Center for Demography and Ecology
University of Wisconsin-Madison

MEASURES AND MODELS OF COMPARATIVE INDUSTRIAL STRUCTURE

Michael D. Irwin

CDE Working Paper 92-13

MEASURES AND MODELS OF COMPARATIVE INDUSTRIAL STRUCTURE

Michael D. Irwin

Department of Sociology

Louisiana State University

August 1992

Partial support for this research was provided by the Center for Demography & Ecology which receives core support for Population Research from the National Institute for Child Health and Human Development. (P30 HD05876). The author thanks CDE for providing facilities and support for this research and thanks Amos H. Hawley, Holly L. Hughes, John D. Kasarda, Gerhard Lenski, Peter V. Marsden and François Nielsen for helpful comments and suggestions. Direct correspondence to Michael D. Irwin, Department of Sociology, 126 Stubbs Hall, Louisiana State University, Baton Rouge, LA 70803 (Bitnet SOIRWI@LSUVM).

MEASURES AND MODELS OF COMPARATIVE INDUSTRIAL STRUCTURE

ABSTRACT

A variety of mathematical models estimate the degree of importation/exportation in local economies. This paper evaluates underlying assumptions of three widely used indexes and identifies deficiencies in each. A new index is presented that addresses these deficiencies, while incorporating strengths of previous indexes. This exportation index provides stronger inference about local exportation, is sensitive to variations in local conditions and is more useful for analytic procedures.

MEASURES AND MODELS OF COMPARATIVE INDUSTRIAL STRUCTURE

The degree to which industries are oriented toward the local population, toward other local industries or toward non-local economies is a central issue in theories of local economic structure. Economic approaches, such as economic base theory, assert that most local (nonbasic) industries are dependent upon a few export (basic) industries (Eberstein, Wrigley and Serow, 1985; Thompson, 1965). Sociological approaches, such as human ecology, argue that export (key functional) industries integrate localities into larger functional systems (Hawley, 1950; 1981). In the central place tradition, social geographers stress the importance of consumer provision industries (higher order services) for extra-local populations (Christaller, 1933; Pred, 1973). Concepts of exportation and extra-local production are central in all approaches and the identification of the degree of exportation is critical in research derived from these theories (Gibbs and Poston, 1975).

If data were available on flows among sectors in localities and between places, then the operationalization of industrial dominance and exportation would be a straightforward matter. Since these data are not available researchers must infer these key theoretical concepts indirectly through the use of industrial indexes. These indexes are estimates and the concepts they represent are only imputed, not directly measured. As a result, the validity of such indexes is affected as much by the assumptions that shape their construction as by the data upon which they operate. This paper re-evaluates the construction and implicit assumptions of three widely used indexes (the minimum requirements model, the location quotient and the index of sufficiency) and catalogs deficiencies that limit their utility. A new measure, based on patterns of interindustry and consumer demand, is presented. This exportation index incorporates the strengths of these indexes while rectifying many of their deficiencies.

Generally, local industrial indexes identify key industries by constructing a hypothetical industrial mix that represents an optimal production recipe for the provision of necessary goods and services. Key industries are identified by comparing the observed industrial structure to these hypothetical optimal models. When a locality has more of an industry than would be expected from the hypothetical optimum, exportation, specialization, dominance, etc. is inferred. The critical component of these indexes is the construction of the hypothetical optimum since such models embody assumptions about the optimal relationship among industries, communities and population, and provide a baseline model for comparison to actual local industrial structures. Seldom, however, are the assumptions inherent in optimal models clarified and evaluated. The following section provides an overview of three commonly used industrial indexes, making explicit the assumptions underlying each hypothetical model and discussing deficiencies in each.

The Minimum Requirements Model

The intent of the minimum requirements model is to estimate the amount of production in a locality generated for exportation (Ullman and Dacey, 1960). To do so, a model of the hypothetical minimum amount of industrial activity needed by a locality is constructed by selecting the smallest industry specific percentage of total employment (or other measure of industry size) across localities:

$$\min \frac{E_{ij}}{E_{\bullet j}} = \textit{minimum value of all } \frac{E_{ij}}{E_{\bullet j}} \tag{1}$$

where

E=Employment;
i=industry;
j=locality;
•j=total employment in locality j

This term gives the hypothetical minimum proportion of an industry needed by a local economy. Comparison of each hypothetical minimum proportion with the observed industrial proportions in a local economy indicates the degree of exportation for that industry in that locality. The greater the difference between the observed and minimum proportions, the greater the imputed level of local

$$I_{ij}^{M} = \left[\frac{E_{ij}}{E_{\bullet j}}\right] - \left[\min\frac{E_{ij}}{E_{\bullet j}}\right] \qquad (2)$$

exportation.

The explicit assumption in this approach is that the smallest proportion found in any locality represents production only for local needs and that production beyond this proportion is exported, not stockpiled. Conversely, this assumes that goods or services are not exported until local needs are met. While these minimum proportions are clearly sensitive to the level of geography defining locality, when applied appropriately this approach seems to provide a reasonable estimate and to justify an inference of exportation. However, several problems emerge on closer examination of the optimal minimum which call into question such an inference.

First, the optimal model intrinsically assumes that no locality ever produces less than is needed locally since the optimal minimum production necessary for a locality is defined as the minimum proportion found in any locality. That is, the observed minimum proportion is assumed to exactly meet local needs. If this assumption were true, then no locality would ever import for local needs while virtually every locality would export at least some of its production.

