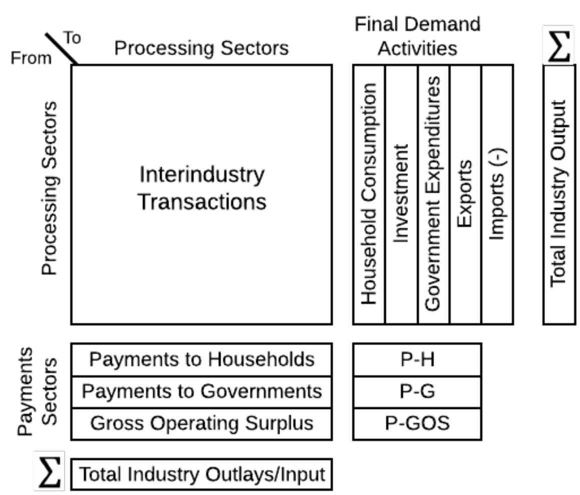

Figure 1: Imports-Ridden Input-Output Accounting Framework

[1]For simplicity, we have omitted inventory and capital accumulations and depletions from this discussion, but these are often present in more comprehensive national accounting systems, and can be incorporated in a straightforward manner.

[2]Note that there can be entries in quadrant four of these diagrams, especially in the imports row of imports-purged accounts. However, the entries in these quadrants have no effect on impacts modeling solutions, so they are not the focus of any discussion in this monograph. These entries can play a more important role in social accounting matrix models and computable general equilibrium models. Interested readers should look to those literatures for more details.

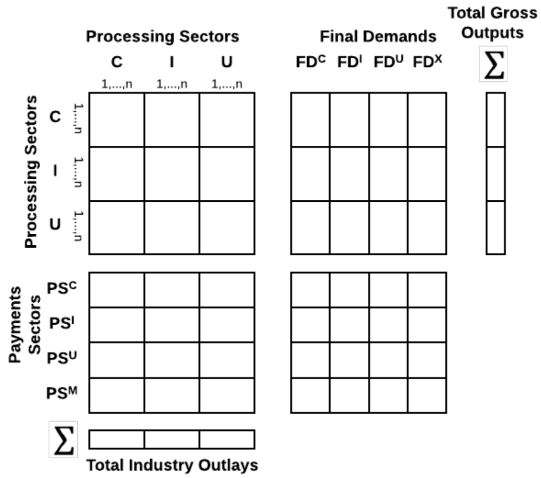

Figure 2: Imports-Purged Input-Output Accounting Framework

In terms of the accounting framework, we can make several mathematical statements. These include:

1. The sum of all n industrial final demands $(Y_1 + Y_2 + ... + Y_n)$ equals total final demand, Y;
2. The sum of all intermediate outputs sold from one industry to all others $(x_{i1} + x_{i2} + ... + x_i n)$ plus the output from that industry that serves final consumption, Y_i, equals gross industrial output for that industry, or X_i[3] ; and
3. The sum of all gross outputs by industry $(X_1 + X_2 + ... + X_n)$ is equal to gross output for the region, or X.

The accounting equations for each industry in an economy can be grouped in the following fashion:

$$\begin{aligned}
&x_{11} + x_{12} + ... + x_{1n} + Y_1 = X_1 \\
&x_{21} + x_{22} + ... + x_{2n} + Y_2 = X_2 \\
&. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \\
&x_{n1} + x_{n2} + ... + x_{nn} + Y_n = X_n
\end{aligned} \tag{1}$$

These equations represent the disposition of all output in the economy. In this framework, final demand includes not only those demands for products by consumers in the region, but also those industrial demands for products by consumers outside the economic region (exports). Imports are treated as negative final demands since they can be seen as replacements for locally produced output.

Up to this point, there is no reason why the transactions shown by the output equations need to be expressed in common units. Units of steel or coal could be tons, oil could be in gallons, and so on. The units in any one row would all be the same, but to sum outputs across industries, we need to denominate the transactions in common units. Dollar (or other financial) terms are the most

[3]When the demand for imports is counted as a final demand activity and entered as negative values, X_i will represent gross *domestic* output.

attractive units for representing industrial output flows, because production units (establishments) most often measure success or failure in dollar terms, and they track costs and revenues more closely than other units.

With transactions in dollar units, we can transform the inter-industry transactions into average coefficients by dividing each element in a column of the inter-industry transactions table by its corresponding industry output (now also in dollar terms). In this fashion, $(x_{11}/X_1) = a_{11}, (x_{12}/X_2) = a_{12}, (x_{34}/X_4) = a_{34}$, and so on. More generally, $X_{ij}/X_j = a_{ij}$, or $a_{ij}X_j = X_{ij}$. The result is a set of coefficients that represents the average cost to the column industry for inputs from the row industry for each dollar of output the column industry produces. We can now arrange these coefficients in tabular – or matrix –format, as shown below (referred to as a technical coefficients matrix).

$$\begin{array}{cccccccc} a_{11} & a_{12} & a_{13} & . & . & . & a_{1n} \\ a_{21} & a_{22} & a_{23} & . & . & . & a_{2n} \\ . & . & . & . & . & . & . & . \\ a_{n1} & a_{n2} & a_{n3} & . & . & . & a_{nn} \end{array} \tag{2}$$

> This matrix is often referred to as the input-output coefficients matrix. Coefficient a_{ij} represents dollars worth of output from industry i per dollar output of industry j. An input-output coefficient is a technical coefficient if and only if the values in the rows are "import-ridden," that is, they represent the values of both domestic and imported row sector goods or services sold to the purchasing sectors. Import-ridden input-output accounts record imports as a final demand activity, whereas "import-purged" accounts record imports as a payments sector row. A technical coefficient represents technology in addition to a purchasing pattern.

We can now rewrite the inter-industry portion of the output equations as:

$$\begin{array}{ccccccccc} a_{11}X_1 & a_{12}X_2 & . & . & . & a_{1n}X_n \\ a_{21}X_1 & a_{22}X_2 & . & . & . & a_{2n}X_n \\ . & . & . & . & . & . & . & . & . \\ a_{n1}X1 & a_{n2}X_2 & . & . & . & a_{nn}X_n \end{array} \tag{3}$$

The products in this table, called the transactions table, are in dollar units since the X's are dollars and the a_{ij}'s are proportions. If we let A be the table of coefficients, then we can represent equation set 3 simply by AX. AX represents the sum of inter-industry transactions across each row. The set of equations that represents the disposition of each industry's output (equation set 1) can now be rewritten simply and parsimoniously as

$$AX + Y = X \tag{4}$$

The earlier equilibrium assumption and the above equation both indicate that the output equations must all be satisfied at the same time. It is appropriate, then, to consider the set of output equations as a "system of equations." Of what use is this system of equations?

The most common use of the system of input-output equations is the assessment of impacts of changes in final demand, or final demand *shocks*. Actually, almost any perturbation in regional economic activity can be modeled as a change in final demand. Military base closings, defense contracts, and other government expenditures are common examples of changes in final demand. Another example is that of a new firm locating in the region. We can often assume that the new firm has purchasing patterns similar to those of existing firms in the same industry. Therefore, the direct input requirements of the new firm, although they actually represent inter-industry demand, have the same effect on the accounting framework as if they were demands of external origin and could therefore be modeled as a final demand shock. In addition, the incomes generated by the new jobs associated with the new firm generate final demands for consumer goods (milk, bread, clothes, housing, etc.).[4]

> Establishing a production facility in a new industry in response to final demand increases also can increase local capacity that subsequently can be directed to satisfying intermediate and final demands that were previously imported. If local demands for products from this industry had previously been imported, then new, locally produced product can replace those imports, leading to an additional set of positive direct and indirect impacts on the regional economy.

