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A Method for Improving Economic Contribution Studies for Regional Analysis

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Abstract. Economic contribution studies are full of challenging theoretical and methodological issues. The economic export base method for conducting contribution analysis presented addresses the challenge of double counting while increasing an analyst's insight into a regional economy. Using data from regional social accounts, an economic export base model is presented that simultaneously separates export base contributions for each sector as a row of column vector sums. The export base measures of economic activity by sector serve as an internally consistent and externally correspondent measure of any given sector's *ex post* regional economic contribution. The sum total of the export base and original "gross" measures of economic activity across sectors are equal for the economy but are almost always unequal by sector. These base measures are also valuable by themselves and as inputs into further analyses into questions regarding competitive advantage, diversity, resilience, dependency, typology, and growth.

1. Introduction

When considering issues of economic development, people often wonder about the current status of the local economy and the extent to which different sectors or events drive the economic activity in the region (Green, 2001; Vollet, Callois, and Roussel, 2005). Likewise, for monitoring and planning purposes, it is common to conduct an economic contribution or impact study of a specific sector of the regional economy to establish a baseline from which to compare future conditions (Miller and Sabbarese, 2012; Connaughton and Madsen, 2012). There are countless studies conducted each year on the economic impact or contribution of an array of industries or sectors. Criticism of these studies focuses on the perverse incentive for publicity and advocacy purposes to double count the contribution of a given sector by making its direct, indirect, or induced effects appear responsible for a larger share of the economy than the observed data can support (Crompton, 1993; Hudson, 2001; Crompton, 2006).

For the purposes of this analysis, the primary focus will be on economic contribution analysis rather than economic impact analysis. Economic contribution analysis is generally regarded as referring to the *ex post* effects on economic activity in a region from the exogenous sales of a given sector in a previous time period. Conversely, economic impact analysis represents a projection of an *ex ante* change in economic activity within a region's economy due to a change in the exogenous sales of a given sector. More discussion of impacts and benefits is presented in Watson et al. (2007), and we consider the discussion of economic contribution presented here to be a clarification and expansion of that previous elaboration of economic contributions. For the purposes of standard *ex post* economic contribution analysis, we feel that the methodology presented here is conceptually the most appropriate approach. Furthermore, we acknowledge that exports are not the only driver of a regional economy. Along with increasing regional exports, import substitution, capital investment, and innovation are all drivers of a regional economy. However, for small regions (i.e., single counties) exports and the associated new dollars brought into the region are often thought to be the major contributor to the region's economic engine. At larger scales, however, the primacy of exports certainly breaks down. For further discussion of these issues see Kilkenny and Partridge (2009), Cooke and Watson (2011), and Tiebout (1956).

A solution to the ubiquitous double-counting problem in economic contribution analysis is to conduct a comprehensive economic contribution study for all sectors of a region's economy simultaneously by using social accounting data within an economic base framework. This approach prevents the sum of the parts from being greater than the whole—no double counting allowed. An economic base contribution analysis is "square" in the sense that the sum of the sectors' export base and gross measures of output, employment, income, and value-added contributions must add to those *actually observed* in the region. For the purposes of this paper we use the term "gross" to refer to the observed measures of economic activity that are reported in secondary data sources (e.g., BEA, BLS, Census). Waters, Weber, and Holland (1998) and Watson and Beleiciks (2009) propose that any economic contribution analysis performed *ex post* should be conducted in a way that the sum of all contributions equals the observed total of their respective measures of economic activity.

At first blush, this suggested solution to the double-counting problem may seem discouraging – as attempting to navigate between perceived burdensome data requirements and a potentially complex methodology. However, the data already exists in a convenient format and modeling framework to conduct a "square" contribution analysis is relatively straightforward, as we will demonstrate below.

The methodology, employed initially by Waters, Weber, and Holland (1998), simply requires diagonalizing exogenous final demand. In particular, an (n x n) economic base model is the product of an (n x n) Leontief inverse matrix of multipliers that include the effects of endogenous household spending and an (n x n) diagonalized vector of exogenous final demand. The key to this approach is this diagonalized vector, which has exogenous final demand expressed as elements on the principle diagonal with zeros on all the off diagonal elements. The result is an economic base matrix that simultaneously separates export base contributions for each sector as a row of column vector sums and gross contributions as a column of row vector sums. The export base and gross measures by sector are internally consistent and externally correspondent for a regional economy. The total of the export base and gross measures across sectors are equal to each other and to the total output for the economy but are almost always unequal by sector.

The data for economic contribution analysis are readily available in the social accounts of a commonly used commercial product – IMPLAN (Rodriguez, Braak, and Watson, 2011). IMPLAN is currently the most common tool used in the literature to conduct an economic contribution study. IMPLAN data provide double-entry bookkeeping social accounts showing the region's primary and intermediate inputs used in production as well as its goods and services consumed for final demand for each county in the U.S. with a one year publication lag. Social accounting data in general are "square" because of the accounting requirement that production equals consumption both by sector and overall. This is exactly the data needed for comprehensive contribution analysis at the local level.

An economic base contribution methodology is applied to readily available IMPLAN data for several heterogeneous regions in the U.S. to demonstrate the broad applicability of this approach. An important bonus from doing comprehensive base contribution analysis is the revelation that dramatically different conclusions can be drawn from these measures when used in isolation because of the difference in the strength of the role sectors play in bringing or keeping money in the economy. A sector's rank order of relative importance can change dramatically when switching between the export base and gross measures of economic activity. This suggests that both base measures are needed for a more complete picture of a sector's importance to a regional economy.

We propose that the method described here is the most appropriate and theoretically sound method for conducting an input-output based ex ante economic contribution study for any given sector in any given region. The export base and gross output vectors can also be used to determine similar vectors of employment, wages, or value added using sector-specific ratios of the respective economic activity measure to the industry's output (Miller and Blair, 2009). The combination of different metrics in different units can be used as dependent and independent variables to explore questions of competitive advantage, diversity, resilience, dependency, typology, and growth.

2. Deriving the Comprehensive Economic Base of an Economy

When doing comprehensive economic base analysis, data and method intersect in the concept of social accounts. Because of their central role, let's begin with a brief overview of social accounts and their expression within a social accounting matrix. Social accounts connect total aggregate demand and supply for an entire economy. A social accounting matrix connects total demand and supply by sector.

The social account of total aggregate demand for a region represents the combined effect of intermediate demand among sectors as well as final demand for goods and services by institutions including households, private and public investments, and exports. The accounting identity for total aggregate demand is defined as:

$$Z + C + I + G + E \equiv X \tag{1}$$

The elements of aggregate demand are as follows: Z is intermediate demand, C is household demand, I is private investment demand, G is public investment and government spending, and E is export demand. X represents total industrial output.

