APPENDIX 2: Input Output Analysis and the IMPLAN Model

1. Overview of Input-Output Analysis

Input-output analysis and input-output models are mathematical representations of an economy. Input-output analysis provides a means for examining the relationships within an economy, both between businesses and between business and final consumers. One objective of input-output models is to capture all the monetary market transactions between industries and final consumers for a specific period of time. The resulting mathematical representation of the economy allows analysts to examine very detailed representations of a region's industrial structure and to trace how changes in one or more sectors of an economy affects other sectors in the region.

Set-out in matrix form, each economic activity is represented as both a purchaser of industrial inputs and the seller of its output. The model is typically described as a double-entry accounting model of a regional economy in which industries are linked to one another via their buying and selling patterns. These linkages, called inter-industry transactions, represent the dollar flows between industries necessary to produce their goods and services. Because these transactions are recorded in terms of dollar flows, input-output models are also sometimes called cash flow models of production. Further, because input-output models allow an analyst to trace all the transactions between sectors of regional economy and represent the economy at a very fine level of detail, input-output analysis has gained widespread popularity for industrial targeting studies and economic impact assessment. Though results of impact assessments are frequently aggregated to facilitate presentation and discussion, the input-output models developed for this study represent 528 industrial sectors, the highest level of detail possible. The detail provided by input-output models is one reason why input-output analysis has become the accepted standard for economic impact assessment.

Input-output models consist of three basic components: A matrix of inter-industry transactions, vectors of final demand, and vectors of value added. The matrix of inter-industry transactions, called the transactions matrix, is the heart of an input-output model. In this matrix all the monetary transactions between businesses in different sectors are recorded. Because all industries are represented as both buyers and sellers to other sectors in the economy, the matrix is square, with one row and one column for each industry. Reading across the rows of such a matrix illustrates sales of one industry to all other industries in the region. Reading down the columns of the matrix shows all the purchases an industry makes from other industries to produce its output. In effect, each column of a transactions table represents the production function for that industry. The transactions recorded in this matrix are sales between industries for intermediate use, not sales to end-users.

Sales to end-users are recorded in several vectors of final demand. The entries in these vectors represent the sale of finished goods and services. Vectors of final demand include sales to consumption, investment, governments and exports. Value-added consists of several vectors that include payments to labor, profits and imports. Because this is an accounting model of the economy, total output from industries must equal total inputs. Total outputs can be determined by summing all entries across the rows of the transactions table (intermediate output) with the entries in the vectors of final demand (final output). Likewise, total inputs can be calculated by summing down the columns of the transactions table and adding the components of the value added vectors. The diagram below illustrates the basic structure of an input-output model.

Industry 1, 2, 3, ..., n 1 2 3 . . n	Inter-industry transactions	Final Demand	Total Output
Value Added			
Total Input			

In order to convert this descriptive model of the economy into a predictive model, several computations are required. First, the matrix of transactions needs to be converted to a matrix of coefficients, so that a change of any level in production can be traced throughout the economy. If the transactions matrix reflects all the purchases and sales made within the region, then a change in one sector will affect the outputs of other sectors that are linked to it. How can these linkages be traced? We start by deriving a table of direct input coefficients from the transactions table by dividing each column entry in the transactions table by its corresponding column total. The result is a table of direct input coefficients that illustrates the cents worth of input purchased by one industry from all other industries in the region to produce $1 of output. In other words, if we call the transactions matrix X_{ij} and divide each entry by its column sum, X_j, a matrix of direct requirements will be produced. These coefficients are typically denoted by a_{ij} and the collection of them in a matrix is represented by A, or

$$a_{ij} = X_{ij} / X_j$$

which produces a matrix of coefficients A, with $A = [a_{ij}]$.

The matrix *A* illustrates all the direct requirements of each industry from all other industries. Multiplying this matrix by a vector of total industry outputs produces a measure of all intermediate output produced in the region. To determine the level of total output, we must also add to intermediate output any sales to final demand or end users. If these sales are represented by *Y*, then the regional industrial production identity can be expressed as

$$AX + Y = X$$

where X is total industry output. If the above equation is rearranged and factored, a solution for X can be derived by

$$Y = X - AX$$

$$= (I - A)X$$

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

where *I* is an identity matrix of the same dimension as *A*.