When the activity in one industry increases, the demands placed on its suppliers also increase. These suppliers, in turn, need additional supplies to satisfy their new demands. Output produced by an industry to be delivered to final demand are called the direct impacts. The inputs needed for the initial increase in activity are referred to as the impacts of the first round of spending. The inputs necessary for the suppliers to increase their output levels are the second round impacts, the additional inputs needed by the suppliers' suppliers are the third round impacts, and so on. At some point, usually around the fourth or fifth round, the additional inputs necessary become very small. Certainly by the tenth or eleventh round, the additional impacts are negligible. Recalling that final demand is represented by Y, we could represent the change in final demand by ΔY and the direct and indirect impacts can be represented mathematically by

$$(I + A + A^2 + A^3 + \quad . \ . \ . \ . \ . \ .)\Delta Y \tag{5}$$

These impacts are the changes in gross output occasioned by ΔY and can be represented by ΔX. Recalling equation 4, we could also solve for ΔX by the following:

$$AX + Y = X \tag{6}$$
$$Y = X - AX \tag{7}$$
$$Y = (I - A)X \tag{8}$$
$$X = (I - A)^{-1}Y \tag{9}$$
$$or \Delta X = (I - A)^{-1}\Delta Y \tag{10}$$

[4] We will revisit the proper accounting of employment, income, and income induced consumption impacts below.

Since the equation is written in matrix notation, it is correct to use I, the identity matrix, in place of a one in the above equations. The symbol I is the matrix equivalent to a one in scalar algebra, hence $AI = A$. Also, $(I - A)^{-1}$ must be written in this form because matrix inversion is a more involved process than inverting a single value. In fact, given the two alternative approaches to finding ΔX, it is apparent that if both are correct (and they are), $(I - A)^{-1}$ must equal $(I + A + A^2 + A^3 + \quad . \ . \ . \ . \ .)$.

Equation 9 is a simple algebraic restatement of equation 6. Equation 10 is a difference equation, and with it we can detect the difference in gross output that will result from a difference in final demand. However, this formulation moves us away from the context of a set of mathematical identies and into the realm of behavioral modeling. This transformation comes as a result of making a behavioral assumption. In the input-output model, the assumption is that the relationships between inputs and outputs will remain constant over the ranges of output indicated and during the time period in which the impacts will work their way through the economic system.

The table denoted $(I - A)^{-1}$ is a table of coefficients in the same sense as the direct coefficients table. For convenience, let $B = (I - A)^{-1}$, and let $b_{ij} \in B$ ($\in$ is read as *is an element of*). This matrix is referred to as the Leontief inverse, the multiplier matrix, or simply the inverse matrix. Whereas the coefficients in the A matrix represent the direct input requirements coefficients per dollar of output, the coefficients in the B matrix represent the direct and indirect inputs required, over all rounds of spending, per dollar of final demand for the column industry. Coefficient b_{ij}, for example, represents the direct and indirect requirements for outputs from industry i needed to meet a one-unit change in final demand for output from industry j.

If we sum all of the coefficients in one column of the B matrix, the result will be the requirements for outputs from all row industries (the i's) that result from a unit change in final demand for the output from the column industry j. Since the column sum includes the direct impacts, it is equal to the ratio of direct and indirect impacts to direct impacts, and is called the output multiplier for industry j. The multipliers for each industry can be used as indicators of the importance of the industry to the economy. They indicate the degree of interdependence of the specific industry with the other industries in the economy. Multipliers are useful in impact assessments, for they represent a summary of the overall importance of a specific industrial activity.

To this point, we have treated households as though they are external to the processing system. Households also can be treated as an additional processing sector in the transactions table, providing further insights. The household row coefficients in such a table represent the dollars of income paid directly to households per dollar of output from the column industry, information that is available from the payments sector row. The household column, on the other hand, represents the dollars of each row industry's output consumed per dollar of household income. Adding households to the model is, in effect, expanding the inter*industry* portion of the accounts to include the household payments row and the consumption column of final demand.

By *endogenizing* the household sector in this way, we account for the income that is generated by payments to households and the for additional demand placed on industries by the income generated from indirect demands. The household sector is essentially treated as though it were an additional industry or processing sector. A table in which households are endogenous is referred to as *closed with respect to households*, and a Leontief inverse computed from such a table is called an *closed inverse*. Multipliers calculated from a closed IO table capture the direct, indirect, and *income induced* impacts on industrial sectors per unit change in final demand. This additional impact is often referred to as the *induced income* effect.

3 REGIONAL INPUT-OUTPUT MODELS

The discussion to this point has centered around a generic economy, but this generic economy has some specific attributes that should be made explicit. First, the economy described by the model above is assumed to be mostly self-sufficient. Imports are not expected to play a large role in the accounting framework. Were there no imports, the coefficients would represent purely technical relationships. Such a framework might best represent a highly developed national economy. Although they are increasingly interdependent, national economies, especially those of developed nations, have been less reliant on imports, historically, than their subnational counterparts.

This discussion introduces the concept of *openness* in regional economic analyses. An *open* economy is characterized by high levels of imports and exports, while a fully *closed* economy does not interact with the rest of the world. Hence, when we move from IO frameworks for nations to those for regions (regions will refer from this point on to subnational regions), it becomes important to consider the differences between the frameworks for closed and open regions.

3.1 Regional Coefficients

The most important distinction here is that the coefficients in the regional table (let R be the regional counterpart to A) are less likely to represent technical relationships. These new coefficients (r_{ij}'s) represent the trade relationships that an industry has with the rest of the regional economy. If a national industry does not purchase imports, the a_{ij} values are often taken to represent upper bounds to the corresponding r_{ij} values. When industry j in a region is sufficiently supplied by regional industry i, its r_{ij} coefficient will be equal to its national counterpart a_{ij}; no importing is necessary. We can offer a mathematical definition of the r_{ij} by defining a new variable denoted m_{ij}. The variable m_{ij} represents the outputs from industry i that must be imported to the region for a unit of output from industry j in the region. The mathematical relationship is

$$r_{ij} + m_{ij} = a_{ij} \tag{11}$$

The set of all r_{ij}'s is called the table of intraregional *trade* coefficients, and represents the intraregional, interindustrial, input-output coefficients. Each r_{ij} represents the dollars worth of output from local industry i per dollar output from local industry j.

> There can be exceptions to the general relationship between national technical coefficients and regional technical coefficients. In some cases, an industry may produce its product using a technology quite different from the national average technology. Therefore, a given r_{ij} can be larger than its corresponding a_{ij}. The national coefficient, however, is usually treated as a suitable upper bound for the kinds of analyses described here.