The social account for total aggregate supply is the combined effect of firms producing their goods and services by using primary, intermediate, and imported inputs. Intermediate inputs are defined as the part of a sector's output used as an input to produce another sector's output. These inputs are intermediate in the sense that their value can be disaggregated back into the primary inputs of labor and private and public capital used to make them. The social accounting identity for total aggregate supply is defined as:

$$Z + L + K + T + M \equiv X \tag{2}$$

The elements of total aggregate supply are defined as follows: Z is intermediate input supply, L is the value added from labor, K is the value added from private capital, T is the value added from public capital paid as indirect business taxes, and M is the imports used in production. X represents total industrial outlays.

In passing, a region's gross regional product, i.e., income, is derived by setting total aggregate demand equal to total aggregate supply. We can let eq. (1) equal eq. (2) because total industrial output (X) equals total industrial outlays (X) in both an accounting and economic sense.

$$C + I + G + E - M = L + K + T \tag{3}$$

Eq. (3) shows that gross regional product equals either net final demand—net of imports—or total value added. Net final demand is the endogenous and exogenous output consumed by institutions: households, investment, government, and exports minus imports. Total value added is the sum of the returns to the primary inputs of labor and public and private investment. The social accounting connection between value added and net final demand exists largely though a system of transfer payments. Transfer payments are made from the primary inputs of labor and capital to the institutions of households, private investors, and governments' investment and spending.

The comprehensive accounting approach to production, consumption, and transfer payments by sector across institutions represents a social accounting matrix of a regional economy. An example of a social accounting matrix from a simple economy in Table 1 shows the data needed by the economic base contribution model. This is an economy with six sectors, two institutions, and two primary inputs plus exports and imports. The first six rows show the intermediate demand purchases made by sectors from each other and the final demand purchases by institutions, the row sum of which equals total output. The first six columns record the value of the intermediate inputs supplied as well as payments to labor, capital, taxes, and imports necessary for production, the sum of which equals total outlays. Purchases by and transfer payments to and from households, investors, government, and for export make up the remaining column elements. This economy produces an observed total aggregate output of \$9,191 million − a key number to compare with subsequent base and gross output model results in order to check for double counting. At the end of the paper, the comprehensive economic base model is applied to additional representative economies with more disaggregated sectors to further illustrate how this model works.

Table 1. A U.S. county's social accounting matrix (millions $).

	Intermediate inputs (z)						Final demand: endogenous.		Final demand: exogenous (y)	Total	
	Agr.	Util.	Const.	Manuf.	Transp.	Serv.	HH (C)	Invest. (G + I)	Exports (E)	Output (X)	Rank
Agriculture	0.6	0.0	0.1	12.4	0.0	0.8	1.8	0.1	5.5	21.3	6
Utility	0.2	0.2	1.1	28.0	8.3	29.4	39.3	10.1	99.1	215.8	5
Construction	0.1	2.7	0.4	5.1	7.2	21.0	0.0	304.3	11.2	352.0	4
Manufacture	1.4	2.9	44.7	378.3	113.0	106.8	156.1	127.1	1562.6	2492.6	2
Transport	0.1	3.9	2.3	21.3	79.0	19.3	16.5	6.8	2048.8	2198.0	3
Service	2.2	6.6	65.9	325.7	356.2	519.3	1075.7	295.1	1264.9	3911.6	1
	Value added						Transfers				
Labor (L)	5.1	59.7	100.8	465.5	583.6	1383.6	134.6	352.6	0.1		3085.6
Capital (K+T)	2.5	59.1	12.3	207.4	252.7	760.5	976.5	630.1	41.7		2942.9
Imports (M)	9.0	80.7	124.5	1049.0	798.0	1070.9	685.1	1216.8	0.0		5034.0
Total Outlays (X)	21.3	215.8	352.0	2492.6	2198.0	3911.6	3085.6	2942.9	5034.0	9191.2	

Source: David Kay

Mathematically, a social accounting matrix for output by sector x_i can be expressed as a symbolic set of total demand equations:

$$
\begin{array}{llllll}
a_{11}x_1 & +a_{12}x_2 & +\cdots & +a_{1n+1}x_{n+1} & +y_1 & =x_1 \\
a_{21}x_1 & +a_{22}x_2 & +\cdots & +a_{2n+1}x_{n+1} & +y_2 & =x_2 \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
a_{n+11}x_1 & +a_{n+12}x_2 & +\cdots & +a_{n+1n+1}x_{n+1} & +y_{n+1} & =x_{n+1}
\end{array} \tag{4}
$$

The row-column elements i and j (i,j = 1 ... n), respectively, of the demand equations include those for intermediate demand by sector Z as $a_{ij}x_j$, endogenous final demand by institution ij ($i,j = n+1$) − in this case ($C + I + G$) − as $a_{in+1}x_{n+1}$ and the exogenous final demand for exports ($y_i = E$) (Chiang and Wainwright, 2005).

In the set of eqs. (4), each element for intermediate demand is expressed as the share of total outlay ($z_{ij}/x_j = a_{ij}$) multiplied by the sector's total industrial outlays. In the case of endogenous final demand, the shares correspond to household spending and public and private investments as shares of the column total for these categories of final demand ($z_{in+1}/x_{n+1} = a_{in+1}$). The ($n$ x n) "A" matrix of intermediate input shares is bordered by an additional row and column represented here for simplicity as the sum of endogenous household, investment, and government income and spending, respectively. The result is an augmented A matrix of size (n+1 x n+1) (Miller and Blair, 2009, p. 26). A region's augmented matrix of sector shares is presented in Table 2.

Table 2. A U.S. county's social accounting matrix of factor and institution shares: augmented (A) matrix.