The matrix $(I\text{-}A)^{-1}$ is frequently called either the Leontief Inverse, or simply the multiplier matrix. It illustrates how a change in one sector affects other sectors of production. This matrix is important for at least two reasons. First, although not all industries are directly related to each other, they may be indirectly related through other industries. Second, how these relationships affect each other quantitatively can be summarized by adding down the columns of the matrix which provides an estimate of all the direct and indirect effects on production from a one unit change initiated in any of the sectors in the regional economy. Because linkages will be of varying strength, each industry will be characterized by different multipliers.

The solution to the above formulation implies that there is some level of final demand that needs to be satisfied by local producers. In other words, input-output models are demand-driven models that seek to capture how changes in the demand for final goods and services affect the economy as a whole. To estimate the economic impact of any new industry or change in final demand, input-output analysis can be used to capture the interdependencies of the region's economy with those industries experiencing an initial change in the demand for their goods and services. In such a case, the model can be used for predictive purposes by solving the following equation:

$$\Delta X = (I - A)^{-1} * \Delta Y$$

where ΔX is the change in total economic activity stimulated by the change in final demand, ΔY.

Like any model, input-output models rest on a set of assumptions. These assumptions include:

- Constant returns to scale
- Linear and homogenous production functions
- Perfectly elastic factor supplies
- Constant technology

Through the use of input-output models, we are able to capture industry linkages and estimate the economic impact of one set of activities on all other industries in the region. Because all industries in a region are to some degree linked to one another, a change in one sector of the economy will ripple through other parts of the economy. The estimation of these ripple effects, called multiplier effects, is the main objective of economic impact assessment.

2. Input-Output Multipliers

Multipliers are numeric summaries that indicate the total change in economic activity due to a one-unit direct change. For the purposes of discussion, the 'direct effect' is the level of economic activity directly attributable to the economic sector(s) experiencing an initial (exogenous) change in demand for their goods or services. 'Indirect effects' measure the secondary *industrial* impacts set into motion by the goods and services demanded by the sector(s) included in the direct economic impact. As direct and indirect industrial effects are initiated, regional firms pay wages to labor who, in turn, spend part of their income in the region causing another 'round' of spending in the form of new demands for goods and services produced by regional firms. These latter effects are called 'induced' effects. The sum of all three effects yields an estimate of the total economic impact of a change in the local/regional economy. As a short-hand means for summarizing the total impact associated with a given direct impact, analysts will make reference to 'multiplier effects'. Multiplier effects can be expressed in terms of employment, industrial output, or income; however, all multipliers are calculated by calculating the ratio of total impacts to the direct impacts.

Input-output analysts frequently make a distinction between Type I and Type II multipliers. The Type I multiplier summarizes the relationship between the direct and indirect effects. They are calculated as the direct effect plus indirect effect, which are then divided by the direct effect. The Type II multiplier includes the impact of consumption-induced effects and is calculated as the direct plus indirect plus induced effects, all divided by the direct effect. The distinction is important, especially to development policy analysts, because the Type I multiplier summarizes the strength of the regional *industry linkages* in the economy and indicates the extent to which the industry in question is functionally integrated with the rest of the regional economy. The inclusion of the induced effects in the Type II multiplier is also important, but for different reasons. Because Type II multipliers capture the effects of household spending on regional economies, they reflect patterns of consumer demand. The size of the induced effects, i.e. the difference between the Type I and Type II multiplier, also reflects the relative pay scales in industries affected by the economic impacts. In other words, Type II multipliers are apt to be higher when the direct and indirect effects of the impact involve expanding employment levels in high wage industries.