3.2 Tracking Cash Flows

Consider a regional table that distinguishes between a substate region, say an SMSA (Standard Metropolitan Statistical Area), the rest of a state, and the rest of the nation. Such a table might account for flows of inputs and outputs within and among the Chicago SMSA, the rest of Illinois, and the rest of the U.S. (C, I, and U, respectively). Graphically, the accounting framework can be represented as in Figure 3. In theory it is possible to track all of the flows in the U.S. (or any other) economy in such a fashion.

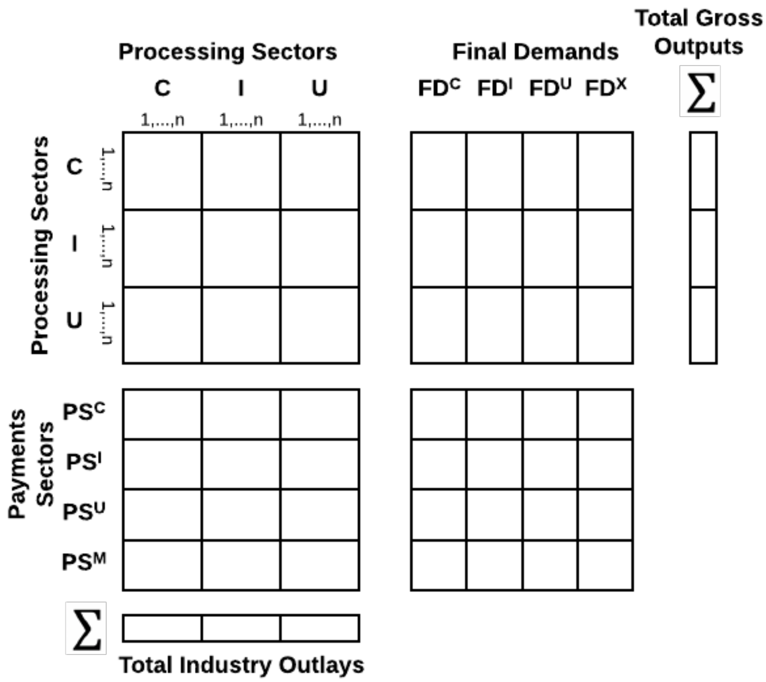

Figure 3: Multi-Regional Input-Output Accounting Framework

The second (upper left) quadrant of Figure 3 represents the inter-industry flows in the U.S., and draws a distinction between origins and destinations (C, I, U) of flows. The diagonal blocks $(C-C, I-I,$ and $U-U)$ represent intraregional interindustrial transactions, and the off-diagonal blocks $(C-I, C-U, I-C, I-U, U-C, U-I)$ represent interregional interindustrial transactions. The first quadrant (upper right) shows the disposition of output delivered to final demand. Note that final demand met by Chicago producers may be located in Chicago, elsewhere in Illinois, elsewhere in the U.S., or elsewhere in the world. The first three blocks in a final demand row (FD^C, FD^I, FD^U) do not include foreign exports (since Chicago, Illinois, and the rest of the U.S. are internal to the national economy); the last block (FD^X) includes only foreign exports.

Similarly, payments to nonindustry sectors may also be located in Chicago, elsewhere in Illinois, elsewhere in the U.S., or elsewhere in the world. A helpful example here is that of payments to governments (taxes) at various levels. The final row of the payments sector block, PS^M, includes all imports, payments to foreign governments, and payments to foreign households. The processing sectors in Figure 3 were divided into three geographical regions. A similar model can be formulated for multi-state regions, states, or even areas as small as Bureau of Economic Analysis (BEA) functional areas. The advantage of such a multiregional formulation is that it becomes possible to assess the impacts of a change in economic activity in one region on the economy of another. This information is often quite useful in evaluating the distributional impacts of area-specific projects funded by tax dollars from larger areas (for example, the impact on downstate Illinois of general revenue funds devoted to transportation projects in Chicago, or the impacts of national defense dollar expenditures in California on the Illinois economy).

3.3 Difficulties in Interregional Modeling

The drawback to the multi-regional formulation is the expense associated with collecting the necessary data. Rarely are such detailed accounts kept at the level of the establishment, and even the compilation of such a table even given a sufficiently large sample of data is no small task. Sales and purchases data require reconciliation, and numerous judgements must be made. (Some less-expensive non-survey methods for compiling regional and multi-regional tables exist; for a review, see (Round, 1983).[5]

Limiting a model to two-regions is a major simplification, conceptually, methodologically, and empirically (e.g., Chicago and the rest of the U.S.). In this formulation, four rather than nine blocks form the processing portion of the account. In addition, equation 11 becomes extremely helpful in the estimation of off-diagonal blocks ((Round, 1979)). This framework appears graphically in Figure 4. We will return to Figures 3 and 4 in later sections.

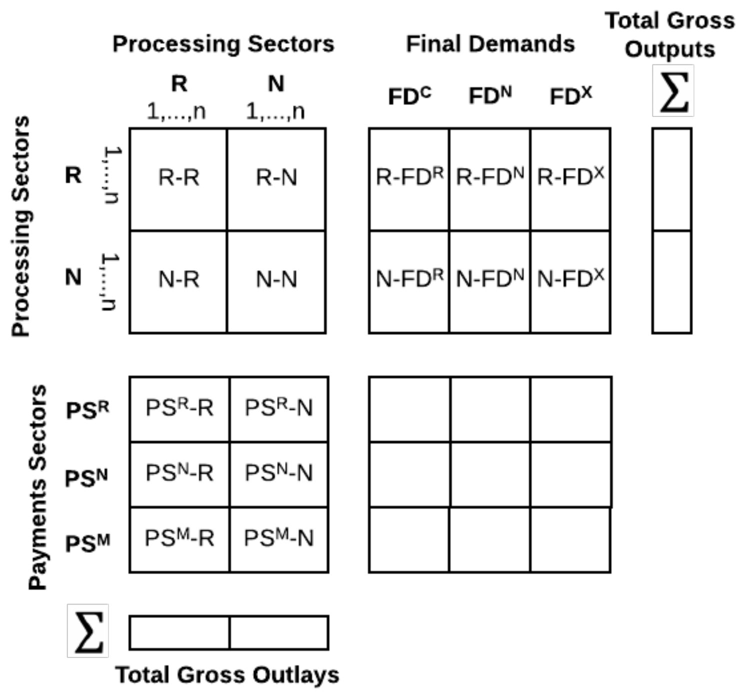

Figure 4: Two-Region Input-Output Accounting Framework

[5]Several approaches to estimating the parameters of multiregional IO tables have been developed and published since the initial publication of this document. Readers are encouraged to consult (Miller and Blair, 2009) for citations to such contributions, including (Jackson et al., 2006) and (Schwarm et al., 2006). (Jackson and Schwarm, 2011) provides a conceptual overview of various families of interregional accounting structures.

4 INDUSTRY TARGETING

Numerous attempts have been made to identify those industries that have the greatest potential benefit for a regional economy. These efforts fall under the broad heading of industry targeting, which involves identifying industries that, for any number of reasons, might be ideally suited to contribute to the socioeconomic health of a region. This identification process can form the basis for industrial recruitment or retention programs and policies.