	Agr.	Util.	Const.	Manuf.	Transp.	Serv.	HH	Invest.
Agr.	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Util.	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.00
Const.	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.10
Manuf.	0.07	0.01	0.13	0.15	0.05	0.03	0.05	0.04
Transp.	0.01	0.02	0.01	0.01	0.04	0.00	0.01	0.00
Serv.	0.10	0.03	0.19	0.13	0.16	0.13	0.35	0.10
Labor	0.24	0.28	0.29	0.19	0.27	0.35	0.04	0.12
Capital	0.12	0.27	0.03	0.08	0.11	0.19	0.32	0.21
Imports	0.42	0.37	0.35	0.42	0.36	0.27	0.22	0.41
Outlays	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Solving the set of equation in (4) for the dependent variables (x_j) in terms of their independent variables (y_i) we find:

$$\begin{array}{llllll} x_1 & -a_{11}x_1 & -a_{12}x_2 & -\cdots & -a_{1n+1}x_{n+1} & = y_1 \\ x_2 & -a_{21}x_1 & -a_{22}x_2 & -\cdots & -a_{2n+1}x_{n+1} & = y_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{n+1} & -a_{n+11}x_1 & -a_{n+12}x_2 & -\cdots & -a_{n+1n+1}x_{n+1} & = y_{n+1} \end{array} \quad (5)$$

The set of equation in (5) can be simplified by combining like terms for the dependent variables:

$$\begin{array}{lllll} (1-a_{11})x_1 & -a_{12}x_2 & -\cdots & -a_{1n+1}x_{n+1} & = y_1 \\ -a_{21}x_1 & +(1-a)_{22}x_2 & -\cdots & -a_{2n+1}x_{n+1} & = y_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ -a_{n+11}x_1 & -a_{n+12}x_2 & -\cdots & +(1-a_{n+1n+1})x_{n+1} & = y_{n+1} \end{array} \quad (6)$$

The parameters on the left hand side of the set of eqs. in (6) are represented numerically for a region as a coefficients matrix in Table 3.

Table 3. A U.S. county's social accounting matrix of coefficients: augmented (I-A) matrix.

	Agr.	Util.	Const.	Manuf.	Transp.	Serv.	HH	Invest.
Agr.	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Util.	-0.01	1.00	0.00	-0.01	0.00	-0.01	-0.01	0.00
Const.	0.00	-0.01	1.00	0.00	0.00	-0.01	0.00	-0.10
Manuf.	-0.07	-0.01	-0.13	0.85	-0.05	-0.03	-0.05	-0.04
Transp.	-0.01	-0.02	-0.01	-0.01	0.96	0.00	-0.01	0.00
Serv.	-0.10	-0.03	-0.19	-0.13	-0.16	0.87	-0.35	-0.10
Labor	-0.24	-0.28	-0.29	-0.19	-0.27	-0.35	0.96	-0.12
Capital	-0.12	-0.27	-0.03	-0.08	-0.11	-0.19	-0.32	0.79

Writing the set of coefficients ($1-a_{ij}$) and the sets of dependent and independent variables x_j and y_i in eq. (6) as rectangular arrays with labels (I-A), x, and y, respectively, we have:

$$(I-A)=\begin{bmatrix} (1-a_{11}) & -a_{12} & \dots & -a_{1n+1} \\ -a_{21} & (1-a_{22}) & \cdots & -a_{2n+1} \\ \vdots & \vdots & \vdots & \vdots \\ -a_{n+11} & -a_{n+12} & \cdots & (1-a_{n+1n+1}) \end{bmatrix}, \quad (7)$$

$$x=\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_{n+1} \end{bmatrix} \quad and \quad y=\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_{n+1} \end{bmatrix}$$

(Chiang and Wainwright, 2005, p. 49).

Applying this compact notation to eq. (6) and solving for the output vector x as a function of exogenous final demand y we find:

$$x=(I-A)^{-1}y \quad (8)$$

Output vector x is the product of the matrix of output multipliers $(I\text{-}A)^{-1}$ and the vector of exogenous final demand y. Examples of the Leontief inverse $(I\text{-}A)^{-1}$ multiplier matrix are presented for the example region both without and with the induced effects from endogenous institutions' spending in Tables 4 and 5, respectively. Output multipliers that include the direct and indirect effects only are labeled "type 1," while "type 2" multipliers include the induced effects.

Table 4. A U.S. county's social accounting matrix of type 1 output multipliers: $(I\text{-}A)^{-1}$ of direct and indirect effects by sector.

	Agr.	Util.	Const.	Manuf.	Transp.	Serv.
Agr.	1.031	0.000	0.001	0.006	0.000	0.000
Util.	0.013	1.001	0.007	0.015	0.006	0.009
Const.	0.004	0.013	1.003	0.004	0.005	0.006
Manuf.	0.086	0.020	0.159	1.187	0.070	0.039
Transp.	0.008	0.019	0.010	0.012	1.039	0.007
Serv.	0.136	0.045	0.242	0.183	0.206	1.162
Multiplier	**1.278**	**1.099**	**1.421**	**1.406**	**1.327**	**1.224**
Rank	4	6	1	2	3	5

Table 5. A U.S. county's social accounting matrix of type 2 output multipliers: $(I\text{-}A)^{-1}$ of direct, indirect and induced effects by sector.

	Agr.	Util.	Const.	Manuf.	Transp.	Serv.	HH	Invest.
Agr.	1.032	0.001	0.002	0.007	0.001	0.002	0.002	0.001
Util.	0.025	1.015	0.021	0.026	0.020	0.026	0.030	0.016
Const.	0.060	0.088	1.056	0.054	0.066	0.084	0.090	0.167
Manuf.	0.164	0.114	0.242	1.258	0.157	0.145	0.171	0.147
Transp.	0.015	0.028	0.017	0.018	1.047	0.016	0.017	0.011
Serv.	0.442	0.395	0.588	0.464	0.550	1.577	0.748	0.421
Labor	0.550	0.585	0.654	0.506	0.621	0.739	1.499	0.441
Capital	0.518	0.708	0.492	0.467	0.566	0.719	0.824	1.585
Multipliers	**1.738**	**1.641**	**1.927**	**1.827**	**1.841**	**1.850**	**1.057**	**0.764**
Rank	5	6	1	4	3	2	7	8

The model of comprehensive economic base analysis uses the type 2 multiplier matrix that include induced effects. An example of the source of induced effects is the link from regional wages to labor and household spending. This link is an expression of endogenous consumption − money earned in the region that is also spent in the region. A sector's export demand typically creates the combined effects of induced along with the direct and indirect effects. Interestingly, a source of pure induced effects happens when outside-the-region payments, e.g., social security payments from the federal government, are made to households. Regional household spending from outside sources of income can have a strong induced effect, but it does not have any direct or indirect effect. This is because, by convention, institutions like households do not produce an output as measured by social accounts. As shown below, a comprehensive economic base contribution analysis allows the data within the social accounts of a region to determine its export base without the prejudice of imposing a predetermined notion of what constitutes that base. Thus the base contribution method can reveal the effects that exogenous household transfers into a region have on its export base through the induced effect alone − an innovative way to understand an economy. Similar examples could be found for public and private investments.

