BUL 835

A Guide to Building County Input-Output Models

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Introduction

As Idaho's regional economies continue to adjust to new political and economic environments, local government officials have asked for ideas about what they can do to sustain or enhance their local economic situations. When officials feel responsible for their local economy and are questioning how they might spend limited resources to assist the local economy, what do you tell them?

Helping leaders evaluate alternative policies for potential impacts and linkages within their jurisdiction is one use for community economic models. County modeling efforts are being used to evaluate the policy impacts of alternative industries for a local economy. The models also show which sectors to support because of their linkages to other sectors of the local economy. They permit evaluating potential effects on different groups and sectors in the economy. This type of evaluation can take place before committing to actions and investments.

This bulletin explains input/output analysis, different means of handling data, and how to develop models adapted to the local economy.

Input/Output Model

Regional models can be categorized as nonstructural or structural. Nonstructural models lack economic behavioral structure and thus base regional changes upon trends used to predict future changes such as historical shift-share, employment, tax revenues, and expenditures. Nonstructural models can range from simple time-series forecasts to multiple simultaneous equations.

Structural models are behavioral. They predict agent behavior as the effect or impact response from a specific stimulus. The advantage of structural models for policy analysis is that they can estimate the impacts of a policy change on the various agents in the economy. To address impacts on all agents in the economy, structural models require economic structure and behavioral mechanisms for each agent. The model of choice for regional impact analysis is regional Input/Output (I/O).

The precursors to regional I/O models were simplified Keynesian framework accounts that developed a single multiplier from an economic base. The more complex the intersector linkages among agents, the greater the advantages I/O has for impact analysis. As the applicability of Leontief's national I/O structure to a regional scale was recognized, survey-based regional I/O models were constructed. The availability of non-survey based I/O models, in particular IMPLAN (IMPLAN,1997), has greatly increased the use of regional I/O modeling.

In addition to the general limitations of I/O in impact analysis, non-survey based I/O models have the inherent drawbacks stemming from the use of secondary or national data combined with an identical algorithm to estimate an I/O model for every county in the United States. The models generated by IMPLAN are then modified extensively with a combination of Department of Labor ES-202 data, direct surveys, and other data sources. The analysis portion of the IMPLAN program is often not used in our applications to Idaho counties. The multipliers and subsequent impact analysis are accomplished with a spreadsheet.

Input/Output: An Accounting System for an Economy

I/O comprises both a system of economic accounts for a region as well as a tool for economic analysis and forecasting. I/O is first a method of social accounting. I/O accounts are displayed in matrix form as the transactions-among-sectors table, which depicts the economic structure and interdependencies among industries and agencies of an economy. The focus of input/output analysis is the cumulative interdependent nature of expansion or contraction of an economy. By accounting for each industry's direct purchases or sales we can then ascertain the indirect impact of each industry. A social account is an empirical framework resulting from a theoretical structure that sets forth relationships among various aspects of a social entity. An account refers to the framework itself and/or the values within that framework.

Users of the I/O technique need to know the definitions of the I/O accounts and have an understanding of how the accounts are used to model the economic interdependencies in an economy. This section provides a summary of I/O accounts and compares and relates them to regional income and product accounts.

As with any accounting system, I/O accounts are governed by a set of rules that allows a uniform interpretation of the accounting system. Production, distribution, and consumption are described in an I/O table by the volume of transactions that takes place over a period of time. Thus, the units accounted for by I/O tables are gross dollar flows from one sector or account to another over a defined time period. The rules for I/O accounts are the focus of this section.

Stock Versus Flow A flow is the economic goods moving among markets over a set period of time. Stock amounts (capital, land, inventory, etc.) are not reflected in the usual I/O model. However, if expenditures are made for stock purchases (e.g., purchases of inventory) or stocks are used up (e.g., depreciation) during the accounting period, the purchases or expenditures of stocks are considered flows to or from respective stock accounts during that time period. This concept is analogous to an accountant's financial statements, i.e., an income statement as opposed to a net worth statement or balance sheet. The I/O model is similar to the income statement in that it shows incomes and outlays over a given period (i.e., fiscal year). This contrasts with the balance sheet, which shows liabilities and assets that are stocks at one given point in time.

I/O Margins or Producer Prices The purpose of the I/O accounting stance is to represent real production, distribution, and consumption activity and to exclude transactions that represent only asset transfers. Asset transfers, such as sales of real estate, stocks or bonds, or insurance, and debits to demand deposits at banks are excluded. Thus, a finance, insurance, and real estate (FIRE) sector of an I/O model consists only of the commissions and other costs related to the sales, storage, or other services provided by those industries. The trade sector does not usually add further processing to the goods like other industries in the processing quadrant of the I/O table. For this reason, it is often argued that trade can be treated like transport costs. Thus, if such costs are "assumed" to be paid by the buyer rather than the seller, a certain portion of any purchase from the trade industries (anywhere from 15 to 25 percent) is shown as a payment to trade and the remainder is shown as flowing directly to the sector that would have supplied the goods to the trade sector.

Model Time Period Because a flow can only occur over a time period, the unit of time must be explicitly defined. Besides defining the accounting period in which flows are measured, the time period is a reference or base period for measuring real dollar economic activity. All subsequent projections and technologies must be measured using the I/O model compilation date as the base year. For example, if crop revenues were projected to increase over a ten-year period, but this increase was simply inflation or loss of purchasing power of the dollar from the base year of 1993, then no real demand increase should be made for the I/O model. All final demand changes introduced to create I/O forecasts should be expressed in base year dollars through the use of appropriate price indices. Inflation in the total value of final demand does not represent real changes in physical output and thus its impact should not be included.

Double-Entry Accounting Double-entry accounting in the I/O framework means that for every purchase there is a corresponding sale, and the outputs of one industry are the inputs to all the others, including exports. Because profit and saving are included with other purchases, total spending equals total receipts for each industry in the intermediate processing quadrant (Quadrant 1) in Figure 1.