Second, since the minimum model is constant across all localities, interindustry demand for the products of any specific industry are not taken into account. The same hypothetical minimum is used regardless of the industrial mix of that locality. In actual economies, locally used output (and therefore the hypothetical minimum) will vary according to the presence or absence of other local industries demanding that industry's output. Thus levels of exportation are mis-estimated to the extent that such variation in local industrial mix (and the corresponding local demand for an industry's output) occurs.

Third, the optimal minimum model does not control for variations in population size among localities. Clearly the minimum amount of industry needed to support a locality is influenced by the number of people in that locality. Variations in the ratio of population to industry will lead to mis-estimation of exportation.

In sum, although the minimum requirements models is intended to estimate exportation, such an inference is only justified when 1) there is not significant variation in the ratio of population to industry and 2) local industrial mix is relatively constant across localities. However, when the latter condition is met there will be little variation in the minimum requirements index either, severely limiting its utility. In addition, the assumption that minimum industrial proportions identify a locality's minimum industrial requirements leads to an untenable view of trade; all localities exporting, none importing for local needs. Both conceptually and empirically the minimum requirements estimates of exportation are suspect.

Location Quotient

The location quotient is the most widely used of the industrial indexes. It identifies key industries in terms of a locality's specialization in one or several industrial activities (Isard, 1960). The location quotient is not technically a measure of industrial exportation; nevertheless the location quotient is widely interpreted as a measure of exportation or as measuring associated concepts such as basic/nonbasic or dominant/subordinant industries (Duncan et al., 1960).

To distinguish a locality's degree of industrial specialization, the location quotient compares the observed industrial mix to a model of optimum industrial mix and identifies departure from this hypothetical optimum. The basic assumption of this approach is that this hypothetical optimum represents the necessary production recipe for an economy at any given time. That is, to produce what is needed in an economy requires a set proportion of each industry. Greater industrial activity than this optimal proportion represents over-production, less under-production. Therefore, if a locality has more activity in an industry than is optimal it is presumed that output is exported.

Conversely, if there is a less than optimal industrial activity, importation into the locality is inferred. Like the minimum requirements model this assumes that goods are not exported if local needs are unmet and that goods are never stockpiled for future use. Unlike the minimum requirements model, however, the location quotient allows for both exportation and importation for local needs.

Usually national industrial proportions are assumed to represent the optimal industrial mix at any point in time; national economic output is the product of its industrial mix. This treats the economy as a closed system (international trade is not considered) and assumes that production is exactly meeting demand (economic equilibrium). The optimal proportion for an industry is given as:

$$opt\frac{E_{ij}}{E_{\bullet j}} = \frac{\sum_{j}^{n} E_{ij}}{\sum_{j}^{n} E_{\bullet j}} = \frac{E_{ij}^{N}}{E_{\bullet j}^{N}} \tag{3}$$

where N=Nation;

and the location quotient for an industry in a locality as:

$$I_{ij}^{L} = \frac{\left(\frac{E_{ij}}{E_{i\bullet}}\right)}{\left(\frac{E_{ij}^{N}}{E_{\bullet j}^{N}}\right)} \tag{4}$$

When the ratio of an observed industrial proportion to the hypothetical optimum proportion is greater than one, the location quotient implies specialization or exportation; when less than one importation.

Although the optimal model used in the location quotient is different than that of the minimum requirements models, the basic structure of the two indexes is quite similar. For both, the numerator of the index, the actual industrial mix, is measured as an industry's percent of total employment. Thus the two indexes differ only in terms of their denominators (national industry percent of total employment vs minimum industrial percent). Since, for both indexes, the denominators are constant across all localities, the resultant scores will differ only in terms of scale. The prime difference between the two indexes is in the ability of the location quotient to describe importation as well as exportation. Because of the similarity in index structure, the location quotient suffers from two of the same deficiencies as the minimum requirements model. The hypothetical optimum does not control for either variations in industrial mix or for variations in population size among communities. This is not problematic if the location quotient is regarded as a simple index of industrial dissimilarity but, does limit its interpretation as an indicator of export/import, basic/nonbasic or dominant/subordinant industries.

An additional problem, expressing both optimal and actual industrial mix in proportions, hampers the index's interpretation as an indicator of exportation. Like the minimum requirements model, the sum of a locality's industrial mix in the numerator is constrained to 1.00; increases in the proportion of one industry necessarily decrease the proportion of other industries. Unlike the minimum requirements model, however, this same constraint exists in the denominator (national industrial percentages) which constrains the sum of deviations in each locality to zero:

$$\sum_{i}^{n} \frac{E_{ij}^{N}}{E_{\bullet j}^{N}} = \sum_{i}^{n} \frac{E_{ij}}{E_{\bullet j}} = 1 \quad \therefore \quad \sum_{j}^{n} \left[\frac{E_{ij}}{E_{\bullet j}} - \frac{E_{ij}^{N}}{E_{\bullet j}^{N}} \right] = 0 \tag{5}$$

Such a zero sum constraint makes sense only if the location quotient is interpreted as an index of specialization; as a local economy becomes more specialized in one industry it is simultaneously becoming less specialized in others. When interpreted as indicating exportation, however, this is tantamount to assuming that increases in exportation in one industry necessarily decrease exportation in another, and forces exports to equal imports in all localities. Clearly this is an unrealistic condition.