The philosophical bases upon which these targeting projects are undertaken vary somewhat, ranging from labor force orientations to inter-industry relationships to infrastructural advantages. Since the regional input-output framework details intraregional, interindustrial relationships, it offers a number of advantages and insights into the targeting process. The three main input-output contributions to targeting fall into the following categories:

1. measuring import substitution potential
2. analyzing of multipliers
3. identifying key sectors

4.1 Import Substitution Potential

The idea behind import substitution potential (ISP) is that if locally produced goods are substituted for goods that were previously imported (either from the rest of a larger subnational region or from the rest of the nation or from some other nation), a number of benefits will accrue to the region. First, fewer dollars leave the regional boundaries. This results in higher levels of intermediate demand and local personal consumption. Second, the addition to regional employment associated with the local production activity can reduce regional unemployment, ease local welfare rolls, and lessen the local tax burden. These direct employment impacts further enhance local consumption by replacing small transfer payments with larger wages and salaries. Totally new employment in the form of inmigrants can also increase local consumption induced multiplier effects (multipliers will be treated in more detail in later sections). Third, provided that tax exemption is not granted to the new establishment as a recruitment incentive, local business, operating, and property taxes are enhanced. Finally, the introduction of the new production activity will have indirect and induced income effects on the regional economy in the form of increased demand for necessary inputs into the production process, increased labor necessary to meet these increased demands, wages and salaries that accompany the indirect labor increases, still greater levels of local consumption, and so on.

The key to identifying industries with high ISP lies in evaluating the relationship between levels of local supply and local demand. If the ratio of the former to the latter is greater than one, the implication is that the industry engages in export activity. If the same ratio is less than one, the industry is said to be undersupplied locally, and ISP exists. How might we use a regional input-output table to assess this under- or over-supply condition?

First, recall from equation 11 that the regional input-output coefficient for an industry (r_{ij}) is equal to its national counterpart (a_{ij}) minus an import coefficient (m_{ij}). Since we are evaluating the supply of output from industry i to consuming industry j, it is possible to evaluate the supplying industry i with respect to all consuming industries, $j = 1, \ldots, n$, by summing the difference between the regional coefficients and their national counterparts across row i, or

$$\sum_{j=1}^{n}(a_{ij} - r_{ij}) = \sum_{j=1}^{n} m_{ij} \tag{12}$$

for any industry i. (The symbol Σ(sigma) is used to indicate the sum of what follows when the subscript is varied from what is below to what is above the symbol.)

Alternatively, if the total output for all regional industries is known, the level of supply deficiency (ISP) for an industry in terms of output dollars can be found by summing the products of all m_{ij}'s $(a_{ij} - r_{ij})$ and regional industrial outputs, Xj's, or

$$ISP_i = \sum_{j=1}^{n}(m_{ij}X_j) \tag{13}$$

In practice of course, an analysis of the results from equations 12 and 13 would not be used in isolation. Average plant sizes by industry (in terms of output dollars), minimum efficient scales, employment and occupational structures, value added, service requirements (water, sewer, electricity, etc.), and other industry attributes, including environmental considerations, should all be considered. ISP is but one of many factors that enter into the industrial targeting decision. We will return to import substitution at the conclusion of a brief section on multiplier analysis.

4.2 Multiplier Analysis

Industrial multipliers are among the most often used summary measures obtained from IO analysis. An industry output multiplier measures the dollar value of output in the entire regional economy needed to meet the input requirements of all industries to deliver one dollar of output from the column industry to final demand. A row multiplier calculated from the Leontief inverse matrix represents the dollar value of output required from the row industry to meet the input requirements of all industries to deliver one dollar of output from each regional industry to final demand.

4.2.1 Income Accounting Analogy

To clarify the multiplier concept, consider the following relationships drawn from national income accounting models. Let gross regional income (Y) equal local consumption (C) plus investments (I) and exports (X), minus import consumption (M). In equation form,

$$Y = C + I + X - M \tag{14}$$

If we assume that consumption and imports of income are fixed shares of income, represented by c and m, then

$$C = cY \tag{15}$$

$$M = mY \tag{16}$$

where $0 < c, m < 1.0$. We can substitute cY and mY into equation 14 to obtain

$$Y = cY + I + X + mY \tag{17}$$
$$Y = (c - m)Y + I + X \tag{18}$$
$$1 - (c - m)Y = I + X \tag{19}$$
$$Y = (1 - c + m)^{-1}(I + X) \tag{20}$$
$$\tag{21}$$

The interpretation is that every unit increase in $(X + I)$ increases gross regional income by the proportion

$$(1 - c + m)^{-1} \tag{22}$$

This proportion is known as a system multiplier for the region. Because m is in the denominator of the equation, the multiplier decreases with increases in imports and increases as imports decline and the region becomes less open. The multiplier increases reflect greater regional self-sufficiency and reductions in leakages from the regional economy. Likewise, increasing values of c increase the system multiplier. Hence, replacing consumption from imports with consumption from local production will increase the magnitude of economic impacts of changes in investment or exports.

4.2.2 Regional Industrial Multipliers

The regional counterpart to equation 10, from which national industrial multipliers were derived, is

$$X = (I - R)^{-1}Y \tag{23}$$

where X = gross regional output and Y is regional final demand. Let $B = (I - R)^{-1}$. The column sums of B are the intra-regional industrial multipliers for region R. A large multiplier for a given industry indicates an especially strong backward linkage from the specific industry. Backward linkages are the purchasing relationships one industry has with all others and the extent to which first round purchases stimulate additional purchases and rounds of spending. An industry whose multiplier is large at the national level may have a low regional multiplier if that industry's suppliers are absent from the region.

In Figure 4, the $R - R$ block corresponds to the regional table R in equation 23. Notice that in equation 23, Y corresponds not only to those final demands that are met by the region $(R - FD^R, R - FD^N, R - FD^X)$ but also to the elements of the $R - N$ block since these become exports with respect to region R. Import substitution effectively reduces the size of the m_{ij}'s for R (elements in the $N - R$ and/or payments sector blocks), increasing the size of the r_{ij}'s. Given the ratio $(1 - k)^{-1}$ (or $1/(1 - k)$), if $0 < k < 1$, increasing k increases the value of the ratio. Although matrix inversion is much more complicated than a simple ratio, increasing the values in R (the r_{ij}'s) will increase the values in $B = (I - R)^{-1}$. Therefore, as with the national income accounting example, import substitution will increase the industrial multipliers for the region, provided either the household sector is included in the model or the new establishment purchases and/or sells within the region.

4.3 Digression on IO Models as Economic Maps

It might be helpful to envision the processing sector partition of the IO framework as a special kind of economic map. The three blocks on the diagonal of this partition in Figure 3 represent economic interaction that does not cross regional boundaries. The off-diagonal blocks represent interactions that do cross regional boundaries. Interactions, of course, refer to interindustrial flows of goods and services in one direction, and monetary flows in the other. What makes one map different from another?

If two economic regions had the same proportion of each industry and had equivalent export-import relationships, their corresponding IO maps would be almost indistinguishable. There could still be some variation due to differing wage rates, price differentials, slightly different production technologies, or transportation-oriented materials and market advantages. If all of these factors could somehow be equalized, however, we would expect no differences between the two IO maps.