Sector and Industry Delineation The formats of I/O accounts vary according to the application and limitations of the research. Industries are delineated to balance concerns and constraints over: 1) data availability and confidentially for a regional economy with the sector often being a single firm, 2) useful number and definition of sectors, 3) desire to estimate the impacts for those directly impacted industries, 4) reduction in aggregation error, and 5) level of aggregation used on accounts to display the impacts.

Transactions Table

Spending flows among sectors in the Input/Output (I/O) framework are displayed as a table or matrix. The matrix format of the accounts is a convention to allow for its use as an analytical model as well. An I/O table of gross flows (transactions among sectors) can be broken down into four quadrants: Quadrant 1 contains the intermediate processing transactions matrix, which includes sales to and purchases from other industries within the region. Quadrant 2 contains final demands. Quadrants 3 and 4

Figure 1. Schematic of an I/O transactions table, showing the four quadrants of accounts.

	Purchasing Industries & Agencies	
Selling Industries and Agencies	**QUADRANT 1** Intermediate Processing (Interdependent variables)	**QUADRANT 2** Final Demands (Independent variables)
	QUADRANT 3 Final Payments (Dependent variables)	**QUADRANT 4**

together are referred to as final payments.

Quadrant 1: Intermediate Processing Transactions This quadrant constitutes the largest part of the I/O table. To maintain a double entry accounting framework, the n number of purchasing sectors (in column headings) are the same as the n number of producing sectors (in row headings). Thus, quadrant 1 is a square n by n matrix, where n is the number of intermediate processing industries in the local economy. The intermediate processing quadrant only contains industries that purchase inputs to combine, transform, or use in production. End users of inputs, such as governments or exports, are excluded from the first quadrant. By convention, columns of an I/O transactions table are the purchasing sectors, and rows are the producing or supply sectors. As with standard matrix notation, an entry in the transactions among sectors table is denoted as the i^{th} row and the j^{th} column. To maintain equality of row sums and column sums, rows exist for profit and saving as well as spending.

Quadrant 2: Final Demands This quadrant accounts for the exogenous export demand for goods and services made upon local production capabilities. Final demand spending represents all sales but those that are inputs to local processors. For example, exports could be for final use outside the local economy, final use inside the study area by tourists, or intermediate inputs to processors located outside the study area. Because final demand is exogenously determined, it is in effect the driving force for the economy. According to the I/O model framework, if the spending in quadrant 2 were to disappear, i.e., go to zero, the local economy would also disappear. By "exogenous," we mean that purchases of these goods and services are either made by sectors located outside the study area or factors that influence changes in these demands are outside the control of local business or personal spending decisions.

$$\left[\begin{array}{cc|cccc} z_{11} & z_{12} & c_1 & g_1 & e_1 & X_1 \\ z_{21} & z_{22} & c_2 & g_2 & e_2 & X_2 \\ \hline l_1 & l_2 & l_c & l_g & l_e & L \\ t_1 & t_2 & t_c & t_g & t_e & T \\ v_1 & v_2 & v_c & v_g & v_e & V \\ m_1 & m_2 & m_c & m_g & m_e & M \\ X_1 & X_2 & C & G & E & X \end{array}\right] \quad (1)$$

Quadrant 3: Primary Inputs (final payments sector) This quadrant accounts for input purchases which do not recirculate in the economy. The two principal accounts in quadrant three are imports and value added (wages and salaries, proprietors' income, taxes, and dividends, interest, and rents). Primary inputs are termed leakages because these flows go out of the local economy to taxes, savings, or imports if local industries are unable to produce needed inputs. The more self-sufficient a local economy is, the smaller proportion these purchases of primary inputs will be and the more an economy will depend upon its own industry. Primary input accounts are recorded by place-of-work, not place-of-residence. Thus, the value added accounts of wages and salaries, proprietors' income, taxes, and dividend, interest, and rents reflect payments to workers, governments, and owners of capital, regardless of place of residency. The wages and salaries account is bifurcated into wages and salaries paid to residents and wages and salaries paid to in-commuters. This accounting system allows the portion of the wages and salaries paid to residents to be included in Quadrant I for more accurate calculations of Type II multipliers. Similarly, proprietors income is bifurcated into regional proprietors and outside business owners.

Quadrant 4: Primary Inputs to Final Demands (final payments sector) The fourth quadrant records the primary inputs purchased directly by the sectors of final demand. Entries in this quadrant are not necessary to construct multipliers for impact analysis and are thus omitted from the regional accounts.

The I/O Accounting Identity

The double-entry accounting identity can now be demonstrated with the definitions provided by the four quadrants of the I/O matrix. To do this, we use Equation 1 (left) that shows the four quadrants with notation for the highly aggregated accounts within each quadrant. The accounting identity is obtained by summing down all the columns and across all the rows.

Gross outlay (purchases) by the i^{th} industry, Xi, is obtained by summing down the i^{th} column. Correspondingly, total gross outlay by all sectors in the economy is obtained from summing the column totals for consumption (C), government (G), and exports (E). Correspondingly, total gross output by all sectors in the study area is obtained by summing row totals plus labor wages (L), taxes (T), other value added such as dividends, depreciation, and rent (V), and imports (M).

$$X = (X_1 + X_2 + X_3 + ... + X_n) + C + G + E \qquad (2)$$

Thus, total outlay is the sum of all column totals of interindustry spending plus the sum of household consumption, state and federal government, and exports.

Gross output by the i^{th} industry, X_i, is obtained by summing across the i^{th} row. Correspondingly, total gross output by all sectors in the study area is obtained by summing row totals plus labor wages (L), taxes (T), other value added such as dividends, depreciation, and rent (V), and imports (M).

$$X = (X_1 + X_2 + X_3 + ... + X_n) + L + T + V + M \qquad (3)$$

Thus, total output is the sum of the row totals of interindustry spending plus the sum of wages paid to households, taxes, depreciation, rents, and imports.

We can equate the two parts of the identity using the definition inherent in our I/O double entry accounting principle that defines total outlay as equal to total output.

$$(X_1 + X_2 + X_3 + ... + X_n) + C + G + E = X =$$
$$(X_1 + X_2 + X_3 + ... + X_n) + L + T + V + M$$

This gives the desired result of final product measured in terms of final payments to factors equaling final product measured by final demand:

$$L + T + V + M \equiv C + G + E \qquad (4)$$

The identity holds for the total of all final payment and final demand sectors but not for each sector individually.