The location quotient does provide a reasonable index of industrial dissimilarity or specialization. However, specialization does not necessarily imply any extra-local influence since this specialization may be due to variations in population size among localities or in local demand from other industries. Because of these deficiencies and because of the zero sum constraint, the location quotient does not imply exportation or dominance, although most applications using this measure assume such concepts are inferred.

Index of Sufficiency

The index of sufficiency is a measure of the fit between local production and local consumption, and estimates importation and exportation for a locality (Feldt, 1965). However, the optimal model expressing a hypothetical balance between production and consumption is based on industry to population ratios rather than a percentage of total industrial activity. Like the location quotient, the optimal model of sufficient production for a population is derived from the national aggregate data. The ratio of national industrial output to total national population is assumed to exactly meet population needs. The optimal ratio is given as:

$$opt\frac{E_{ij}}{P_j} = \frac{\sum_j^n E_{ij}}{\sum_j^n P_j} = \frac{E_{ij}^N}{P_j^N} \tag{6}$$

where P=Population

Like the location quotient, this assumes that the national economy is a closed system in economic equilibrium; production exactly meets demand. Again, it is assumed that stockpiling is not taking place and disregards international imports and exports. Additionally this assumes the national ratios of population demand to industrial supply are invariant from one locality to another and that population demand is the only determinant of industrial production. The ability of an industry to meet local demand is evaluated by comparing these national ratios (optimal model) to the observed ratio of local industries to local populations:

$$I_{ij}^{S} = \frac{\left(\dfrac{E_{ij}}{P_j}\right)}{\left(\dfrac{E_{i\bullet}^{N}}{P_j^{N}}\right)} \tag{7}$$

In this ratio of ratios, values greater than one indicate more than sufficient production for local needs and imply exportation. Values less than one indicate economic insufficiency and imply importation for local needs.

Expressing optimal industrial activity as a function of the size of a local population adds an important dimension not found in either the location quotient or minimum requirements model. Unlike the minimum requirements model, the index of sufficiency allows both importation and exportation. Since population varies independently of local industrial structure imports are not constrained to equal exports (zero sum constraint), as in the location quotient. With the index of sufficiency, a locality may have all exporting industries, may import products to all sectors or combine imports and exports (outcomes the other two indexes will not produce). However, such estimates will be incorrect when there is significant variation in local industrial structures, since interindustry demand is not considered.

Exportation Index

A deficiency common to all these indexes is the failure to control for variations in industrial mix among localities. Since a certain proportion of any industry's output is used by other industries, variations in the industrial mix among localities will alter the proportion of an industry's output consumed locally (and therefore estimates of exportation and importation). In this section a new index of exportation is developed which addresses deficiencies in previous indexes. This exportation index is based on actual transactions among industries and population.

While not available for smaller geographic units, information on the flow of goods and services among industries and to consumers is available on a national level. In the U.S. these national accounts tables have been produced every five years since 1947 (cf U.S. Dept. Commerce, 1984). The exportation index uses these national interindustry transactions to construct a hypothetical optimal model of sufficient production in a local economy. This optimum, based upon demand from other local industries and from the constituent population, is then compared to actual industrial activity to estimate importation and exportation.

The national accounts tables provide dollar transactions among 85 sectors. Total sales (in dollars) for an industry (in the following example, industry 1) is partitioned into a) sales to other industries, b) sales within industry 1, c) sales to consumers:

$$X_{i=1} = Z_{ik=1} + Z_{ik=2} + \ldots + Z_{ik=n} + Y_i \tag{8}$$

where

X=total activity in dollars;
Z=transaction in dollars;
Y=sales to consumers in dollars;
i=selling industry;
k=buying industry.

These data provide the basic information used to construct the hypothetical optimum for the exportation index. However, since most local economic information on industrial activity is indicated by employment rather than dollar output, it is useful to convert these tables into the amount of labor involved in industrial transactions, and the amount of labor dedicated to local consumers.

$$Z_{ik}^{E} = \frac{E_i}{X_i}(Z_{ik}); \quad Z_{ik}^{P} = \frac{P}{Y}(Y_i) \tag{9}$$

For purchases among industries this transformation assumes a dollar input into labor results in a proportional dollar value of output from labor, and that the ratio of employment to output is the same for all commodities produced by an industry. The transformed data are interpreted as employment allocations for production to other sectors. Similarly, for population, this transformation assumes that the ratio of consumers to their dollars is constant across industries. The transformed population data are interpreted as employment allocations for production to the constituent population. These interrelationships among industries and population may then be summarized in coefficients that express industrial employment as a function of demand from other sectors:

$$a_{ik} = \frac{Z_{ik}^{E}}{E_k}; \quad a_{ik=p} = \frac{Z_{ik}^{P}}{P_k} \qquad \textbf{(10)}$$

These direct or technical coefficients express the employment allocated for production from sector i to sector k as a function of demand from sector k (Leontief, 1966; Miller and Blair, 1985). The coefficient is interpreted as the number of jobs in sector i required to support a given level of activity in sector k. This assumes that sector k will demand a fixed amount of employment activity from i regardless of the size of sector k. That is, the effects of scale associated with size are not taken into account. Additionally, the relationship assumes that output flowing from sector i to sector k is used by sector k (no stockpiling). The total employment in an industry is expressed as the interaction between direct coefficients and actual population, and employment levels in other industries. This express total employment in industry i as a function of demand from all other sectors and of internal demand:

$$E_i = a_{ik=1}(E_{k=1}) + a_{ik=2}(E_{k=2}) + \; . \; . \; . + a_{ik=n}(E_{k=n}) + a_{ik=p}(P) \qquad \textbf{(11)}$$