We know, though, that regions never have the same mix of industries, and that the other factors mentioned can never be equalized. From equation 11, we can infer that the self-sufficient nation will have an IO map that is a standard with which regional IO maps can be compared. The more closely a region resembles the nation as a whole in terms of its industry mix and its other factors, the less difference will be observed between the regional and national map. We can also conclude from equation 11 that over-concentration in an industry in a region will be less likely to cause map differences than will under-concentration. Hence, if we believe that the national standard map is a desirable one, we should strive for at least the self-supply levels of activity by industry exhibited by the nation. We would want to increase the self-sufficiency of the region. The effect would be to increase the values in R, which will in turn increase the multiplier ratios for the region.

4.4 Zero Sum Games?

Returning to Figure 2, however, a potential problem surfaces. If in the process of pursuing industries for import substitution purposes, Chicago succeeds only in attracting an establishment that was formerly located elsewhere in Illinois, Chicago's map may move closer to the standard, but the overall Illinois map will remain the same. Chicago may effectively gain at the expense of the remainder of the state. Some benefit to the state may still accrue, especially if the Chicago location represents a more rational and economically profitable location for the activity. However, these state-wide benefits may not be seen as important by the newly unemployed downstate worker.

The IO model–map analogy is useful for considering the variety of implications of economic development programs. Different regions benefit to varying degrees from the implementation of almost any development policy. The scenario above could, for example, easily be extended to assess interstate competition for national industry. The purpose of these examples is to emphasize the uneven distribution of regional policy impacts. One region's gain is often another region's loss. Gains and losses also can occur within regional boundaries (as in the Illinois- Chicago example). Practitioners should continually be alert to the distributional impacts of policies and programs.

The combination of information from multiplier analyses and ISP identification represents a valuable tool for those concerned with regional economic development. If for example, a regional analysis reveals a large multiplier for a specific industry coupled with a high potential for import substitution, then that industry is a strong candidate for further analysis. If the industry fits well in terms of labor force requirements, suitable sources for input factors, environmental considerations, comparative advantages, infrastructure, and regional policy goals, then successful targeting for recruitment has been accomplished, and policies can be formulated to encourage activities in that industry.

Although industry targeting for retention does not rely on ISP identification per se, supply-demand relationships for those industries threatening to leave the region can be very helpful in the policy process. Input-output analysis also can be of great value in this context. Multiplier analysis as described above is equally applicable, if not more so, to targeting for retention.

Whereas the direct impacts on jobs and income of establishment leaving a region may be very easy to estimate, the indirect impacts of such changes are seldom as simple to assess. Industrial multipliers indicate, among other things, the degree to which industries are integrated with the rest of the economy or the importance of an industry as a purchaser of regional output. This discussion relates more strongly, however, to the area of input-output impact assessments, which will be covered in greater detail in a later section.

4.5 Alternative Methods for Key Sector Identification

A number of other input-output-based methods for identifying key sectors exist. Many of these are quite complex and will not be reviewed here. A full review of literature pertaining to this issue may be found in (Hewings, 1982).[6] Indeed, the remainder of this section draws heavily on the Hewings review.

Key sectors are defined as those industrial sectors that exercise, through purchases and sales linkages, a greater than average impact on the economy. Rasmussen (1956) proposed two indices that have gained general acceptance as measures for key sector identification. These are the power of dispersion, U_j, and the sensitivity of dispersion, U_i. These measures are based on the Leontief inverse matrix, B, as discussed above, and are calculated as follows:

$$U_j = (b_{.j}/n)/b \tag{24}$$

and

$$U_i = (b_{i.}/n)/b \tag{25}$$

where $b_{i.}$ and $b_{.j}$ represent the row and column sums over n industries, and b is the average value from the inverse table. The power of dispersion is the ratio of the average direct and indirect coefficient from column j to the average direct and indirect coefficient in the table. When this ratio is greater than one, a unit change in final demand for the column industry will generate a greater than average change in activity in the economy.

The sensitivity of dispersion is a similar ratio relating the average row value to the average table value. Rows for which this index is greater than one will experience greater than average increases from a unit change in final demand in all sectors.

Since these first measures ignore the possibility of unequal variation in coefficients among rows or columns, Hazari (1970) proposed the coefficient of variation as an alternative. The analagous indices are then

$$V_j = o_j/b_j \tag{26}$$

and

$$V_i = o_i/b_i \tag{27}$$

where o_i and o_j are row and column standard deviations, and b_i and b_j are row and column averages.

There are other alternatives. Hazari (1970) suggested weighting the row or column sums according to policy preferences for a given region. These weights could be sectoral final demands, regional

[6]Again, since the original publication of this piece, numerous contributions to key sector analysis can be found in the literature.

sectoral outputs, sectoral employment levels, income to output ratios, or others. The weighting of the coefficients places differing emphases on each sector in accordance with the level and desirability of activity in each. A large multiplier when applied to a small absolute change may not yield significant magnitudes, whereas smaller multipliers associated with high absolute levels of activity may yield large impacts in terms of output, employment, or income.

A number of students of industrial structure have noted difficulties associated with the measures presented above. A major objection concerns the use of the rows of the inverse matrix to measure forward linkages when, in fact, the direct and indirect coefficients are more strongly related to backward linkages. For this reason, one might wish to focus attention primarily on the column indices. Finally, it is important to bear in mind that each of the measures presented in this section represents a single piece of information. Only when taken together do the pieces prove useful in aiding the industrial targeting process.

4.6 Caveats

The major pitfalls in applying input-output-related methods of industry targeting relate directly to the accounting framework itself. The relationships displayed in an input-output table are a snapshot: a static picture of an economy's interrelationships. As such, the table gives no indication of what interrelationships will exist after the targeted industries have been recruited.

A given measure can indicate sectors for targeting that currently supply an amount equal to all that is (or will ever be) demanded by local producers and consumers.. Introducing such a production activity will then lead to an oversupply condition. The newer establishment could be expected to employ more current technologies and could conceivably force the older establishments out of the market. It would certainly be impolitic to promote new activities at the expense of existing ones. The importance of a concurrent analysis of sectoral supply/demand conditions and the use of professional judgment cannot be overstated.

5 IMPACT ANALYSIS - MULTIPLIERS

The most common use for the input-output analysis framework is assessing the economic impacts of changes in final demand. The set of final demand activities includes personal consumption expenditures, exports, inventory increases, imports (-), investment, and government expenditures at various political levels. The application of input-output impact analysis to government expenditures is perhaps the most common. Policy decisions almost always involve the distribution of public funds among various locations and industrial sectors in the economy.

As an illustrative example at the national level, consider the disposition of federal defense dollars across the United States. Suppose a decision has been made to increase the production of cargo aircraft. Likely candidates for directly generated activity are Texas (Lockheed), Washington (Boeing), and California (numerous aircraft manufacturers, including the above). Clearly, the distribution of direct impacts of the defense decision is geographically uneven. The distribution of indirect impacts is even less apparent.

Given the importance of income-induced impacts, those regions directly affected stand to gain the most from this policy decision. A number of other interindustrial relationships may help to spread the impacts sectoraly and geographically. Machine tools industry activity, perhaps in the Chicago area, may ultimately be increased. Financial institutions in Chicago or New York may also benefit. Iron and steel may be supplied from Gary, Indiana. Iron ore may originate from Michigan's Upper Peninsula. Coal to fire the furnaces may come from Colorado, and each state may ultimately benefit to some extent from the policy decision. Clearly, however, all states will not benefit equally. Repercussions of this one expenditure may have dramatic impacts on the national distribution of income and regional economic health and performance.