For the i^{th} industry, output equilibrium can be expressed as:

$$X_i = (z_{i1} + ... + z_{ij} + ... z_{\varepsilon}) + C_i + G_i + E_i + L_i) \qquad (5)$$

Each sector of the economy is in equilibrium when the sum of the demands of the processing sectors plus the sum of the final demands for that same sector equal its total gross output (Equation 5). A single industry (or row of the intermediate processing section of the transactions table) is in equilibrium when the sum of the interindustry flows for the i^{th} industry ($z_{i1} + ... + z_{ij} + ... + z_{in}$) instead of the aggregate for all industries ($X_1 + X_2 + X_3 + ... + X_n$) is equal to the demands for the i^{th} industry.

Matrix algebra is used to put all n industries into one equation. To simplify notation, let Z stand for the intermediate processing matrix (Quadrant 1) and Y stand for the final demands matrix (Quadrant 2). The accounting equation for output can now be written as:

$$X = (Z)(U) + (Y)(U) \qquad (6)$$

where U is a column vector of ones whose function is to provide conformation of matrices for addition. Again, this is the statement in matrix form: total output of the local economy is composed of intermediate processing transactions and final demands, which includes all sectors of the economy.

I/O as an Analytical Tool

The underlying theory that transforms the I/O accounting framework into an economic model for a local economy is the interpretation of the spending flow accounts vis-a-vis local industry production functions. The I/O accounts are recast into a model of regional economic behavior, that is, a general equilibrium model of regional production and consumption, by substituting linear production and expenditure functions into the accounting identity. To view the I/O accounts on the basis of production functions, let us first define a production function and then set forth the assumptions that make this interpretation possible.

The Production Relation Assumptions of I/O Models

A production function defines the engineering/ technical or physical relationship between inputs and outputs for a firm or for an industry. I/O accounts are assumed to contain information reflecting production functions of industries in the study area. No one argues that outputs are not a function of inputs, i.e., the existence of a production function. The exact nature of the form of this relationship is a matter for empirical testing. In the I/O model, however, the implied production relationship is a consequence of the simplified accounting system that is necessary to capture complex economic activity in a linear model. Transformation from accounts to general equilibrium requires the assumption of linear production processes which in turn exacts a rigid interpretation of the impact analysis with multipliers. Specifically, the most important limitations are: (1) Constant production coefficients, which bars scale economies, externalities, technological change, relative price changes, and changes in trading patterns or the production recipe; (2) Output is a single homogeneous product with no joint or substitute products; (3) Supply and demand functions are fixed price, whereby producers in one sector react to changes in demands from other sectors by changing output rather than changing prices or supplies. Thus, I/O analysis operates under the assumption that supplies are unconstrained with fixed prices and resources are used efficiently with no resource unemployment.

The production function in I/O requires that input budget shares remain in a fixed proportion to each other. Changes in relative prices of inputs result in offsetting substitution among inputs so that spending shares remain constant among inputs (unitary elasticity of substitution). Thus, the spending by a given industry is defined as fixed percentages down a column of the transactions matrix,

$$a_{ij} = \frac{z_{ij}}{X_j} \qquad (7)$$

where each a_{ij} is the direct input coefficient showing direct input requirements for each dollar of output. The latter is found by dividing the payment flow to each input supply sector (z_{ij}) by the purchasing industry's column total (X_j) (see Equation 7 above). With each sector's direct input coefficient defined as $a_{ij} = z_{ij}/X_j$, the *n* by *n* matrix of direct input coefficients is

$$A = Z\,\hat{X}^{-1} \qquad (8)$$

where Z represents the intermediate processing flows and X is a matrix with the total output vector on the main diagonal and zeroes elsewhere (Equation 8). The direct input coefficients, also called the technical coefficients, measure the fixed relationship between any sector's flow of output measured in dollars and inputs measured in dollars. A direct input coefficient tells us the direct requirements as a fraction or percent of total spending by an industry. A direct input coefficient is the cents' worth of inputs each industry needs to produce a dollar's worth of output. The direct input coefficients, which include an allocation to retained earnings and imports, must sum to one. Since I/O models measure spending rather than the physical input data, the fixed direct input coefficients refer not to physical input quantities but rather to the dollar spending on inputs by the industries in the model.

The direct input coefficients measure the share of spending or income allotted to each input. The I/O model assumes that if spending on all locally supplied inputs, savings or profit, depreciation, taxes, and imports increase proportionately, then total sales of output will increase by that same proportion. This is a long-run adjustment that satisfies the definition of a change of scale but refers to spending on inputs and sales revenue from outputs rather than physical units as in a production function. The I/O spending relationships are consistent with constant returns to scale but are not strictly limited to that assumption if the I/O flows are measured as spending rather than physical output. The constancy of the spending distributions down each industry column is thus a critical requirement for the I/O technique to provide accurate impact forecasts.

I/O Output Equilibrium

The accounting and production facets of I/O can now be combined into a model of regional economic behavior. The I/O accounts are recast into a model of regional economic behavior, that is, a general equilibrium model of regional production and consumption, by substituting linear production and expenditure functions into the accounting identity. Rearranging the terms for each sector's direct input coefficient ($a_{ij} = z_{ij}/X_j$) shows the i^{th} sector's purchases from sector j in terms of the production relationship; i.e. $z_{ij} = (a_{ij})(X_{ij})$. For the i^{th} industry, the sum of sales to intermediate processing industry demands plus the sales to final demands (total gross output) equals total gross spending and saving (total gross input):

$$X_i = z_{ij} + \ldots z_{i,n} + c_{in} + y_i = z_{ij} + \ldots z_{i,n} + l_{in} + p_i = X_i \qquad (9)$$