By applying a bit of vector calculus to eq. (8), the derivative of x with respect to y allows the analyst to do ex ante impact analysis for one sector, all sectors, or anything in between. However, for comprehensive economic base analysis purposes, eq. (8) helps us check the math of matrix inversion but adds little else, because, ex post, the "gross" output by sector x_j is already known (see Table 1). For comprehensive contribution analysis we would like to know not only "gross" output, but also "base" output and the individual elements from which they are derived.

To fully appreciate how it is possible to measure gross and export base output simultaneously, we need a more detailed understanding of how the output multipliers are calculated. To understand output multipliers, we need to look carefully at how an (I-A) matrix is inverted. Mathematically, matrix inversion can be defined as the process of dividing the adjoint (*adj*) of a matrix by a scalar − the matrix determinant (*det*) (Cullen, 1972, p. 119). An adjoint matrix is a set of coefficients whose elements equal the transposed cofactors (*cof*) of the matrix. A cofactor equals the determinant of a minor (*M*) adjusted for the correct sign. A minor is a sub-matrix of the original matrix in which the row and column at the intersection of the minor in question have been deleted (Cullen, 1972, p. 111). The matrix inversion can now be represented as:

$$\begin{aligned}(I-A)^{-1} &= \frac{1}{\det(I\text{-}A)}adj(I-A)\\ &= \frac{1}{\det(I\text{-}A)}\begin{bmatrix} cof_{1,1}(I-A) & cof_{2,1}(I-A) & cof_{3,1}(I-A)\\ cof_{1,2}(I-A) & cof_{2,2}(I-A) & cof_{3,2}(I-A)\\ cof_{1,3}(I-A) & cof_{2,3}(I-A) & cof_{3,3}(I-A)\end{bmatrix},\end{aligned} \quad (9)$$

where: $cof_{ij}(I-A) = (-1)^{i+j}\det\left(M_{ij}(I-A)\right)$

Economically, from structural path analysis, we know that each symbolic cofactor-determinant interaction pair of the $(I\text{-}A)^{-1}$ multiplier matrix represents all the direct and indirect paths of the supply chains that are possible between the origination and destination sectors associated with the subscripts of a given multiplier element (Defourny and Thorbecke, 1984).

The cofactor elements that go into the gross output calculation can be reconstituted to produce a base output multiplier. First, let's analyze the derivation of the vector of gross output using the information from eqs. (8) and (9). The vector of gross output equals the sum of product of a scalar (one over the determinant), the vector of exogenous final demand, and the matrix of transposed cofactors:

$$\begin{aligned} x &= (I-A)^{-1} y \\ &= \frac{1}{\det(I\text{-}A)} \begin{bmatrix} cof_{1,1}(I-A) & cof_{2,1}(I-A) & cof_{3,1}(I-A) \\ cof_{1,2}(I-A) & cof_{2,2}(I-A) & cof_{3,2}(I-A) \\ cof_{1,3}(I-A) & cof_{2,3}(I-A) & cof_{3,3}(I-A) \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} \\ &= \frac{1}{\det(I\text{-}A)} \begin{bmatrix} cof_{1,1}(I-A)y_1 + cof_{2,1}(I-A)y_2 + cof_{3,1}(I-A)y_3 \\ cof_{1,2}(I-A)y_1 + cof_{2,2}(I-A)y_2 + cof_{3,2}(I-A)y_3 \\ cof_{1,3}(I-A)y_1 + cof_{2,3}(I-A)y_2 + cof_{3,3}(I-A)y_3 \end{bmatrix} \end{aligned} \tag{10}$$

A given sector's gross output equals the sum of 1) the product of the scalar and the dot product of the vector of exogenous final demand; and 2) a set of cofactors whose destinations change but their origination does not. Between sectors, only differences in size of the cofactor change the amount of gross output. From structural path analysis, it can be assumed that the size of a cofactor-determinant interaction varies directly with the number and strength of the supply chains between the pair of origination and destination sectors that exist in the region.

Without losing the original pattern, a base output multiplier represents a patterned re-aggregation of the cofactor-exogenous final demand elements that make up a gross multiplier. A diagonalized vector of exogenous final demand is responsible for making this subtle restructuring possible − to which we turn next. To diagonalize an (n x 1) vector is to place the n row elements along the corresponding principle diagonal's row of an (n x n) matrix with zero in all the off-diagonal elements. The importance of diagonalizing a vector becomes apparent in the process of matrix multiplication. The product of matrix-vector multiplication is a vector, while the product of matrix-matrix multiplication is a matrix. By diagonalizing a final demand vector into a matrix, the resulting output matrix effectively disaggregates the elements contained within an output vector (Waters, Weber, and Holland, 1998). This allows the analyst to "look inside" a calculation in hopes of finding previously hidden important relationships.

To diagonalize vector y is to transform it into *diag*(y):

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} \rightarrow \begin{bmatrix} y_1 & 0 & 0 \\ 0 & y_2 & 0 \\ 0 & 0 & y_3 \end{bmatrix} \tag{11}$$

So, by diagonalizing the vector of exogenous final demand, the resulting output matrix contains the elements needed for both the gross and base measures of output:

$$\begin{aligned} X_B^G &= (I-A)^{-1} diag(y) \\ &= \frac{1}{\det(I\text{-}A)} \begin{bmatrix} cof_{1,1}(I-A) & cof_{2,1}(I-A) & cof_{3,1}(I-A) \\ cof_{1,2}(I-A) & cof_{2,2}(I-A) & cof_{3,2}(I-A) \\ cof_{1,3}(I-A) & cof_{2,3}(I-A) & cof_{3,3}(I-A) \end{bmatrix} \begin{bmatrix} y_1 & 0 & 0 \\ 0 & y_2 & 0 \\ 0 & 0 & y_3 \end{bmatrix} \\ &= \frac{1}{\det(I\text{-}A)} \begin{bmatrix} cof_{1,1}(I-A)y_1 & cof_{2,1}(I-A)y_2 & cof_{3,1}(I-A)y_3 \\ cof_{1,2}(I-A)y_1 & cof_{2,2}(I-A)y_2 & cof_{3,2}(I-A)y_3 \\ cof_{1,3}(I-A)y_1 & cof_{2,3}(I-A)y_2 & cof_{3,3}(I-A)y_3 \end{bmatrix} \end{aligned} \tag{12}$$

An example of the diagonalized matrix of exogenous final demand for the example region is found in Table 6, which shows the exports by sector on the major diagonal − households and public and private investments have transfer payments on the diagonal rather than exports.