The direct coefficients are regarded as the optimal production recipe for a closed system in equilibrium, one in which the economic activity in industry i exactly meets demand from all other sectors. Changes in the levels of other sectors necessarily require changes in the level of activity in industry i. This suggests that an optimal level for industry i in a specific locality may be derived by substituting the observed local population and sizes of other industries into equation 11 as follows:

$$E_{i=1j}^{opt} = a_{ik=1}(E_{jk=1}^{opt}) + a_{ik=2}(E_{jk=2}) + \ . \ . \ . + a_{ik=n}(E_{jk=n}) + a_{ik=p}(P_j) \qquad \textbf{(12)}$$

However, in this form equation 12 cannot be estimated since the unknown optimal size for industry 1 (when i=1) is, in part, a function of its intra-industry demand (when k=1) and therefore dependent upon this unknown optimal size. Neither the optimal level nor the level of internal production can be calculated until the other components are known. One solution is to assume that the level of employment in industry 1 is determined first by known levels of external demand in other sectors and that internal production is required in fixed proportions to this external demand. A coefficient describing this relationship between external and internal production is calculated as:

$$a_{i=k}^{*} = \frac{Z_{i=k}^{E}}{Z_{i\neq k}^{E} + Z_{ik}^{P}} \qquad \textbf{(13)}$$

This coefficient calculates internal production necessary for estimated external demand for industry 1 output. Once substituted, the optimal level for local industry i is solved entirely from the direct coefficients, from the size of other industries in a locality and from the size of the local population:

$$\begin{aligned} E_{i=1j}^{opt} = {} & a_{ik=2}(E_{jk=2}) + \ . \ . \ . + a_{ik=n}(E_{jk=n}) + a_{ik=p}(P_j) \\ & + a_{i=k=1}^{*}\left[\sum_{i\neq k}^{n}\left(a_{i\neq k}(E_{jk})\right) + a_{ik=p}(P_j)\right] \end{aligned} \qquad \textbf{(14)}$$

Equation 14 gives the amount of employment in industry 1 required to meet the demands generated by other local industries, by the local population, and for its own use.

Unlike the previous indexes, this hypothetical optimum is based on actual levels of population and employment observed in each locality. The only elements not observed in the locality are the direct coefficients, derived from national data. The use of the national coefficients intrinsically assumes that population demands are constant, and that the inputs into the production process do not vary across localities. That is, the national pattern of interindustry transactions is assumed to represent an optimal production recipe which will not vary among places within the nation. Additionally, like the minimum requirements model, location quotient and index of sufficiency, the exportation index assumes that all locally produced goods and services are not exported until the local market demands are met.

As in the other indexes, the exportation index expresses exportation and importation as a ratio of optimal employment in industry i to actual the actual employment observed in that locality. The exportation index is:

$$I_{ij}^{E} = \frac{E_{ij}}{E_{ij}^{opt}} \qquad \textbf{(15)}$$

Values greater than one indicate over-production relative to demand in the local area and imply exportation. Values less than one indicate underproduction and imply the good or service must be imported to meet local needs. As in the index of sufficiency, there are no constraints placed on local exportation and importation. A locality may have all exporting industries, may import products, or mix exportation and importation, depending upon its unique industrial mix and population size. Where the denominator for other indexes is constant across areas, however, the denominator of the exportation index will be different for each locality. That is, the hypothetical optimums for each industry will vary according to the unique population and industrial mix observed in that locality.

Although constructed from very different assumptions, the exportation index shares three deficiencies with the other indexes. Mis-estimates will arise when local demand is not first met by local supply, when production is stockpiled, and when demand from other sectors varies among localities. However, the exportation index addresses two critical deficiencies of the other indexes.

First, the hypothetical optimum is constructed from actual inter-sectorial production transactions measured for the nation. Other indexes presume the proportions or ratios found on the national level represent necessary production relationships. However, examination of national accounts tables clearly demonstrate that inter-sectorial interdependence is not coterminous with the sizes of sectors. Second, none of the previous indexes simultaneously control for both local population size and the unique local industrial mix. Both dimensions clearly effect the amount of local exportation and importation and previous indexes will produce inaccurate results when these dimensions vary across localities. The exportation index does simultaneously control for local interindustry and population demand and is more sensitive to local variations in population and industrial mix than other indexes. This is demonstrated in the following sections.

Application of Indexes to Simulated Economies

This section demonstrates how different levels of employment, population and industrial mix affect index performance by applying them to four hypothetical city economies. These simulations illustrate the conditions under which each index produces unreasonable estimates. Table 1A is a hypothetical national economy and presents the ratios, percentages and coefficients used to calculate index scores shown in Table 1B.

<Table 1A About Here>

This hypothetical national economy has exactly twice as many people as jobs (Pop/Emp Ratio= 12000/6000=2.0) and, as seen in column 1, each industry has the same number of employees (1000). As a result, the employment to population ratios (column 2) used by the index of sufficiency are all equal, as are the percentages of total employment used in the location quotient (column 3). The hypothetical minimum percentages used by the minimum requirements model are found in column 4. The direct coefficients used by the exportation index (columns 5 through 11) are derived from actual national accounts tables, then transformed to employment coefficients using equations 9 through 13 and the hypothetical population and employment totals shown in Table 1B.