A more localized example concerns a state-level decision, perhaps with respect to rehabilitation or expansion of a transportation route. Consider an infusion of highway development funds.

The construction dollar expenditures will be distributed among paving and asphalt, concrete, gravel, mining, fabricated metals, iron and steel, machinery, heavy equipment, and other industries. Since these activities are not distributed evenly across the state, the direct impacts will likewise be unevenly distributed. Further, given the various industrial mixes in different regions of the state, these regions will benefit unevenly from the transportation project. Regional and inter-regional input-output models are ideal tools for evaluating these types of impacts at the local level.

One of the key concepts in impact analysis is the sectoral (industrial) multiplier as discussed briefly above. These multipliers represent summary measures of impacts generated by specific changes in final demand. Given the importance of the multiplier concept, the remainder of this section is devoted to a discussion of multipliers.

5.1 Output Multipliers

To this point, the discussion of multipliers has been framed in terms of output dollars. An increase of one million dollars of final demand for a sector with a column output multiplier of 1.5, for example, would generate one and one half million dollars of output over all sectors in the economy (including the original one million). At least two major types of multipliers can be distinguished.

> The literature, in fact, discusses more than just two types of multipliers. The others are formed by treating households in different ways, and by endogenizing other activities. The broadest distinction, however, is between multipliers based household endogenous and household exogenous input-output models.

The Type I multiplier is computed from the Leontief inverse based on a table of input-output coefficients that excludes the household sector (row and column). Type I multipliers are the ratios of direct and indirect changes to direct changes, calculated from an *open* input-output table. The Type I multiplier for an industry is the sum of the values in the column of the Leontief inverse corresponding to that industry.

The Type II multiplier, on the other hand, is derived from a coefficient table that includes an endogenous household row and column. Households are now treated as processing sectors with respect to the modeling framework. Labor is moved from an external payments sector to processing, and personal consumption expenditures likewise become internal to the model. The effect of this transfer is in some respects similar to that of import substitution. An activity that formerly was treated as exogenous to the processing sectors now becomes an endogenous sector with important intersectoral feedbacks. As a result, the multipliers would be expected to increase, as was the case with import substitution. The Type II output multiplier is calculated by summing the elements of a column of the new, expanded *closed* Leontief inverse table.

5.2 Income Multipliers

Just as final demands generate direct and indirect output changes, they generate direct and indirect income associated with the production of that output. Type I income multipliers are ratios of direct and indirect income change to direct income change, and Type II income multipliers are analogous to Type II output multipliers. The calculation of income multipliers, however, requires extra computational steps.

The direct change in income is the same for both types of income multipliers. This direct change in income for an industry is the value in the household row of the direct coefficients matrix (closed with respect to households) that corresponds to that industry. Because increasing the output in one industry requires increased output from others, income in other sectors also will increase. When computing indirect or indirect and induced income, we must include increased income from all sectors in the calculations.

Recalling that each element in the inverse matrix represents the direct and indirect dollars worth of output needed from the row sector for a one-unit change in final demand for the column industry's output, direct and indirect income change can be calculated by summing the products of each column value and its corresponding household row coefficient (hh_i). Mathematically, direct and indirect income generated equals

$$\sum_{i=1}^{n}(b_{ij})(hh_i) \tag{28}$$

for any industry j. Hence, dividing this sum by the household row coefficient for industry j (hh_j) yields the Type I income multiplier.

The Type II income multiplier is simpler to find and has the advantage of including, over and above the Type I effects, the impacts on the economy of increased consumer spending. Since the household row of the Leontief inverse matrix (closed with respect to households) is treated as a processing sector, its values reflect the direct, indirect, and induced changes in income given changes in corresponding column industries. All that remains for the derivation of Type II income multipliers is to divide each value in the row by its corresponding value in the row of direct coefficients.

5.3 Employment Multipliers

A number of methods can be used to calculate employment multipliers. The most straightforward of these is to make the assumption that for each industry, output and employment are proportional. The proportions vary across industries since industries vary in labor intensities. If this were not the case, output and employment multipliers would be proportional. Since the proportions do vary, we must define employment coefficients in units of, for example, full-time equivalents (FTEs) per dollar output. Multiplying these coefficients by direct and indirect or direct, indirect, and induced changes in output dollars will result in direct and indirect or direct, indirect, and induced FTE's.

Given the employment coefficients for each industry, the first step in finding an employment multiplier for industry j is summing the products of the elements in column j of the inverse table and their corresponding employment coefficients (FTE_i). Mathematically, we have

$$\sum_{i=1}^{n}(b_{ij})FTE_i \tag{29}$$

When this value is divided by the direct employment change in an industry, the Type I or Type II multiplier is obtained (depending on which inverse table has been used).

5.4 Caveats

These summary measures concerning total output, employment, and income impacts of changes in economic activity can be used to provide valuable information to the policy decision maker. The implications of changing employment and income levels for a region vary widely. The industrial sector can benefit from an advance look at future output requirements. The commercial sector can benefit through increased information concerning probable consumption activities. Public sector agencies can benefit by using the impacts assessments for planning purposes.

The measures are not perfect, and errors will always be present. Each measure rests on assumptions concerning behavior in the economy that are, to greater or lesser extents, unrealistic. Employment, for example, would rarely be expected to be perfectly proportionate to output over all scales of production. Labor can be intensified (e.g., speeding up production lines), overtime practices can be instituted, and machinery may be added or utilized more fully. The income effects of these alternatives will all be different. A similar argument applies to all Type II multipliers, since consumption coefficients imply that constant proportions of income are used for consumption. Consumption coefficients (actually average propensities to consume) vary according to attributes such as income, age, sex, and family composition of wage earners, so different demographic structures will affect impacts.

Although the summary measures are not error free, we should not discount their utility for planning. The income, employment, and output multipliers provide valuable information for both the public and private sectors. Alternatives to input-output multipliers are aggregate multipliers of the Keynesian macroeconomic type or the simpler economic base type. Although these aggregate multipliers have their utility, they do not indicate how the impacts work themselves out through the various sectors of the economy. This is one major advantage of the input-output modeling framework and represents a significant step toward an understanding of the interaction among activities in and among regional economies.

6 SUBREGIONAL APPLICATIONS

Subregional applications of IO models become an issue when communities that are integrally tied to larger economic areas are confronted with the need to assess the local impacts ofprojected changes in economic activity. Since the IO map for a community will undoubtedly differ from that of the base region, the results of an IO analysis for the base region must be tempered by an understanding of the role of the community in the economic region. Before moving to a discussion of methods, a few words should be said about the selection of regional boundaries for IO models.

The section on regional versus national input-output models pointed out that the primary distinction between the two lies in the degree of openness of an economy. There are two major reasons for attempting to define boundaries in such a way as to close the region as much as possible. The first has to do with the area in which the strength of the framework actually lies: representing inter-industry interactions. When regions are delineated without regard to openness, many important details concerning inter-industry flows are lost. Import-supplying industries are all (usually) lumped together and treated as one sector, and the same is true for export-consuming industries. If these industries have strong ties – feedback effects – the local economy, multipliers will be underestimated due to second, third, and further rounds of interaction being inappropriately excluded from model consideration. Ideally then, a region should be defined to incorporate as much inter-industry interaction as possible. This is equivalent to the goal of defining as closed a region as possible.