Table 6. A U.S. county's diagonalized matrix of exogenous final demand: exports and transfer payments.

	Agr.	Util.	Const.	Manuf.	Transp.	Serv.	HH	Invest.
Agr.	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Util.	0.0	99.1	0.0	0.0	0.0	0.0	0.0	0.0
Const.	0.0	0.0	11.2	0.0	0.0	0.0	0.0	0.0
Manuf.	0.0	0.0	0.0	1562.6	0.0	0.0	0.0	0.0
Transp.	0.0	0.0	0.0	0.0	2048.8	0.0	0.0	0.0
Serv.	0.0	0.0	0.0	0.0	0.0	1264.9	0.0	0.0
Labor	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Capital	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.7

The symbolic array of elements found in the output matrix in eq. (12) is identical to those that make up the vector of output in eq. (10). The only difference is that within the output matrix these elements are not yet added together.

By adding the elements of the output matrix of eq. (11) across the rows, the results are the same measure of gross output as those created using the vector of final demand in eq. (10):

$$
\begin{aligned}
x^G &= \sum_{i=1}^{3}(I-A)^{-1}diag(y) \\
&= \frac{1}{\det(I\text{-}A)}\begin{bmatrix} cof_{1,1}(I-A)y_1 & +cof_{2,1}(I-A)y_2 & +cof_{3,1}(I-A)y_3 \\ cof_{1,2}(I-A)y_1 & +cof_{2,2}(I-A)y_2 & +cof_{3,2}(I-A)y_3 \\ cof_{1,3}(I-A)y_1 & +cof_{2,3}(I-A)y_2 & +cof_{3,3}(I-A)y_3 \end{bmatrix} \\
&= (I-A)^{-1}(y)
\end{aligned}
\tag{13}
$$

Not only can the output matrix be aggregated across the row, but also down the column:

$$
\begin{aligned}
x_B &= \sum_{j=1}^{3}(I-A)^{-1}diag(y) \\
&= \frac{1}{\det(I\text{-}A)}\begin{bmatrix} cof_{1,1}(I-A)y_1 & +cof_{1,2}(I-A)y_1 & +cof_{1,3}(I-A)y_1 \\ cof_{2,1}(I-A)y_2 & +cof_{2,2}(I-A)y_2 & +cof_{2,3}(I-A)y_2 \\ cof_{3,1}(I-A)y_3 & +cof_{3,2}(I-A)y_3 & +cof_{3,3}(I-A)y_3 \end{bmatrix}^T
\end{aligned}
\tag{14}
$$

The sum of the column elements of the output matrix is called base output.

Similar to gross output, base output is the product of a scalar (one over the determinant), the matrix of transposed cofactors, and the vector of exogenous final demand. However, within sectors, these results show that base output equals the sum of 1) the interactions of the product of the determinant and the dot product of a single sector's exogenous final demand; and 2) a set of cofactors whose origination changes but their destination does not. Between the sectors, not only do the cofactors change but also the sector associated with exogenous final demand. The difference found in the cofactors and exogenous final demand when measuring gross and base output will be helpful in distinguishing between them more clearly below.

Because the grand total within the output matrix is independent of the order of adding across rows and columns, the sum down the column of row vector totals is equal to the sum across the row of the column vector totals. In addition, these aggregate gross and base output totals are equal to the observed total output for the economy − ensuring no double counting.

A comprehensive economic base analysis of the simple regional economy is presented in Table 7. The principle diagonal includes primarily the measure of the direct effects − in this case the final demand for exports − and secondarily own indirect effects − a sector's using its own output as an input to produce its output. For example, the agriculture sector produced \$5.5 million in exports plus another \$0.2 million as an input into its own production process. The off diagonal elements measure the indirect and induced effects between sectors and institutions. Adding down the column, the agricultural sector generates a total of \$9.6 million in base output and across the row it provides \$21.3 million in gross output. The sum across sectors of base output equals that for gross output, which equals the observed total aggregate output: \$9,191.2 million − verifying no double counting.

Table 7. A U.S. county's comprehensive economic base contribution analysis: gross and export base.

	Agr.	Util.	Const.	Manuf.	Transp.	Serv.	HH	Invest	Gross Output	Rank
Agr.	**5.7**	0.1	0.0	10.8	2.7	2.0	0.0	0.0	**21.3**	6
Util.	0.1	**100.6**	0.2	40.7	40.9	32.6	0.0	0.7	**215.8**	5
Const.	0.3	8.8	**11.9**	84.0	134.3	105.7	0.0	7.0	**352.0**	4
Manuf.	0.9	11.3	2.7	**1965.5**	322.1	183.9	0.0	6.1	**2,492.6**	2
Transp.	0.1	2.7	0.2	28.7	**2145.3**	20.5	0.0	0.5	**2,197.9**	3
Serv.	2.4	39.1	6.6	724.5	1126.0	**1995.2**	0.1	17.6	**3,911.6**	1
Base Output	**9.6**	**162.7**	**21.7**	**2,854.2**	**3,771.2**	**2,339.9**	**0.1**	**31.9**	**9,191.2**	
Rank	7	4	6	2	1	3	8	5		

3. Interpreting base and gross output measures of economic contributions

From eq. (11) it is apparent that the principle diagonal element of the output matrix − a measure of direct and own indirect effects − appears in both the gross (row sum) and base (column sum) measures of output. Therefore, the gross and base measures differ only in the off-diagonal elements of the economic output matrix. These off-diagonal elements measure the indirect and induced effects.

We know that elements of a sector's gross output equals the sum of the product of a scalar and the dot product of the vector of each sector's exogenous final demand and a set of cofactor supply chains whose origination is constant but their destinations change. Therefore, the off-diagonal elements of gross output must be a given origination sector's production of intermediate and induced inputs needed to supply all destination sectors as they produce their goods and services to meet exogenous final demand. Gross output is a measure of a sector's capacity to produce goods and services to meet intermediate and endogenous final demand in the region. Gross output is a sector's production used to help all other sectors produce their exports. Gross output is a quantitative measure of the contribution of a sector to keep money in the region.

A sector's base output equals the sum of the interactions of a scalar and the dot product of a single sector's exogenous final demand and a set of cofactor supply chains whose origination changes but their destination does not. The off-diagonal elements of the base output are the production of intermediate and induced inputs across all origination sectors needed by the destination sector to produce goods and services to meet its exogenous final demand. Base output measures a sector's ability through its exports to bring forth goods and services from other sectors to help meet its exogenous final demand. Base output is a quantitative measure of the contribution of a sector to bring money into the region.