where X_i are industry spending and saving, which equal industry sales; the z_{ij}'s, c_{ij}'s column l_{ij} row are simultaneously endogenous intermediate processing flows from sector *i* to other domestic sectors; y_i are the exogenous final demands (government g, and exports e); and p_i are the endogenous (recursive) final payments or the primary inputs of the economy (taxes *t*, value added *v*, and imports *m*). In matrix form, the Z matrix is substituted into the accounting balance equation:

$$X \equiv ZU + YU \qquad (10)$$

Substituting the direct input requirement coefficients into the accounting equations reduces the n^2 simultaneously determined unknowns (*Z*) to the *n* accounting balance equations to express an output equilibrium for a regional economy. Final payments, such as imports, are endogenous since they supply inputs in proportion to sector output, but not simultaneous since they do not respond by demanding more inputs from the region's economy. Thus, the substitution of direct input coefficients into the accounting identity reduces the number of unknowns to the number of balance equations. When solved for output, the equilibrium condition states that exogenous non-negative final demands are fulfilled by regional production:

$$X = AX + YU \qquad (11)$$

We can further solve the equation for final demands by isolating the final demand vector:

$$(Y)X - (A)(X) = (Y)(U)$$
$$(I - A)(X) = (Y)(U) \qquad (12)$$

where I is the identity matrix with ones on the diagonal and zeroes elsewhere, and U is a column vector of ones.

Solving equation (12) uniquely for regional output X as determined by final demands yields an equilibrium statement for regional production and consumption:

$$X = (I - A)^{-1}(Y)(U) \qquad (13)$$

where I is the diagonal identity matrix. This output equilibrium, the *Leontief Inverse*, shows the amount of output from each of the sectors necessary to supply the exogenously determined final demands. Final demands can exist at any given positive level and local production is assumed to be able to fulfill those demands—thus the output of the economy is backward-linked to exports in the backward-linked, demand-driven I/O model. Further, input supply (imports and other inputs) to regional production is thus assumed to be unrestricted and prices fixed at current levels. This output equilibrium shows the amount of output from each of the sectors necessary to supply the exogenously determined final demands. Final demands can exist at any given positive level; local production is assumed to be able to fulfill those demands.

The *Leontief Inverse* matrix shows the total requirements per dollar of exports by the industry named at the head of the column. Total requirements are composed of the direct and indirect requirements. When households (row *l* and column *c*) are included as a dependent sector, then total requirements are said to also include "induced" requirements. Each entry in the inverse matrix is an interdependency coefficient. Each element (b_{ij}) in the Leontief Inverse or final-demand-to-output multiplier matrix represents the direct and indirect requirements of sector *i* per unit of final demand sold by sector *j*:

$$\beta_{ij} = \Delta x_i / \Delta y_j \qquad (14)$$

and is composed of the direct plus indirect change in total output in sector i resulting from a unit change in final demand j. Column sums of the Leontief inverse are similarly interpreted as the effects of change in sales to final demand upon the entire economy. By setting the level of final demands at any level (including the current level) we can now obtain the gross local economic activity (direct, indirect, and induced) in each sector supplying that level of demand. The immediate impacts computed in the direct input coefficients table produce even longer term effects that can be found by calculating total requirements. Successive rounds of production and demand arise because suppliers need local inputs to make and sell their outputs. Total requirements are much larger than direct requirements, shown by the direct input coefficients, because the total requirements incorporate all of the cumulative effects of each industry supplying each other industry to reach a new equilibrium of the economy, while the direct input coefficients only show the initial round of resource usage.

Conceptually, processing sectors of the regional economy move toward a stable equilibrium in which sales equal receipts in each industry. Receipts are disturbed when final demands such as exports or government purchases from industry change. Changes in final demand set off a series of transactions as each industry responds to either direct or indirect changes in their demands. An example of direct change in demand would occur if agricultural exports increased. An indirect demand change could be the response of farmers to increase output, in which they purchase more fuel, fertilizer, machinery, labor, and similar inputs, thereby creating an indirect demand for the output of other sectors in the economy. When the other sectors find their demand rising, they will also buy more inputs and thus the original export change ripple throughout the economy. These reverberations gradually wane as a portion of each round of spending leak out to savings, taxes, and imports. The greater th leakage, the faster the effects die out and the smalle the multiplier

Final Demand Multiplier

The final demand multiplier (sometimes calle the business multiplier) for any sector *i* is the sum o the direct and indirect (and induced if the model i closed with respect to households) requirements fro all sectors of the local economy needed to sustain on additional dollar of output to final demand by sector *i* Because each element b_{ij} of $(I-A)^{-1}$ measures the tota stimulus, direct and indirect (and induced), to the i^{th} gross output when the j^{th} final demand changes by one unit, the output multiplier ($\Sigma_i b_{ij}$) measures the total effect on gross output of all sectors when final demand for the j^{th} sector changes by unity and all other final demands are zero. The magnitude of the multiplier indicates the amount of demand stimulus that sector of the economy will create when it adds sales to final demand. Each entry in a column of the Leontief inverse shows the total production requirements from the sector at the left when the sector at the column head increases sales to final demand by one dollar. Sectors with large output multipliers have relatively small leakages in their direct and/or indirect purchases. In other words, *a large multiplier means that the sector directly and indirectly purchases a larger proportion of its inputs from within the local economy instead of importing them*. Comparing multipliers for similar sectors across different I/O models provides a measure of the self-sufficiency of a local economy. Regions with larger multipliers often have greater development in the intermediate stages of production.