<Table 1B About Here>

Table 1B presents the scores from these indexes in four scenarios. In Cities 1 and 2 population to employment ratios differ from the nation while levels of employment among industry are held constant. City 1, which has relatively more population than employment (compared to the nation) is constructed to represent an importing economy. City 2, with a smaller population to employment ratio than the nation, represents an exporting economy. Cities 3 and 4 are constructed to represent economies in which some industries export products while other industries are not sufficient to meet local needs, requiring importation of their products.

Turning first to City 1, we see that total employment is held constant at 60 and each industry has 10 employees (column 1) which, like the nation, comprises an even percentage of total employment (16.7%). However, City 1 has a higher ratio of population to employment (3.3) than does the nation (2.0). A locality with a population unusually large for its industrial base must necessarily import goods and services to meet local needs. However, comparison of columns 4 through 7 in City 1 shows that neither the minimum requirements nor the location quotient indicate any degree of importation for provision to consumers, since neither index adjusts for the effects of population size. The minimum requirements index estimates exportation in all industries (values > 0.00); the location quotient indicates economic self-sufficiency (1.00).

The two indexes that do adjust for population to employment ratios (I^S and I^E) indicate that none of the industries in City 1 have sufficient employment to meet local demand (all values are < 1.00). The index of sufficiency estimates the same level of importation (.60) among all industries.

Since the exportation index adjusts for the effects of demands from other local industries as well as population, the estimated degree of importation varies among industries. Industries oriented primarily toward final consumers (population) are more affected by the relatively larger population than industries producing primarily for other industries. Additionally, because a component of demand is from other industries, I^E produces higher estimates (values closer to sufficiency) than I^S. In City 1 each industry is present at sufficient levels necessary to support other industries.

City 2 parallels the City 1 economy except that the population to employment ratio is less than the national average. This reflects a condition where there is more production than is required by the constituent population, implying exportation among all industries. Insensitive to the effects of population, the minimum requirements and location quotients are the same as in City 1. The index of sufficiency and exportation index indicate exportation among all industries, at similar levels. The exportation index, estimating exportation on the basis of both the smaller population in City 2 and interindustry demand (which is unchanged from City 1), indicates slightly less exportation than the index of sufficiency.

In City 3, unlike the previous hypothetical examples, the ratio of population to employment is the same as the nation, while industrial mix varies from that of the nation. Note that the minimum requirements model indicates industry 4 is just sufficient for the local economy (0.00). Additionally, I^M estimates industry 2 exports at twice the level of previous cities (.159), while the remaining industries export at levels identical to Cities 1 and 2.

In City 3, the location quotient and index of sufficiency produce identical values. This will be true whenever a locality's population to employment ratio is the same as the nation. Comparing these indexes to I^M a similar pattern emerges. Like I^M, both I^L and I^S indicate that industry 4 has the smallest value (.500) and industry 2 the largest value (1.5).

While the other indexes are concordant, the exportation index produces significantly different estimates. This is because I^E is sensitive to the larger than usual size of industry 2 in City 3 which necessarily requires greater levels of output from other local industries to meet local needs. As a result, the levels of production in other industries, while just sufficient to meet population demand, are not sufficient to meet this additional demand from local industry 2 and these products must be imported. The differential effect of demand from industry 2 on the other local industries is not indicated in either the location quotient or the index of sufficiency.

City 4 is constructed to reflect the more realistic condition where population ratios, total employment and industrial mix all vary from the nation. In this example, the population ratio is much greater than the national average. Notable in this simulation is the divergence between the location quotient and index of sufficiency. The location quotient indicates slight exportation for all industries except industry 2, while the index of sufficiency indicates importation in all industries. Exportation index estimates ten to fall between the location quotient and index of sufficiency, responding to variation both in industrial mix and population. Minimum requirement estimates indicate exportation in all industries except industry 2 which achieves its minimum percent in City 4.

These hypothetical examples clarify conditions under which the four indexes diverge. First, as discussed previously, for any specific industry the minimum requirements model and location quotient differ only in terms of scale. This exact correspondence between the two indexes will always occur within an industry since the two values differ only by a constant in the denominator. Nevertheless, the inference from the location quotient is quite different since it can indicate importation as well as exportation.

Second, it is clear that I^L will greatly diverge from I^S and I^E whenever population to employment ratios vary significantly across localities. It is reasonable to expect that places with little production, relative to their constituent population, must import industrial output (as in City 1).

Conversely, when there is excessive production relative to population (as in City 2) it seems reasonable to expect exportation. Both the scores for the index of sufficiency and the index of exportation reflect the effects of relative population size on local consumption. In neither case does the location quotient indicate importation or exportation. Only when a city's ratio exactly matches the population/employment ratio of the nation (as in City 3) will these indexes return similar estimates of exportation and importation.

When applied to local economies in which both industrial percentages and population to employment ratios diverge, there is considerable variation among these indexes (as in City 4). The location quotient, only calculated on the variation in industrial percentages, indicates a primarily importing economy. The index of sufficiency, responding only to the relatively lower population, indicates an exporting economy. Only the exportation index is sensitive to both factors and returns values which reflect both exportation and importation.