The second reason for closing a region for modeling relates to the planning process. For planning purposes, it is essential to take a holistic view of the region under analysis. It would make very little sense, for example, to plan for the development of the west side of a city without regard to the east. A host of public services could extend over the imposed boundary, including city streets, school districts, sewer districts, and others. Since the city is a functional unit with a host of interrelated characteristics, it makes more sense to treat it as a unified system than to arbitrarily split it.

In practice, other considerations influence the definition of regional boundaries. Foremost among these is the availability of data. The most reliable data for generating a regional IO table come from a survey of regional business establishments. This can be a very expensive data collection process, however, so it is quite often supplemented or even replaced by other, nonsurvey estimation techniques. These nonsurvey methods are most often based on published data that are uniformly available at no lower than the county level. Hence, counties typically form the lowest-level building blocks for input-output models.

Very few counties can reasonably be assumed to stand alone as functional economic units. Many, if not most, governmental agencies recognize that the appropriate level for data reporting and analysis is above the county. Bureau of Economic Analysis (BEA) areas, Bureau of Labor Statistics (BLS) areas, and Standard Metropolitan Statistical Areas (SMSA's) are all good examples. The Chicago SMSA, for example, includes not only Cook, but Lake, McHenry, Kane, DuPage, and Will Counties as well. The BEA includes several Indiana counties in its Chicago-based area, as does the BLS. The activities in these multi-county areas are so intertwined that to analyze them in isolation makes little sense. At the very least, subregional analyses and forecasts should be consistent with base-region studies. In most instances, this argues for defining a functional region as small yet as rationally as possible, performing the desired analyses, then apportioning the results to subregional areas.

In the absence of additional information, the most straightforward method for adapting regional-level model results to subregional areas is a proportional allocation. Ideally, impacts (or forecasts) for each industry would be scaled according to the weight of that industry in the subregion. Contribution to total employment by industry is one such weight. If we let e_i and E_i equal employment in industry i in the subregion and region respectively, then e_i/E_i is the weight for the local industry and regional impacts would be scaled accordingly as

$$(e_i/E_i)\Delta E_i \tag{30}$$

where ΔE_i is the change in regional activity in industry i.

Using this method assumes that industrial impacts will be spread proportionately across all of the establishments in that industry in the region. Large establishments will experience larger absolute increases in activity than will small establishments. When that local practitioners have better information, it is often possible to revise estimated sub-regional impacts upward or downward. When less specific additional information is available, it may be desirable to specify ranges of possible impacts. One way to accomplish this is to specify a "best case and worst case" scenario for each industry in the impact assessment.

As an example, we might have reason to believe that a certain industry will grow faster in the subregion than it will in the remainder of the region. If industry i is expected to grow 20% faster locally, we can alter equation 33 to reflect this as follows:

$$(1 + LA_i)(e_i/E_i)\Delta E_i \tag{31}$$

LA_i denotes the local advantage observed for industry i, in this case $LA_i = .2$. Note that if LA_i is positive for the subregion, it is negative for the rest of the region. If more than one subregion is included in the apportionment process, the sum of LA_i over all regions must equal zero in order to be consistent with the regional analysis.

In practice, subregions at lower than the county level are faced with shortages of published data. If data collection by survey is deemed too costly for a concerned agency, other more intuitive and less exact methods must be used. One alternative to abandoning the effort is to use population statistics, which generally are more readily available to assist in the apportionment process. If this method is chosen, only the aggregate forecasts should be apportioned, unless population data are industry-specific. Another alternative is to employ the minimum requirements approach to estimating export employment and use the simpler, economic-base, modeling framework. (For a good treatment of economic base models, see (Bendavid-Val, 1983); for a comparison of economic base and input-output models, see (Romanoff, 1974))

7 RELATED ISSUES

7.1 Impact Analysis Considerations

The way in which impacts of activity level change are assessed is directly related to the type of change that occurs. To this point, the discussion has centered around changes in final demand, *per se*. Other changes might include the introduction of a new establishment to an area, the loss of an establishment from an area, and the expansion of an existing establishment's level of activity. Each of these situations requires different treatments within the IO framework.

Recall from Figure 2 that changes in final demand can originate from several regional sources. Final demands can be estimated locally at the state level or at the national or international levels. Demands for exports, for example, originate internationally and will be partly filled by the rest of the nation, partly by the rest of the state, and finally by the region itself. Within the diagrammed framework the levels of export demand for each industry filled by each region are detailed. Therefore, it is possible to calculate proportions of export demand filled by the region. When changes in export demand are forecasted, the impacts of that portion filled by the local region can be assessed.

Similarly, regional shares of national and state-level final demand can be calculated and applied to changes in the respective final demands. If additional information becomes available, it can be used to scale the effective final demand (that portion to which the region will respond) upward or downward.

In the case of new, exiting, or expanding establishments, several points should be considered. If the region under analysis is large and has numerous establishments in the sector being effected, the impacts method typically used is fairly straightforward. Since the multipliers are based on input to output ratios rather than actual dollar flows, it is usually assumed that the ratios will remain constant. The dollar output that is accounted for by the new or old establishment or that corresponds to an expansion or contraction in activity is treated as though it were actually final demand. The idea is that the coefficients that previously applied will continue to apply since the framework is industry based and not establishment based. Also, since supply and demand for output from industries are defined as equal, an increase in final demand generates a direct increase in the supply of an industry's output equal to the change in final demand. The same holds true for decreases.

However, increases in production resulting from expansion can have an impact on the economy very different from those that result from a new establishment. In the former case, the only changes may be in the form of hiring a few extra employees and utilizing existing equipment more fully. The income associated with the additional production labor may be only slightly higher than the welfare payments formerly received. The consumption impacts then stem only from the addition to personal income, not from the total income associated with that job.

In contrast, the start-up of a totally new establishment will not only require more production workers, but will also require additional equipment purchases and even buildings (which will stimulate construction activity, building materials production, employment, income, consumption, and so on). Increases in administrative and managerial employment also will accompany the new operation. These occupations may well have greater impacts on a local economy since they are often higher paying positions. The levels and distributions of occupational impacts may be very different for new and expanding establishments (the same ideas hold true in reverse for the distinction between contracting and closing establishments).

There is another point that should be raised concerning jobs that are filled by the local labor force and those that are filled by importing labor. Jobs filled by the local labor force represent increments to local income of greater or lesser amounts. These jobs may go to unemployed not on welfare, unemployed receiving welfare (*transfer*) payments, or persons already employed in the same or other occupations. The income increments for each would be expected to be different. Likewise, the effect on government spending will vary accordingly. In every case, though, the regional income change is incremental only. Persons filling the jobs very likely already have places of residence in the region, and have established consumption patterns (consumption *levels* would be expected to change more than the consumption *patterns*).

Imported labor, on the other hand, represents totally new regional income, totally new consumption patterns and levels of consumption. The income-induced impacts of a job filled by external labor can be expected to be greater than the impacts of a job filled by a previous resident. This point is underscored when the impact of a new family on the housing market and on public service provision is considered.

All of this is not intended to represent a preference for new over expanded activities, or local versus external hiring practices. Rather, the intent is to emphasize that the impacts estimated through the input-output modeling framework are based on average industrial relationships, and this should be borne in mind when impact assessments are conducted, results assessed, and interpretations and policy recommendations offered.