Output Multipliers

The conventional I/O model equilibrium is demand driven, i.e., the multiplier measures a change in output as determined by change in exports. With an output multiplier, the output of the industry becomes the driving force or the determinant of regional output of the economy (Miller and Blair). Formally, the output-to-output equilibrium for the economy is expressed as:

$$X = (I - \tilde{A})^{-1} X \qquad (15)$$

$$\text{where:} \quad X = (I - \tilde{A})^{-1} = (I - A)^{-1}(\hat{\alpha})^{-1}$$

Computationally, the output equilibrium is obtained by dividing the Leontief inverse by the diagonal elements of the Leontief inverse. To make output the driving force for the economy, the conventional Leontief inverse is normalized or standardized by the direct and indirect output of that respective sector (i.e., the diagonal elements of the Leontief Inverse). Or computationally, in terms of the final demand multiplier of the conventional Leontief inverse, the output-to-output multiplier is:

$$\hat{\beta}_{ij} = \beta_{ij} / \beta_{jj} = \frac{[\Delta X_i / \Delta Y_j]}{[\Delta X_j / \Delta Y_j]} = \Delta Xi / \Delta Xj \qquad (16)$$

Alternatively, the output multiplier can be expressed as:

$$\Delta X_i = \hat{\beta}_{ij} \Delta X_j \qquad (17)$$

An alternative to the final demand multiplier, the demand driven output multiplier is used when the impact to the economy can only be expressed in terms of changes in industry output. The output multiplier is particularly useful when estimating the impact of the presence or absence of an industry in an economy. This is done by setting the final demands to zero and applying the final demand multiplier to the change. In effect, the total impact of the industry presence in the economy is not accurately assessed because impact is understated by the impact of internal regional consumption.

Primary Input Multipliers

Multipliers are not limited to measuring output impacts. They can also be used to measure impacts on inputs or production factors, final payments or primary inputs, and resources (water and employment). Primary input and resource multipliers are calculated and interpreted in an identical fashion. Primary input and resource multipliers assess direct and indirect (and induced) payments to the primary inputs or resource use resulting from a change in final demands of the economy. The difference is that resource multipliers are denominated in physical quantities (e.g., gallons of water, jobs) instead of economic units (dollars). However, because they are measured in physical units, resource multiplier data must be obtained outside the I/O accounting framework.

Primary input multipliers are used to examine the direct and indirect (also induced if the model is closed with respect to households) payments to any of the primary input sectors when final demands for the economy change. Again, the assumption is that primary inputs are used in constant proportion to output. Beginning with the equilibrium condition derived earlier, $X = (I - A)^{-1}Y$, we define a matrix of primary input coefficients, V, exactly as the direct input coefficients were calculated:

$$V = P\hat{X}^{-1} \qquad (18)$$

The primary input multiplier can be interpreted as a linear transform of the direct and indirect impact, i.e., the I-A inverse using the primary input coefficient matrix where V is a *m x n* matrix of primary input coefficients, P is the vector of gross primary inputs or final payments (Quadrant 3), *m* is the number of rows of primary inputs, and *n* is the number of rows or columns in the transactions matrix (Quadrant 1). Premultiply both sides of the original equilibrium condition by X to obtain the definition of the primary input coefficients:

$$PX^{-1}\hat{X} = V(I\text{-}A)^{-1}Y, \text{ or } P = V(I\text{-}A)^{-1}Y \therefore \hat{X}^{-1}X = I \qquad (19)$$

Each element of the matrix $V(I - A)^{-1}$ is the direct and indirect increase in payments to the i^{th} primary input when final demand for the j^{th} sector increases by one dollar. The multiplier for all sectors is the column sum of the elements of the matrix $V(I - A)^{-1}$. *Primary input multipliers are always less than or equal to one, as opposed to output multipliers, which are always greater than or equal to one* (not recognized in the conversion to millions).

Two primary input multipliers, earnings and value added, can be calculated for an economy. Earnings are defined as payments to household (salaries and wages) plus proprietors' income. The inclusion of proprietors' income into earnings was necessary because farming income and owner-operated business income is paid to the owner in lieu of a wage. To the extent that proprietors' income is paid to proprietors residing outside the region, the earnings multiplier is decreased. Value-added is the amount remaining after payments to intermediate suppliers. Value-added is the sum of earnings and taxes plus other income (dividends, profits, and rents). Since value-added includes earnings, the direct value-added and the multiplier will exceed the earnings values. Both earnings and value-added are expressed in millions for ease of interpretation.

The economic impact to an economy is often expressed not as a change in exports but rather as a change in the payment to the primary input. A common example would be the direct impact of a firm being expressed as an increase in payroll, as opposed to an increase in exports. To aid in the use of impact analysis with multipliers we can express the impact as being driven by the primary input, either earnings or value-added. But it is important to remember that the underlying driving force in the economy remains exports. There are two components to the income multiplier: the primary input multiplier for household income, $h(I\text{-}A)^{-1}$, and the average (marginal) propensity to consume for households (i.e., the direct input coefficients for the household row):

$$h = H\hat{X}^{-1} \qquad (20)$$

where H is the gross income paid to households. To calculate the income multiplier, the primary input multiplier is divided by the marginal propensity to consume:

$$\textit{earnings multiplier} = h(I\text{-}A)^{-1}\hat{h}^{-1} \qquad (21)$$

Simplistically, this multiplier shows how an initial change in household sales is multiplied or increased in the economy (directly and indirectly) to create the total change in household income in the economy. More precisely, the household earnings multiplier shows how much the economy must expand in order for income to households to expand by one dollar. The type II earnings multiplier is the direct, indirect, and induced change in household income, i.e., $(I\text{-}A)^{-1}$ is calculated for a closed economy with households included in the transactions matrix. Type II income multipliers are used to examine total (direct, indirect, and induced) household income changes when an initial impact in household income is expected to occur. For example, if a new plant locates in the local economy and the payroll for this new plant is known, then the total (direct, indirect, and induced) income increase for all households can be estimated with an earnings multiplier.

Employment Multipliers

The employment multiplier is computed in an analogous manner to the primary input multipliers but measures the total change in physical amount of resource use resulting from a change in final demands. A second employment multiplier is computed analogous to the income multiplier in which the total change in physical resource use results from an initial change in the physical amount of the resource itself. Both multipliers measure changes in physical units (e.g., gallons of water, jobs) instead of economic units (dollars). The first step is the computation of direct resource input coefficients in terms of physical units of resource use per dollar of gross output for each sector of the economy. As an example, let's look at employment in the economy. A technical resource input coefficient for employment is:

$$\Omega_W = W\hat{X}^{-1} \qquad (22)$$

where *W* is the average annual monthly employment in physical units for each industry of the economy, or the total physical resource use (jobs) in each industry of the economy when computing resource coefficients. An agricultural example of a water resource coefficient would be estimated by total water used growing potatoes divided by the total value of potato production. Linear resource coefficients imply labor use will be used in constant proportion to output, with no efficiency change. This technical resource coefficient implies that in the subsequent multipliers, physical resource use will be in constant proportions, and no change in efficiency of labor is permitted.