City 4 is constructed to clearly differentiate among these indexes by dramatically varying population, industrial mix and total employment size. However, such divergence among these indexes may not occur in actual application if either population ratios are relatively constant across areas or if industrial percentages are relatively constant. To explore this possibility the following section applies these indexes to actual data on 116 areas in 1980.

Application of Indexes in Actual Economies

Table 2 presents index means and standard deviations for 10 industries in 116 areas. These areas are constructed from the 1980 Public Use Micro Sample (U.S. Dept. of Commerce, 1983). <Further information on data structure available from author upon request>

<Table 2 About Here>

First note that the means for I^M differ from the other three measures. Again, this is due to the different scale used by this index. Comparing across industries in column 1, I^M reaches its highest mean level for manufacturing (.118) and its lowest for utilities (.011). All industries are greater than zero, indicating exportation.

Conversely (examining columns 2 through 4) all three remaining indexes indicate a mixed pattern of importing and exporting industries. I^L, I^E and I^S reach the highest level of mean exportation for government (1.07, 1.07 and 1.09 respectively), and the greatest amount of importation for primary industries. I^S, based solely on population ratios, tends to have higher mean values and show wider variation than the other indexes. Clearly there is considerable variation in relative population size among areas: a condition which tends to lead to inaccuracies in the location quotient.

The greatest divergence in mean values among the latter three indexes is found in manufacturing and utilities. For manufacturing, the location quotient indicates exportation (1.02) but not at the levels suggested by the index of sufficiency (1.06). The exportation index however, indicates slight importation (.99). Similarly, for utilities I^S suggests greater levels of exportation than does I^L and the exportation index again suggests slight importation. Despite differences in these two industries, Table 2 indicates a close correspondence in mean values among indexes. However, mean values hide considerable divergence in index scores among these areas. This is apparent in Table 3.

<Table 3 About Here>

Notice first that, within industries, there is perfect correlation between I^L and I^M (column 1). As discussed earlier, the denominators of both indexes are constants. Therefore co-variation reduces to the numerator, which is the same in both indexes (local industry percent of total employment). Similarly, there is exact co-variation between I^S and local employment to population ratios, since its denominator is a constant. Thus, for most analytic procedures it is only necessary to calculate local ratios and percentages. In descriptive applications, however, the hypothetical optimum is vital, and the choice of the denominator will lead to dramatically different inference. Further, note that I^E will not reduce to simple ratios or percentages since its constants (direct coefficients) are used to calculate interaction between variables (local population and the size of each other local industry). The hypothetical optimum is unique for each area.

Examining column 2, it is apparent that I^L and I^S have the lowest correlations. As shown with the simulations, these two indexes will produce similar results only when local population to employment ratios are close to national ratios. Clearly there is considerable variation among areas in these ratios, leading to different results in the two indexes. Since index scores in both I^E and I^S are influenced by relative population size, correlations between them are generally quite high (as seen in column 3). Importantly, as seen in column 4, I^E and I^L correlations are also quite high. Since, I^E scores are based on both population and industrial mix it takes on values intermediate between the other indexes. In the two industries where the divergence between I^L and I^S is very large (trade and professional services) I^E tends to produce result similar to I^S.

Conclusions

All indexes of local industrial exportation and importation provide indirect and imperfect imputation. However, these indexes are critical to social science research since concepts related to exportation are central to many social theories. Without data on inter-local patterns of trade there are no straightforward empirical criteria to choose among these indexes. One way of selecting among indexes is to evaluate the strength of the assumptions used in imputing exportation. Unrealistic assumptions are likely to lead to invalid inferences. As shown, there are unrealistic assumptions and deficiencies in the minimum requirements model, location quotient and index of sufficiency which may lead to erroneous inferences concerning exportation and importation in localities. The minimum requirements model assumes that all areas export but none import. The location quotient assumes that exports must equal imports in any locality and that the only factor influencing exportation is the structure of the local industrial mix. The index of sufficiency assumes that local consumption is only influenced by population. The exportation index, built upon patterns of actual inter-sectorial transactions and observed local characteristics, addresses these deficiencies. Using an entirely different approach to the construction of optimal industrial activity, the exportation index incorporates both population and inter-industrial demand as factors influencing local consumption.

As shown in simulations, the exportation index produces reasonable results where one or all of the traditional indexes produce unrealistic estimates. The location quotient and minimum requirements models both give unrealistic results when there is significant variation in areal population to employment ratios. Such variations in ratios are common, as seen in the application of these indexes to actual areas. The index of sufficiency is sensitive to such variations in ratios but is opaque to different patterns of industrial mix. The exportation index combines both factors and addresses weakness in each of these indexes. When population is the overriding factor influencing sufficient local production, the exportation index produces estimates very similar to the index of sufficiency. When variations in industrial mix occur, I^E estimates parallel I^L.

Finally, this article has shown that only the exportation index is useful in analytic procedures. Both I^L and I^M reduce to simple observed percentages in analytic applications while I^S reduces to simple observed employment to population ratios. Thus conventional indexes lose their interpretations as ratios (and therefore as indicators of exportation) in multivariate designs. Because the hypothetical optimum used in the exportation index is unique in each locality it retains, its interpretation as a ratio and as an index of exportation in analytic applications.

REFERENCES

Christaller, Walter. 1933. Die Zentralen Oter Suddeutschland. Jena: Gustav Fischer. Translated by D. W. Baskin (1966) as *Central Places in Southern Germany*. Englewood Cliff, NJ: Prentice Hall.