For the simple regional economy, the comprehensive economic base analysis shows that all six sectors make both base and gross output contributions, albeit in differing amounts. The sectors with the largest base and gross output are transportation and services, respectively (see Table 8 and Figure 1 for examples). The combination of the export of transportation services and its demand for goods and services from other sectors to produce the exported transportation services makes the transportations sector the largest export base contributor in the region. The transportation sector is most responsible for bringing money into the economy. The service sector's output—as an input to all other sectors as they produced goods and services to meet their exogenous final demand—makes the largest gross output contribution in the region. The service sector is most responsible for keeping money in the economy.

Table 8. Comparison of economic measures and ranks.

	Agr.	Util.	Const.	Manuf.	Transp.	Serv.	HH	Invest.
Measure ($ million)								
Gross Output	21.3	215.8	352.0	2,492.6	2,198.0	3,911.6	na	na
Export Base	9.6	162.7	21.7	2,854.2	3,771.2	2,339.9	0.1	31.9
Rank by:								
Gross Output	6	5	4	2	3	1	na	na
Export Base	7	4	6	2	1	3	8	5

4. Results from example regions

In Table 1, if the size of the output within a social accounting matrix is used to determine the importance of a sector to this economy, an argument could be made for the service sector being most important. If the size of exogenous final demand is used as a criterion, then the transportation sector is first. In Table 4, if the size of the type 1 multiplier is used as the criterion for measuring the importance of a sector, then the construction sector would be selected. Table 5 shows the type 2 output multipliers for a model of the economy. Again the top sector in this economy is construction based on the size of its type 2 multiplier. Table 7 shows that using the comprehensive economic base analysis, the service sector makes the largest gross contribution and the transportation sector makes the largest base contribution. Table 8 shows the results of the rankings across both a gross output and base output as measures of a sector's economic contribution to the economy. Depending on the criteria, Tables 1, 4, and 5 suggest that services, transportation, or construction is the largest sector in the region's economy. Comprehensive economic base analysis presented in Tables 7 and 8 clarifies the relative importance of these sectors to the regional economy and provides a theoretical foundation for its assertions.

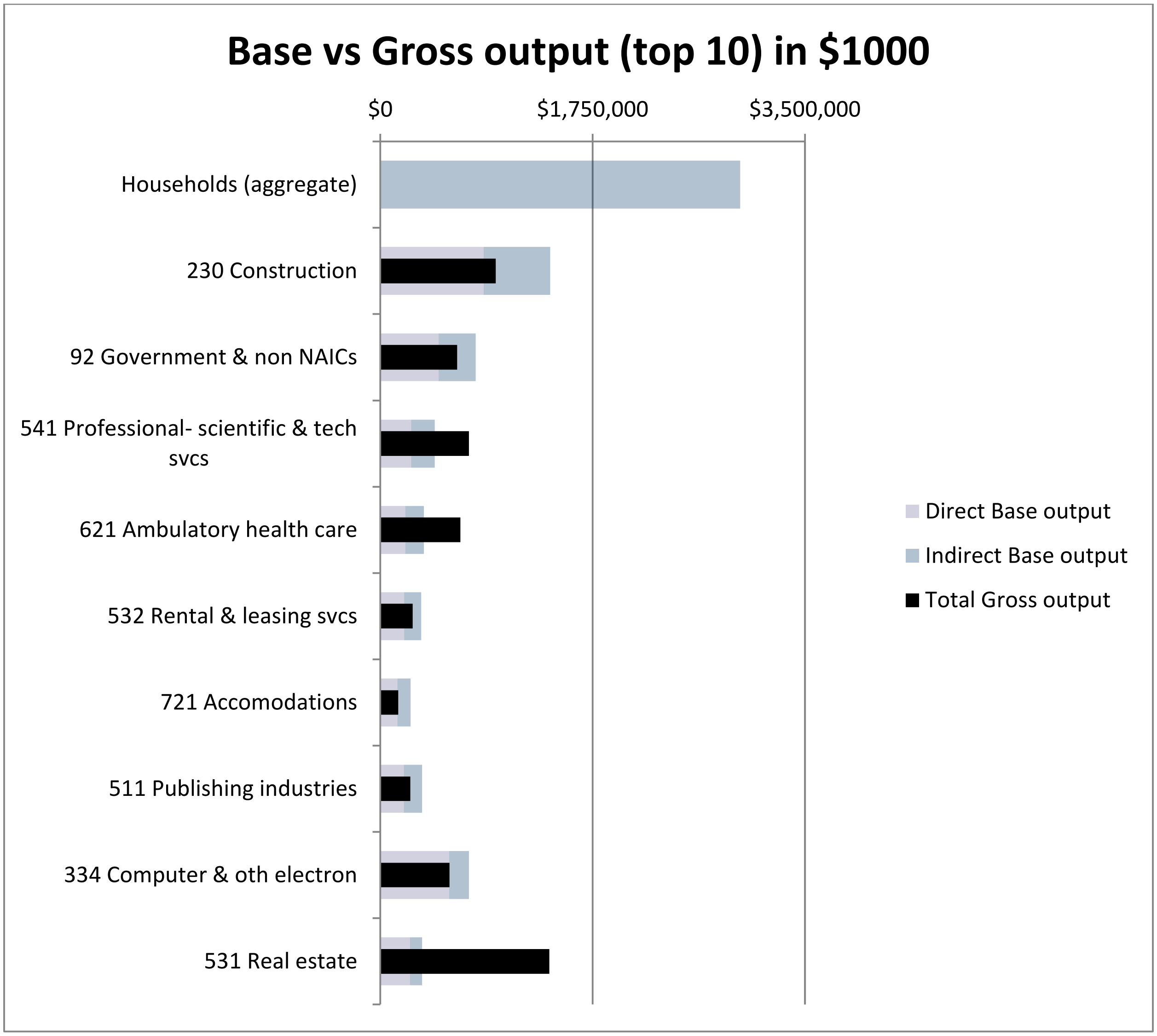

Figure 1. Base and gross measures of output by sector for Deschutes County, OR.

We next present the results of economic base models for three illustrative regions: New Hanover County, North Carolina; Deschutes County, Oregon; and Wayne County, Michigan. While the specific results of the economic base measure and how it differs from the gross measure of economic activity will vary from region to region, it is most likely that the economic base measures will be substantially different from the gross measures. The economic base measures not only provide a theoretically sound measure of the economic contribution of each sector of the economy, but the two measures of economic activity can be used to perform further analysis which can shed additional light on the structure of the regional economy. For example, we will use both the gross and base measures of economic activity to calculate different measures of the economic diversity of the respective regions. The base output matrix can then be translated into other economic activity measures (e.g., employment, wages, value added) using sector-specific ratios of the respective economic activity to output in the region.