To obtain the primary input or resource multiplier, both sides of the Leontief equilibrium condition (Equation 13) are multiplied by the definition of the primary input or resource coefficients:

$$W\hat{X}^{-1}X = \Omega_w(I\text{-}A)^{-1}Y, \text{ or } W = \Omega_w(I\text{-}A)^{-1}Y \therefore \hat{X}^{-1}X = 1 \quad (23)$$

Each element of the matrix $W(I - A)^{-1}$ is the direct, indirect, and induced increase in payments to the primary input (or direct, indirect, and induced physical amount of resource use) in the i^{th} sector when final demand for the j^{th} sector increases by one dollar. Thus, a primary input or resource multiplier is a linear transform of the direct, indirect, and induced impacts measured by the *Leontief Inverse*. This multiplier says that a change in final demand will cause a total (direct and indirect) change in physical resource use throughout the economy.

The employment multiplier states that a change in final demand will result in a backward-linked change (direct, indirect, and induced) in the physical amount of labor used throughout the economy. The labor multiplier is a proration or linear transform of the total labor requirements (direct, indirect, and induced) impacts measured by the *Leontief Inverse* matrix. The total physical amount of labor use is thus proportional to the economic ripple effect (direct, indirect, and induced economic transactions) in the economy. Attached to every sale or purchase in the economy is the labor that was used to produce those goods or services. An element in the employment adjusted *Leontief Inverse* is a total labor requirement coefficient:

$$\beta_{ij}^{w} = \Delta W_i / \Delta y_j \quad (24)$$

where each coefficient β_{ij}^{w} is composed of the direct, indirect, plus induced change in labor use in sector i resulting from a unit change in final demand j. Column sums are thus the change in employment across the entire economy resulting from a change in final demand. Alternatively, an entry or column sum of the inverse matrix can be pictured as a measure of labor interdependency in the economy. Successive rounds of production and demand arise because suppliers need production inputs, which require labor to produce, make, and sell their outputs, which are then inputs for other industries. Total requirements are much larger than the direct requirements shown by the direct input coefficients because the total requirements incorporate all of the cumulative effects of each industry supplying every other industry to reach a new equilibrium of the economy. Recall that the direct input coefficients only show the initial round or direct labor use.

The multiplier formulation does not change the *Leontief Inverse* backward-linked mechanism whereby final demands are set at any given positive level and local production is assumed to be able to fulfill those demands. The processing sectors must always move toward a stable equilibrium where sales equal receipts in each industry. Receipts can be disturbed when final demands such as exports by an industry change. By setting the level of final demands at any level (including the current level), total resource use (direct, indirect, and induced) in each sector is needed to produce that level of demand. Direct input coefficients (Equation 18) are the immediate impacts, followed by even longer term indirect and induced effects, calculated in the total resource requirements. To meet those demands, labor supply, imports, and other inputs to the regional production are assumed to be available without restriction at current prices.

To calculate the second employment multiplier, the first employment multiplier is divided by the technical resource input coefficient. The second employment multiplier is:

$$\Omega_w (I - A)^{-1} \hat{w}^{-1} \quad (25)$$

Simplistically, this multiplier shows how an initial added labor input is multiplied or increased in the economy (directly and indirectly) to create the total change in labor usage in the economy. More precisely, the multiplier shows how much the economy must expand, expressed in terms of total labor use, in order that the given sector can use up the added labor made available to it. The contrast in the two resource multipliers is that the first multiplier is created by changes in final demands while the second type of multiplier is driven by a change in physical units of the resource itself. The second multiplier implicitly assumes that excess final demand exists for the sector receiving the added increment of labor. A type I resource multiplier is the direct and indirect change in resource use, i.e. $(I\text{-}A)^{-1}$ is calculated for an open economy without households in the transactions matrix. The type II resource multiplier is the direct, indirect, and induced change in resource, i.e. $(I\text{-}A)^{-1}$ is calculated for a closed economy with households included in the transactions matrix. The second type of resource multipliers are used to examine total (direct, indirect, and induced) physical resource changes when a new demand for the resource is created in an economy. For example, if a new plant locates in the local economy and labor usage for this new plant is known, then the total (direct, indirect, and induced) employment increase for the entire economy can be estimated with the second type of resource multiplier. Presumably the plant is going to export its output, but if it does not, then the multiplier overstates labor requirements.

I/O Data[1]

Through input/output (I/O) modeling, exogenous shocks to an economy and estimated impacts to industry output, income, and employment can be derived. There are many widely used and published secondary I/O models on the market today, including IMPLAN and RIMS II. With these models, national average tables are often used that do not represent the local agricultural and processing industries and sectors. The models tend to be aggregated for use at the local level. For example, using crop and livestock cost and return estimates, the I/O model can be expanded and localized to investigate impacts to specific industries. Using enterprise budgets, each production cost is allocated to the I/O industry in which it is purchased. If more than one budget exists for a region, then the costs and returns by acreage or unit of output of each commodity for a regional account are averaged or weighted across the region. Margining techniques and regional purchase coefficients are used to convert to producer prices and purge them of all imports. The commodity accounts can now be expanded by multiplying the value of production estimates by the technical coefficients derived from the cost and return estimates. These procedures yield an industry-by-commodity matrix that includes regional rather than national production practices. They also give the researcher the opportunity to disaggregate and broaden the scope of the model.

Given that survey-based models are time consuming and expensive and that conversion of a national model through secondary procedures is unreliable, the hybrid-type county level input/output provides the best solution. There are several hybrid-type approaches. Among the most promising is the "mongrel model," or the mixed survey/non-survey model. This type of model is suggested by Jensen, and uses a two-step approach for its development. First, a non-survey input/output model is developed from a microcomputer program such as IMPLAN. The second step involves the insertion of superior data obtained from surveys, other primary sources, or reliable secondary sources into the model. Then, appropriate techniques are employed to balance the regional models.