Duncan, Otis Dudley, W.R. Scott, Stanley Lieberson, Beverly Duncan, and H.H. Winsborough. 1960. Metropolis and Region. Baltimore MD: Johns Hopkins University Press.

Eberstein, Isaac W., J. Michael Wrigley, and William J. Serow. 1985. "An Examination of the Utility of Ecological and Economic Base Approaches to Regional Structure." Social Science Quarterly 66:34-49.

Feldt, Allan. 1965. "The Metropolitan Area Concept: An Evaluation of 1950 SMAs." Journal of the American Statistical Association 60:617-636.

Gibbs, Jack and Dudley Poston. 1975. "The Division of Labor: Conceptualization and Related Measures." Social Forces 52:468-476.

Hawley, Amos H., 1950. Human Ecology: A Theory of Community Structure. New York: John Wiley and Sons.

Hawley, Amos H., 1981. Urban Society: An Ecological Approach. New York: John Wiley and Sons.

Isard, Walter. 1960. Methods of Regional Analysis: An Introduction to Regional Science. New York and London.

Leontief, Wassily. 1966. Input-Output Economics. New York: Oxford University Press.

Miller, Ronald E., and Peter D. Blair. 1985. Input-Output Analysis: Foundations and Extensions. Englewood Cliffs, NJ: Prentice Hall Inc.

Pred, Allan. 1973. "The Growth and Development of Systems of Cities in Advanced Economies." Lund Series in Geography Series B, 38:1-81.

Thompson, Wilbur R., 1965. A Preface to Urban Economics. Baltimore, MD: Johns Hopkins University Press.

Ullman, E.L., and M.F. Dacey. 1960. "The Minimum Requirements Approach to the Urban Economic Base." Papers and Proceedings of the Regional Science Association Pp. 175-194.

U.S. Department of Commerce, Bureau of the Census. 1983. "Census of Population and Housing, 1980: Public-Use Microdata, Sample B." Machine-readable data file. Washington, D.C.: U.S. Bureau of the Census.

U.S. Department of Commerce, Bureau of Economic Analysis. 1984. "The Input-Output Structure of the U.S. Economy: 1977." Survey of Current Business 64(5):42-84.

TABLE 1A

Hypothetical National Employment and Population

Nation: Pop 12000 Pop/Emp Ratio: 2.0	Emp. 6000 (1)	Emp/Pop Ratios (2)	% Total Emp (3)	Min. % (4)	Direct Coefficients Among Industries and Population						
					Ind 1 (5)	Ind 2 (6)	Ind 3 (7)	Ind 4 (8)	Ind 5 (9)	Ind 6 (10)	Pop (11)
Industry 1	1000	8.33%	16.67%	14.54%	.1237	.1371	.0188	.0618	.0161	.0941	.0457
Industry 2	1000	8.33%	16.67%	9.09%	.0983	.3863	.0135	.0075	.0315	.0390	.0353
Industry 3	1000	8.33%	16.67%	14.54%	.0952	.3429	.1810	.0286	.0286	.1429	.0151
Industry 4	1000	8.33%	16.67%	8.33%	.0482	.2651	.0120	.2169	.2169	.0964	.0120
Industry 5	1000	8.33%	16.67%	14.54%	.0658	.1359	.0085	.0021	.0361	.0361	.0596
Industry 6	1000	8.33%	16.67%	14.54%	.0456	.0764	.0182	.0057	.0787	.1528	.0519

TABLE 1B
Comparison of Indexes in Hypothetical Economies

Hypothetical City	Emp. (1)	Emp/Pop Ratios (2)	% Total Emp (3)	I^M (4)	I^L (5)	I^S (6)	I^E (7)
City 1: Ind % = Nation & Pop/Emp Ratio > Nation							
Pop = 200, Emp=60, Pop/Emp Ratio = 3.3							
Industry 1	10	5.00%	16.67%	.021	1.000	.600	.702
Industry 2	10	5.00%	16.67%	.076	1.000	.600	.612
Industry 3	10	5.00%	16.67%	.021	1.000	.600	.612
Industry 4	10	5.00%	16.67%	.083	1.000	.600	.613
Industry 5	10	5.00%	16.67%	.021	1.000	.600	.615
Industry 6	10	5.00%	16.67%	.021	1.000	.600	.622
City 2: Ind % = Nation & Pop/Emp Ratio < Nation							
Pop = 100, Emp=60, Pop/Emp Ratio = 1.67							
Industry 1	10	10.00%	16.67%	.021	1.000	1.200	1.119
Industry 2	10	10.00%	16.67%	.076	1.000	1.200	1.188
Industry 3	10	10.00%	16.67%	.021	1.000	1.200	1.188
Industry 4	10	10.00%	16.67%	.083	1.000	1.200	1.188
Industry 5	10	10.00%	16.67%	.021	1.000	1.200	1.186
Industry 6	10	10.00%	16.67%	.021	1.000	1.200	1.179
City 3: Ind % Mixed & Pop/Emp Ratio = Nation							
Pop = 120, Emp=60, Pop/Emp Ratio = 2.0							
Industry 1	10	8.33%	16.67%	.021	1.000	1.000	.964
Industry 2	15	12.50%	25.00%	.159	1.500	1.500	1.261
Industry 3	10	8.33%	16.67%	.021	1.000	1.000	.864
Industry 4	5	4.17%	8.33%	.000	.500	.500	.488
Industry 5	10	8.33%	16.67%	.021	1.000	1.000	.937
Industry 6	10	8.33%	16.67%	.021	1.000	1.000	.892
City 4: Ind % Mixed & Pop/Emp Ratio > Nation							
Pop = 200, Emp=55, Pop/Emp Ratio = 3.7							
Industry 1	10	5.00%	18.18%	.036	1.091	.600	.771
Industry 2	5	2.50%	9.09%	.000	.546	.300	.459
Industry 3	10	5.00%	18.18%	.036	1.091	.600	1.054
Industry 4	10	5.00%	18.18%	.098	1.091	.600	1.038
Industry 5	10	5.00%	18.18%	.036	1.091	.600	.710
Industry 6	10	5.00%	18.18%	.036	1.091	.600	.726