The results of the top 10 sectors in terms of gross employment and economic base employment for New Hanover County, North Carolina, are presented in Table 9. This table nicely illustrates the different picture that arises when looking at gross versus base measures of economic activity. For example, in terms of gross employment, NAICS code 722 (food services/restaurants) is the second biggest employer in the county, and chemical manufacturing (NAICS code 325) is not even in the top 25 in gross employment. However, in terms of base employment, chemical manufacturing represents the third largest contributor to employment in the county, which from an economic export base perspective is responsible for generating 9% of the total jobs in the region.

Table 9. Gross and base measures of employment in Hannover County, NC.

Top Sectors	Gross Empl.	% Gross Empl.	Top Sectors	Base Empl.	% Base Empl.
92 Government & non NAICs	18,796	14.6%	Households(aggregate)	30,677	23.8%
722 Food svcs & drinking places	12,954	10.0%	92 Government & non NAICs	19,006	14.7%
541 Prof- sci & tech svcs	9,196	7.1%	325 Chemical Manufacturing	11,637	9.0%
621 Ambulatory health care	9,185	7.1%	230 Construction	10,538	8.2%
531 Real estate	8,935	6.9%	541 Prof- sci & tech svcs	6,796	5.3%
230 Construction	6,856	5.3%	621 Ambulatory health care	6,062	4.7%
561 Admin support svcs	6,824	5.3%	722 Food svcs & drinking places	5,623	4.4%
42 Wholesale Trade	3,718	2.9%	336 Transportation eqpmt	4,592	3.6%
623 Nursing & residential care	2,824	2.2%	531 Real estate	3,396	2.6%
452 General merch stores	2,710	2.1%	517 Telecommunications	3,329	2.6%

Table 10 shows the largest sectors in New Hanover in terms of wages paid, which is arguably a better economic activity measure of a sector's contribution than employment. In 2012, the chemical manufacturing sector was responsible for $140 million in gross wages, or about 3% of the total wages paid in the region. However, in economic base terms the chemical manufacturing sector was responsible for supporting almost $600 million in regional wages, or 12% of the county's wages. In this case, the economic base measure of regional wages differs from the gross measure by 325% and gives a very different picture of what sectors are responsible for generating the region's wages.

Table 10. Gross and base economic wages in Hannover County, NC.

Top Gross Sectors	Gross Wages (in $1000)	Percent of Wages	Top Base Sectors	Base Wages (in $1000)	Percent of Wages
92 Government & non NAICs	$1,040,432	20.31%	92 Government & non NAICs	$933,011	18.21%
541 Prof- sci & tech svcs	$532,722	10.40%	Households (aggregate)	$921,344	17.99%
621 Ambulatory health care	$474,183	9.26%	325 Chemical Manufacturing	$594,552	11.61%
230 Construction	$297,752	5.81%	230 Construction	$416,417	8.13%
722 Food svcs & drinking places	$237,739	4.64%	541 Prof- sci & tech svcs	$318,220	6.21%
42 Wholesale Trade	$234,839	4.58%	336 Transportation eqpmt	$315,529	6.16%
336 Transportation eqpmt	$217,096	4.24%	621 Ambulatory health care	$267,419	5.22%
561 Admin support svcs	$196,970	3.85%	517 Telecommunications	$152,224	2.97%
325 Chemical Manufacturing	$140,248	2.74%	327 Nonmetal mineral prod	$126,097	2.46%
517 Telecommunications	$116,659	2.28%	722 Food svcs & drinking places	$119,115	2.33%
441 Motor veh & parts dealers	$105,008	2.05%	42 Wholesale Trade	$94,841	1.85%
327 Nonmetal mineral prod	$95,901	1.87%	521 Monetary authorities	$85,025	1.66%
521 Monetary authorities	$87,960	1.72%	531 Real estate	$57,617	1.12%
623 Nursing & residential care	$87,465	1.71%	441 Motor veh & parts dealers	$57,252	1.12%
551 Management of companies	$80,814	1.58%	561 Admin support svcs	$56,824	1.11%

Wages paid in Wayne County, Michigan, home to Detroit, show an even more dramatic difference between gross and base measures (Table 11). In this case the largest contributor to base wages, transportation equipment, is only the third largest sector in actual wages paid. In terms of gross wages, the transportation equipment in the county paid $4 billion in 2012, accounting for 8% of the total. However, in terms of base wages, transportation equipment was responsible for generating over $9.6 billion of the region's wages and is the single biggest contributor to regional wages. This provides a better metric of the importance of auto manufacturing in the region and quantifies just how much the sector contributes to income across the economy.

Table 11. Gross and base wages in Wayne County, MI.

Top Gross Sectors	Gross Wages (in $1000)	Percent of Wages	Top Base Sectors	Base Wages (in $1000)	Percent of Wages
92 Government & non NAICs	$6,678,494	13.81%	336 Transportation eqpmt	$9,634,243	19.92%
541 Prof- sci & tech svcs	$5,770,885	11.93%	Households (aggregate)	$8,654,401	17.89%
336 Transportation eqpmt	$4,016,070	8.30%	92 Government & non NAICs	$5,884,634	12.17%
622 Hospitals	$3,565,199	7.37%	541 Prof- sci & tech svcs	$3,974,496	8.22%
551 Management of companies	$2,578,128	5.33%	622 Hospitals	$2,013,488	4.16%
42 Wholesale Trade	$2,493,747	5.16%	230 Construction	$1,909,943	3.95%
621 Ambulatory health care	$2,165,817	4.48%	481 Air transportation	$1,528,607	3.16%
561 Admin support svcs	$1,682,679	3.48%	551 Management of companies	$1,394,412	2.88%
230 Construction	$1,479,157	3.06%	331 Primary metal mfg	$1,367,308	2.83%
722 Food svcs & drinking places	$1,208,697	2.50%	333 Machinery Mfg	$1,175,629	2.43%
481 Air transportation	$1,035,856	2.14%	332 Fabricated metal prod	$1,170,606	2.42%
332 Fabricated metal prod	$795,620	1.65%	42 Wholesale Trade	$1,026,485	2.12%
522 Credit inmediation & related	$750,919	1.55%	325 Chemical Manufacturing	$751,848	1.55%
813 Religious- grantmaking- & similar orgs	$703,011	1.45%	511 Publishing industries	$604,142	1.25%
611 Educational svcs	$684,070	1.41%	721 Accomodations	$588,602	1.22%