7.2 Placing a Dollar Value on an Additional Job

The ability of the input-output modeling framework to capture inter-relatedness among industries in a region makes possible a very interesting perspective on the value of labor in the production process. The marketplace interpretation of the value of a job is that wages reflect worth. With the IO framework, it becomes possible to assess not only the direct wages for one employee, but also the direct and indirect value generated by that employee's participation in the production process.

If we accept the average relationships represented in the IO model, each employee is responsible for a certain number of units of output. For each industry, it is possible to determine the average output per employee ratio. If, for the electrical equipment industry this ratio were $50,000/1, then to each employee in that industry would be attributed $50,000 worth of output. We could then specify a $50,000 change in final demand for electrical equipment to determine the direct and indirect value added over all industries that results from generating the output needed to meet the final demand change change. The sum of all these dollar values over all industries is a measure of the direct and indirect value of an employee to a region, or the value to the region of an additional job in that industry.

This method could be employed for each industry and could give planners additional insight into the role played by employment in each industry in a region. Care must be taken in interpreting this kind of information, however. No one employee actually represents the "average employee" for the industry, because administrative, managerial, and production workers are all lumped together to determine the output-per-employee ratio. Given the need for all types of occupations in a production activity, it is impossible to compute such a ratio for a specific occupation. Still, this alternative perspective yields added insight to the integration of all

Value added is so named because it refers to the value that is added in the production process. If we buy $9M worth of inputs to produce $10M of output, we have added $1M of value to the product in the production process. Some of this value added will be converted to wages and salaries, some to profits, and so on.

economic activities and the importance of considering indirect relationships in an economic system.

8 SUMMARY

This monograph began with the supposition that the input-output modeling framework can provide the planning practioner with a number of insights into the inter-industry interrelationships that exist in an economy, and with a number of tools that can be used for impact analysis and industrial targeting. The treatment of these issues and methods was intentionally non-technical, with the objective of generating an intuitive appreciation of what input-output modeling is and how it can be used.

This presentation has been simplified, and no claim is made for a comprehensive treatment. Other authors have done an excellent job of treating the strengths and limiting assumptions of input-output models more fully. Among the earliest and most often cited of these is (Miernyk, 1965). Other excellent treatments of input-output modeling can be found in (Hewings, 1977, 1985), (Miller and Blair, 1985), and (Richardson, 1972). The serious student of input-output analysis will have no difficulty identifying pertinent literature.

APPENDIX A: SYMBOLIC NOTATION

X	-	gross output
X_i	-	gross output for industry i
Y	-	final demand (consumption)
Y_i	-	final demand for industry i
x_{ij}	-	intermediate output (sold from industry i to industry j)
n	-	number of industries used in a particular industrial classification scheme
a_{ij}	-	dollars worth of output directly required from industry i to produce one dollar of output in industry $j (a_{ij} = x_{ij}/X_j)$
A	-	table (or matrix) of all input-output coefficients (a_{ij}'s)
dX or dY	-	a change in gross output or final demand
$B = (I - A)^{-1}$	-	the inverse of the coefficient matrix subtracted from the identity matrix (I), often called the Leontief inverse
I	-	the identity matrix – ones in diagonal positions, zeros elsewhere
b_{ij}	-	entries in B corresponding to entries (a_{ij}) in A. b_{ij} equals the dollars worth of output directly and indirectly required from industry i to deliver one dollar of industry j output to final demand
R	-	a table of regional input-output coefficients, r_{ij}'s
r_{ij}	-	dollars worth of output from industry i in a region used in the production of one dollar of output in regional industry j
m_{ij}	-	dollars worth of output from industry i in other regions used in the production of $1 of output in regional industry j
C, I, U	-	the Chicago SMSA, the rest of Illinois, and the rest of the nation
FD^C, FD^I, FD^U	-	final demand in the above named regions
FD^X	-	export sector of final demand
PS^C, PS^I, PS^U, PS^M	-	payments sectors in C, I, U, and in the rest of the world
Σ	-	symbol used to denote a summation
ISP_i	-	import substitution potential for regional industry i
Y	-	(in the multiplier analysis section only) gross regional income
C	-	local consumption
M	-	import consumption
X	-	exports
I	-	investment in national income accounting
C	-	consumption in national income accounting
c	-	consumption share of income
m	-	import share of income
R	-	region R
N	-	rest of nation
k	-	arbitrary constant between zero and one
U_j	-	power of dispersion
U_i	-	sensitivity of dispersion
$B_{.j}$	-	jth column sum of Leontief inverse
$B_{i.}$	-	ith row sum of Leontief inverse _
B	-	average value of b_{ij} in Leontief inverse
V_j, V_i	-	coefficients of variation corresponding to U_j and U_i
i, j	-	ith row and jth column standard deviations from Leontief inverse
$\bar{b}_i, \bar{b}_j$	-	ith row and jth column averages from Leontief inverse

hh_i	-	household row coefficient. Labor's input share for industry i
FTE_i	-	full-time equivalents per dollar of output in industry i
e_i, E_i	-	employment in industry i in the sub-region and in the base region
LA_i	-	local advantage for industry i

References

Bendavid-Val, A. (1983). *Regional and local economic analysis for practitioners.* Praeger, New York, NY, new and expanded edition.

Hazari, B. R. (1970). Empirical identification of key sectors in Indian economy. *Review of Economics and Statistics*, 52(3):301–305.

Hewings, G. (1977). *Regional Industrial analysis and development.* The Field of Geography. Methuen, London.

Hewings, G. (1985). *Regional input-output analysis.* Scientific Geography Series. Sage Publications, Beverly Hills.

Hewings, G. J. D. (1982). The empirical identification of key sectors in an economy - a regional perspective. *Developing Economies*, 20(2):173–195.

Jackson, R. W. and Schwarm, W. R. (2011). Accounting foundations for interregional commodity-by-industry input-output models. *Letters in Spatial and Resource Sciences*, 4(3):187.

Jackson, R. W., Schwarm, W. R., Okuyama, Y., and Islam, S. (2006). A method for constructing commodity by industry flow matrices. *The Annals of Regional Science*, 40(4):909–920.

Miernyk, W. H. (1965). *The elements of input-output analysis.* Random House, New York,.

Miller, R. E. and Blair, P. D. (1985). *Input-output analysis : foundations and extensions.* Prentice-Hall, Englewood Cliffs, N.J.

Miller, R. E. and Blair, P. D. (2009). *Input-output analysis: foundations and extensions.* Cambridge university press.

Rasmussen, P. N. (1956). *Studies in inter-sectoral relations*, volume 15. North-Holland.

Richardson, H. W. (1972). *Input-output and regional economics.* Weidenfeld and Nicolson, London,.

Romanoff, E. (1974). The economic base model: A very special case of input-output analysis. *Journal of Regional Science*, 14(1):121–129.

Round, J. I. (1979). Compensating feedback effects in interregional input-output models. *Journal of Regional Science*, 19(2):145–155.

Round, J. I. (1983). Nonsurvey techniques: A critical review of the theory and the evidence. *International Regional Science Review*, 8(3):189–212.

Schwarm, W. R., Okuyama, Y., and Jackson, R. (2006). An evaluation of method for constructing commodity by industry flow matrices.