TABLE 2
Means and Standard Deviations For Indexes in 10 Industries in 116 Areas, 1980

	I^M	I^L	I^E	I^S
Industry[a]	$\bar{X}$ (σ)	$\bar{X}$ (σ)	$\bar{X}$ (σ)	$\bar{X}$ (σ)
	(1)	(2)	(3)	(4)
All Industries	.052(.060)	.98(.40)	.97(.40)	1.00(.50)
Primary	.025(.028)	.64(.61)	.68(.58)	.64(.60)
Construction	.026(.017)	.97(.29)	.98(.34)	.99(.40)
Manufacturing	.118(.089)	1.02(.37)	.99(.28)	1.06(.54)
Tranportation/Comm.	.033(.016)	1.00(.26)	.99(.28)	1.03(.43)
Utilities	.011(.072)	1.03(.47)	.99(.34)	1.05(.54)
Trade (Whol.& Retail)	.055(.022)	1.01(.11)	1.02(.24)	1.04(.35)
Producer Services	.058(.031)	1.01(.28)	1.00(.30)	1.04(.44)
Consumer Services	.019(.012)	.97(.24)	.97(.29)	1.00(.39)
Professional Services	.064(.026)	1.03(.16)	1.04(.30)	1.05(.32)
Government	.045(.033)	1.07(.62)	1.07(.65)	1.09(.69)

[a] N for all industries is 1160 and for individual industries N is 116.

TABLE 3
Correlations Among Indexes in 10 Industries in 116 Areas, 1980

	Correlations[b] Between:			
	I^L & I^M	$I^{L\,c}$ & I^S	I^E & I^S	I^E & $I^{L\,c}$
Industry[a]	(1)	(2)	(3)	(4)
Primary	1.00	.93	.87	.94
Construction	1.00	.68	.98	.80
Manufacturing	1.00	.75	.93	.91
Tranportation/Comm.	1.00	.62	.87	.90
Utilities	1.00	.79	.91	.93
Trade (Whol.& Retail)	1.00	.38	.96	.56
Producer Services	1.00	.69	.93	.89
Consumer Services	1.00	.62	.96	.79
Professional Services	1.00	.30	.99	.31
Government	1.00	.88	.94	.99

[a] N for individual industries N is 116.
[b] All correlations $\leq$ .001 probability.
[c] Correlations are the same for I^M.

APPENDIX A
National Economy, 1980

National Pop: 2,251,714 Pop/Emp Ratio: 1.8	Emp 1231180	Pop/ Emp Ratios	% Total Emp	Min. %	Direct Coefficients Among Industries and Population										
					Prim.	Const.	Mfg.	Tran/ Comm	Utilities	Trade	Prod. Serv.	Cons. Serv.	Prof. Serv.	Govt.	Pop.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Primary	57,111	2.54	4.64	0.04	.1822	.0126	.1318	.0008	.2857	.0034	.0034	.0043	.0006	.0060	.0004
Construction	72,241	3.21	5.87	3.11	.0206	.0012	.0080	.0235	.0536	.0035	.0421	.0070	.0046	.0204	.0251
Manufacturing	296,445	13.17	24.08	5.90	.1295	.3014	.3864	.0512	.1160	.0394	.0204	.0631	.0202	.0107	.0558
Transport./Commun.	76,512	3.40	6.21	2.88	.0221	.0399	.0501	.1003	.0558	.0253	.0298	.0202	.0082	.0117	.0155
Utilities	18,924	0.84	1.54	0.05	.0097	.0018	.0132	.0032	.1745	.0060	.0048	.0067	.0025	.0082	.0003
Trade	238,871	10.61	19.40	14.19	.0641	.1643	.1093	.0275	.0324	.0352	.0230	.0518	.0103	.0063	.0759
Producer Services	134,330	5.97	10.91	5.25	.0722	.0592	.0417	.0321	.0277	.0560	.1430	.0390	.0212	.0058	.0314
Consumer Services	62,352	2.77	5.06	3.03	.0121	.0113	.0132	.0340	.0088	.0212	.0153	.0453	.0063	.0025	.0190
Professional Services	207,834	9.23	16.88	10.96	.0108	.0002	.0052	.0045	.0070	.0030	.0109	.0093	.0181	.0007	.0882
Government	66,560	2.96	5.41	1.35	.0193	.0141	.0392	.0226	.2282	.0248	.0567	.0193	.0118	.0189	.0126

Mailing address:

Center for Demography and Ecology
University of Wisconsin
1180 Observatory Drive, Room 4412
Madison, WI 53706-1393
USA