The emergence of controversial public land management decisions, surface and groundwater regulation, agricultural production regulations, and environmental concerns have created a need for a method to localize I/O models. This localization of I/O models more accurately defines sectors pertinent to a region. Instead of including all of agriculture or forestry in one economic sector or a few broad sectors, numerous sectors can be used.

Many crops grown in the United States are grown strictly in certain regions and are aggregated with other industries in the secondary impact models. These crops, however small in importance nationally, may have large impacts in their respective production area. Most secondary I/O models have economic sectors that may produce aggregation errors. See Morimoto (1970) for further information on aggregation errors in I/O models.

The estimation errors encountered with the secondary I/O models do not necessarily arise from errant agricultural production functions or technology. The problems arise from the aggregation of those agricultural sectors. Burchell et al. stated that even when county technology varies widely from the nation's average for one or more industries, model accuracy might not be significantly affected due to inter-county trade. These errors in technology are reduced through the use of regional purchase coefficients (RPC's) and margining techniques discussed later.

This section of the paper integrates crop or livestock cost and return estimates into a framework suitable for use in a "mongrel" type I/O model using IMPLAN as a base. By studying agricultural enterprises in a less aggregate format, the researcher gains the ability to more accurately estimate the impacts on local and regional economies of these agricultural sectors. For example, expenditure patterns for individual agricultural enterprises in one region can be expected to differ from national averages, improving the forecasting accuracy of the "mongrel" model.

We use five basic steps to create I/O accounts cost and return estimates: (1) gathering cost and return and total output estimates pertinent to the study region, (2) converting from purchaser prices to producer prices using retail trade margin procedures, (3) allocating cost and return accounts to I/O sectors, (4) purging imports with IMPLAN regional purchase coefficients, and (5) updating a secondary model make matrix. IMPLAN was used as a basis for modeling in this discussion. The IMPLAN software helps reduce the costs of obtaining

[1]Major sections of the remaining portion of this paper have been adapted from Darden et al., 1999.

primary data and can be easily updated with primary data such as cost and return estimates, Department of Labor ES202 data, and Department of Commerce BEA numbers. Also, the IMPLAN program and software makes it easy to transfer data into spreadsheet format for model and program construction.

After deciding which sectors to include in the I/O model and how to aggregate them, control totals are gathered for those commodities. Control totals are merely values of production, employment, and income generated from each commodity. The values of production can be found using state agricultural statistics, the Department of Commerce's Census of Agriculture, Bureau of Economic Analysis, and Department of Labor values. These published values are based on statewide numbers and can be disaggregated to county or regional values based on acreage in the county or production of that commodity within the county. The employment and income values are available from the Regional Economic Information System (REIS) database, which is produced by the U.S. Department of Commerce Bureau of Economic Analysis. The employment and income data for agricultural production are published in an aggregate format, so they must be proportioned based on employment in the cost and return estimates, ES202 state-level employment data, relative commodity output, or other methods available to the researcher.

Next, cost and return estimates must be constructed for each of the agricultural sectors for which control totals were compiled. The cost and return estimate is the cornerstone of an accurate and precise I/O account. The detailed cost and return estimates are vital to the creation of reliable production functions for the I/O sector. If more than one enterprise budget exists for a given commodity then the various costs and returns are weighted by the amount of acreage for that crop in the study area. For example, if two grazing enterprise budgets exist for the same size operation, one with a federal grazing lease and another without, weight the numbers in each budget by the relevant number of head for each type of enterprise. Next, sum the various production items from the cost and return estimates to arrive at a localized and weighted production function for cow-calf operations in the region. For the sake of simplicity, we transform the cost and return estimates into a single vector of production purchases and gross returns for the enterprise.

Converting from Producer to Purchaser Prices

Purchases by or from the retail sector (for example, when constructing an I/O account from a crop budget) and the changes in final demands in the retail trade sectors (for example, data from the tourism expenditure surveys) must follow the I/O accounting conventions. All I/O accounting transactions are denominated in producer prices. Thus retail accounts and transactions, in particular, must be denominated in producer prices rather than purchase prices. The producer price is the price paid for a commodity at the factory door. The purchaser price is the price paid for a commodity at a retail outlet and it includes transportation costs, wholesale mark-up, retail mark-up, and producer price. The cost and return estimates contain purchaser prices for most of the purchased inputs and, therefore, margins to be apportioned for all purchases from the retail sector. A margin is the portion of a commodity's value going to each appropriate handler, such as the transportation cost, the wholesale mark-up, and the retail mark-up. There are different types of margins included with the IMPLAN software: household, government, and investment. The margins used in IMPLAN come from the United States Department of Commerce Summary Tape Files, but there are other sources that may better represent rural retail businesses, such as *Financial Studies of the Small Business* by Financial Research Associates which is published yearly, or *Annual Statement Studies* by Robert Morris Associates. Once the margin source is chosen, margins are applied to each of the retail purchases made in the budget by multiplying the margins and the budget costs. Margining makes the I/O model more accurate in terms of the impact local trade has on retail businesses. For regions in which it is unclear whether the transportation and wholesale sectors exist, IMPLAN margins or the best method available should be used to convert from producer prices and allocate costs to their respective sectors.

Allocating Cost and Return Accounts to I/O Sectors

*W*hen allocating costs to I/O accounts some of the cost and return items may be "lumped" together and may need to be separated into two or three different accounts. However, more detailed cost and return estimates will likely have most cost items separated. When using IMPLAN as the modeling software be sure to include the value-added accounts, employee compensation, indirect business taxes, proprietor income, and other property type income. These numbers can be derived from ratios between IMPLAN and your employment, income and output totals for each given sector. Note that the (sum of the) new I/O accounts vector equals the value of production because the I/O model must balance purchases and sales. Updates can be made with the simple insertion of new values of production for each model sector.