In regional impact assessment, it is not uncommon for the impacts from induced household consumption to be larger in magnitude than the production-related indirect effects. This is especially true in small, rural, or lesser developed economic regions. While most cities and towns have a sufficient number of establishments to accommodate the household demand for everyday low-order goods such as gas stations and grocery stores, not all small towns or rural regions have a diversified industrial base characterized by dense networks of inter-industry transactions. This means that much of the demand induced from household spending can be met with local production. However, the economic base in smaller and rural economies tends to be correspondingly smaller and less diversified such that many inputs needed for industrial production need to be imported from outside the region. This causes the indirect production-related impacts to be small relative to the consumption-induced impacts in less developed regions. It is for this reason that there is also a general relationship between the size of the region and size of its multipliers, with smaller regions having smaller multipliers and larger regions having larger multipliers. As the size of the region increases, the likelihood that inputs needed for production will come from other producers in the region (rather than through imports) also increases. The greater this likelihood, the more likely income and demand will re-circulate in the local economy rather than leaking to other regions.

3. The IMPLAN Input-Output Model

The IMPLAN model is a regional input-output modeling system developed by the Minnesota IMPLAN Group, the most recent version of which is maintained in the Department of Geography and Earth Sciences at the University of North Carolina at Charlotte. The IMPLAN modeling system is an interactive, computer-based modeling system capable of producing input-output accounts and input-output models for any region in the United States as small as a single county. The system consists of regional data bases and software that allow users to develop these models for the purposes of describing the structure of regional economies and/or predictive analyses, especially those associated with estimating the economic impacts of a quantifiable change in regional production.

Like most regional input-output models, the IMPLAN model is 'stepped down' from a set of national input-output accounts. Combined with local data, IMPLAN relies on national sources for base accounting data such as the national 'Use' and 'Make' matrices and their associated 'Absorption' and 'Byproducts' coefficient tables. These data sources show, at the national level, which industries produce specific goods and services (Make Table) and the sets of inputs these industries use in their production process (Use Tables). An underlying assumption of stepped-down input-output tables is that the industrial technology implied by the national accounts is applicable to sub-national regions as well.

What differentiates the national input-output accounts from the regional accounts produced with IMPLAN are parameters that describe trade flows between the region and the rest of the world. Estimating the volume of trade for a sub-national area is a critical step in 'regionalizing' a national input-output table. There is a large academic literature on this subject that focuses on several computational strategies for regionalizing input-output tables such as partial survey techniques, location quotients, bi-proportional RAS procedures, and supply-demand pooling. The default procedure employed in the

IMPLAN system, one which has gained widespread acceptance, is the Regional Purchase Coefficient procedure, or RPC. According to IMPLAN developers, "an RPC represents the proportion of local demand purchased from local producers. For example, an RPC of 0.25 for a given commodity means that for each $1 of local need for that commodity 25 percent will be purchased from local producers. This method is based on the characteristics of the region and describes the actual trade flows for a region mathematically" [3].

Each commodity produced in a region has an associated RPC which is determined via a set of econometric equations and used to estimate trade flows (imports and exports) of that commodity. If, as in the example above, a particular commodity has an estimated RPC value of 0.25, then 25 percent of that commodity will be purchased from local establishments, and the remaining 75 percent of commodity demand will be imported from other regions. Trade flow estimates are important to regional input-output models because they are what differentiate the regional model from its national counterpart. Trade flows affect the amount of local commodity production available to industries and thus affect the elements of the transactions matrix, which in turn affect the direct requirements matrix, A, that is necessary to compute the Leontief multiplier matrix.

Input-output models are extremely data-intensive and IMPLAN makes extensive use of many data sources. For example, industry outputs are derived from economic censuses from the Bureau of the Census and projections from the Bureau of Labor Statistics. Employment data are derived from ES202 employment security data and are supplemented with information from *County Business Patterns*. Data from the Regional Economic Information System (REIS) are also used supplement ES202 employment information as well as providing a data source for employee compensation (wages and salaries) and proprietor income. The elements of final demand are largely derived from the National Income and Product Accounts (NIPA) and federal procurement and sales reports. The end result of combining reliable data with accepted modeling techniques is an extremely flexible system for generating regional input-output accounts that can be used for industrial targeting, economic impact assessment, and analysis of regional development policy.

References

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