Deschutes County, Oregon, a high natural amenity county in the Cascade Mountains, highlights another strength of this method − the ability to consistently attribute economic activity to endogenous institutional accounts, such as households, based on the non-labor income they bring into the region and their spending patterns. For example, in terms of gross employment, the government, food services, and professional and scientific services sectors are the three largest in the county (Table 12). However, after performing the economic base contribution analysis, households become the largest generator of jobs in the region. This does not mean that people are working in the household directly; it means that the exogenous non-labor or commuter income generated directly by endogenous households is responsible for generating economic activity across the sectors of the local economy. The explicit inclusion and quantification of the economic contribution that local institutions, such as households, have on the local economy is an important feature of this methodology. For example, by including households inside the model one can trace the sources of exogenous income to households that help drive endogenous household spending. In Deschutes County, Oregon, major sources of outside income to households include 1) government transfers (Social Security, Medicare, transfer payments, etc.); 2) dividend payments by non-local businesses; 3) drawing down of capital assets (incurring debt, 401(k), etc.); and 4) domestic trade such as tourism spending – in that order of importance (Table 13). This is an interesting finding. Much of Deschutes County is located in the national forest and the region contains several destination resorts that attract tourism spending. This can be observed in the SAM from the payment that domestic trade makes to households and a number of other tourism-related industries. However, more important in terms of supporting endogenous household spending are the government, dividend, and capital payments received by local households. Even more than direct tourism spending, these payments provide additional income to households that help sustain tourism as a feasible economic activity within the region. The contribution of households to amenity-based regions may provide evidence that local development strategies should seek to prioritize the quality of life needs of residents and tourists.

Table 12. Gross and base employment in Deschutes County, OR.

Top Gross Sectors	Gross Empl.	Percent of Empl.	Top Base Sectors	Base Empl.	Percent of Empl.
92 Government & non NAICs	8,357	9.0%	Households (aggregate)	27,574	29.8%
722 Food svcs & drinking places	7,040	7.6%	230 Construction	10,453	11.3%
541 Prof- scientific & tech svcs	7,018	7.6%	92 Government & non NAICs	9,155	9.9%
230 Construction	6,103	6.6%	541 Prof- scientific & tech svcs	4,235	4.6%
621 Ambulatory health care	5,840	6.3%	621 Ambulatory health care	3,241	3.5%
531 Real estate	5,342	5.8%	532 Rental & leasing svcs	2,426	2.6%
561 Admin support svcs	5,007	5.4%	721 Accomodations	2,413	2.6%
622 Hospitals	2,740	3.0%	511 Publishing industries	2,190	2.4%
624 Social assistance	2,722	2.9%	334 Computer & oth electron	1,765	1.9%
452 General merch stores	2,264	2.4%	531 Real estate	1,757	1.9%
42 Wholesale Trade	1,981	2.1%	561 Admin support svcs	1,730	1.9%
445 Food & beverage stores	1,870	2.0%	813 Religious- grantmaking- & similar orgs	1,496	1.6%
713 Amusement- gambling & recreation	1,683	1.8%	42 Wholesale Trade	1,469	1.6%
611 Educational svcs	1,641	1.8%	321 Wood Products	1,450	1.6%
813 Religious- grantmaking- & similar orgs	1,601	1.7%	722 Food svcs & drinking places	1,229	1.3%

Table 13. Sources of household income from exogenous final demand in Deschutes County, OR (2012 IMPLAN model, thousands $).

	Federal Gov't (non-defense)	Federal Gov't (defense)	State and Local Government	Enterprises (Corporations)	Capital	Domestic Trade	Foreign Trade
Households	$1,197,167	$221	$703,714	$495,312	$710,368	$78,455	$2,015
Rank	1	7	3	4	2	5	6

Beyond providing a better way to conduct economic contribution analysis, the economic base contribution vectors that are generated in this type of analysis can be used in any way that traditional vectors of employment, wages, or value added by sector have been used. For example, Shannon-Waver index scores have been used in economics for decades to evaluate the economic diversity of a region. A Shannon-Weaver analysis applied to the base vectors of economic activity provide an alternative measure of the region's economic diversity. Rather than analyzing the diversity of where people work or receive income, the interpretation of the economic base diversity score analyzes the diversity of the sectors which are responsible for generating the respective measure economic activity within a region. In looking at traditional gross employment, the normalized Shannon-Weaver diversity index for Wayne County (Michigan) in 2012 was 0.805, indicating a diversified economy. However, in terms of economic base employment, the normalized Shannon-Weaver diversity index for Wayne County in 2012 was 0.648, a score which is 20% lower than the traditional diversity score and indicative of an economy which is not very diverse. In analysis where economic diversity is used as an indicator of economic performance, this difference is likely to be substantial.

5. Summary and conclusion

An economic base social accounting analysis conducted simultaneously across all sectors of the regional economy provides a theoretically consistent and data-driven method for performing economic contribution analysis. This method does not require a priori impositions of which sectors comprise the economic base, but rather relies on actual data for sectoral and institutional exogenous sales and income. This method also allows for contributions for non-traditional components of economic base (households, government transfers, etc.) to be accounted for in a consistent and theoretically sound manner and can be performed with readily available and commonly used data tools (e.g., IMPLAN).

Additionally, the vectors of economic base output, employment, and income from the economic base analysis provide an additional metric for determining important concepts such as economic dependency, economic diversity, and economic stability. Previous research on economic dependency, economic diversity, and economic stability has used gross employment or earnings by sector as the measure of economic activity. The authors maintain that the vectors of base output, base employment, and base income provide a fertile avenue for future research which has the ability to illuminate regional economic concepts, provide more in depth analysis, and would serve as ideal independent variables in regional economic development regression analysis.

The use of the simultaneously derived economic base contribution method presented here for conducting regional economic contribution analysis greatly reduces the opportunity for inadvertent double counting of a sector's economic contribution. The authors advocate that any methods used to compute *ex post* estimates of an economic contribution should conform to the "square" criterion where estimates of the contribution of all sectors performed in the same way yields results where the sum of all sectors' contributions equal the actual original measure of economic activity. However, the use of this economic base contribution method does not completely eliminate the possibility for errors, either willful or unintentional. The model is still sensitive to properly specifying the sectoral production function, regional purchases, and level of exogenous sales. However, the availability and customizability of IMPLAN regional social accounting matrices enables this methodology to be easily implemented and will go far to reducing the misleading and overstated estimates of regional economic contributions.

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