Purging Imports and Direct Requirement Calculation

I/O modeling is a technique to capture impacts on local economies. Within the model, it allows for true regional interaction of one sector with the other sectors of the economy, as explained by Coupal and Holland. Import purging is done through the use of regional purchase coefficients (RPCs). RPCs represent the proportion of the total local demand met by local production. In addition, it attempts to account for cross-hauling of goods, which refers to the practice of transporting like goods into and out of the region. The RPC's are generated by the IMPLAN software and may be exported for use outside of the software framework. To purge the imports from an account, each item in the vector of margined costs is multiplied by the RPC generated for that industry. This process does not change the total output or value of production for the I/O account; it is simply a transformation of the vector into local purchases and imports of all other commodities and services. Some imports were already derived when margining the retail trade sectors. If better data than IMPLAN is available for estimating regional purchases, that data may be used instead and either entered into the IMPLAN software directly or used outside of the software.

With the imports now purged from the I/O account, the technical coefficients for the new sector can be derived. Dividing the vector of now margined and import-purged costs by the value of production results in a vector of technical coefficients. Once the direct requirement vector (or matrix with all sectors in the I/O model) is constructed, all that is needed for updating the I/O model, if all production functions remain unchanged, is the output (value of production for the sectors), income, and employment estimates. These estimates of output can be multiplied through the direct requirement matrix and re-balanced to create an updated model.

I/O Model Application

I/O models can be used to show economic impacts from governmental policy, business introductions and other potential changes in a local or regional economy. To derive economic impacts from a change or "shock" to an economy, we must first decide whether it is a change to final demand or to output. Final demand changes are changes in purchases of goods and services for final consumption, such as purchases made by the federal government or households. These purchases may be food, computers, houses, buildings, or any other good or service. Output changes are sales or value of production (agricultural commodities, computers, or tourist visits) from a given industry. These sales can be anything ranging from alfalfa hay and cattle to gold and electronic parts or sales to regional visitors.

The I/O model formalizes the linkages that exist in local and regional economies. Based on these known relationships and assuming they will remain the same in the future, it is possible to predict where adjustments (changes in economic activity) will occur in the economy. Knowing the direct effects as well as the indirect and induced effects will assist local policy makers in deciding appropriate policy and investment decisions.

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Glossary of Terms for Input-Output Analysis

Total Final Demand

Total final demand is a derived element. The components of final demand are *personal consumption expenditures*, *state and local government purchases*, *federal government purchases*, *commodity credit*, *inventory purchases*, *capital formation*, and *foreign exports*. Total final demand sums all the purchases for final use or consumption.

Personal Consumption Expenditures **-** Personal consumption expenditures are commodity purchases by individuals for personal use by low, medium, and high income households.

State and Local Government Purchases **-** State and local government purchases are expenditures for goods and services required to provide government services. These include both education and non-educational goods and services.

Federal Government Purchases **-** Federal government purchases are expenditures for goods and services required to provide federal government services. Federal government purchases include both military and non-military purchases.

Commodity Credit **-** Commodity credit is excess goods bought by the federal government Commodity Credit Corporation.

Inventory Purchases **-** Goods that are not dispersed in a particular year are stored for sale in the next year. The value of inventory purchases reflects the gross additions to inventories in the year.

Capital Formation **-** Capital formation is goods purchased for the formation of private capital.

Foreign Exports **-** Exports of commodities to foreign countries are foreign exports.

Sales

Sales include all *government and inventory sales* (see below).

State and Local Government Sales **-** State and local government sales are sales of goods and services that have been produced or stockpiled by state and local governments.

Federal Government Sales **-** These are sales of goods and services that have been produced or stockpiled by the federal government.

Inventory Sales **-** These are sales of private inventories that were stored in the previous year and sold in the current year.

Value Added

Value added is defined as the costs which are added to the intermediate costs of producing goods and services, such as:

Employee Compensation **-** Employee compensation is wages and salaries paid to employees by industries plus the value of benefits, and any contributions to social security and pension funds by employee and employer.

Proprietary Income **-** Proprietary income is the income of sole proprietorships (self-employment).

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Indirect Business Taxes **-** This category covers sales, excise, and value added taxes, as well as customs duties. These are taxes paid during normal operation of industry. Since other types of taxes, such as income and property taxes, are paid out of income, they are exogenous to the I-O model and are not included in the economic model database.

Other Property Income **-** Other property income includes corporate income, corporate transfer payments, interest, and rental income.

Total Value Added **-** Total value added is the sum of employee compensation, proprietary income, indirect business taxes, and other property income. This is the total value added to the intermediate cost of goods and services.

Employment

Employment estimates include both full-time and part-time employees.

Total Employment **-** Total employment is the number of jobs of both full and part-time employment utilized to produce the total industrial output in the county.

Glossary of Terms for Input-Output Analysis, cont.

Full Time Equivalent Employment **-** Full-time equivalent employment is the number of full-time jobs plus the sum of the part-time employment divided by the employment of one worker.

Total Industry Output

Total industry output is the gross industry sales from production.

Other Definitions

Exogenous Transfers **-** Exogenous transfers are inflows into the county from sources outside the county.

Base sectors **-** Base sectors include agriculture, mining, manufacturing, and federal government. These are sectors that would exist regardless of the rest of the sectors.

Personal Income **-** Personal income is the current income of residents of an area from all sources. It is measured after deduction of personal contributions of Social Security, government retirement, and other social insurance programs but before deduction of income and other personal taxes. It includes income received from business, Federal, State and local governments, households, institutions and foreign governments. It consists of wages and salaries (in cash and in kind, including tips and bonuses as well as contractual compensation), various types of supplementary earnings (the largest item being employer contributions to private pension, health, and welfare funds), the net incomes of owners of unincorporated businesses (agriculture and nonagriculture, with the latter including the incomes of independent professionals), net rental income, royalties, dividends, interest, and government and business transfer payments (consisting, in general, of disbursements to persons for which no services are rendered currently, such as unemployment benefits, Social Security payments, Medicare benefits, retirement pay of governmental programs, and welfare relief payments)

Real Personal Income **-** Real personal income is personal income that has been adjusted for inflation.

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