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Location quotients are frequently used as a quick and inexpensive means of categorizing economic activities into those that are "basic" or systematically traded and those that are "non-basic" or locally produced and consumed. Any current text in urban or regional economics provides a host of criticisms of the general location quotient approach. There are three important deficiencies in using location quotients for basic activity identification: (1) differences in taste can give rise to variable location quotients that do not reflect trading patterns; (2) differing economies of scale across nonbasic industries may give rise to variable location quotients; and (3) the existence of a central place hierarchy destroys the identity between nonbasic location quotients and a value of unity. This paper deals explicitly with problem number three - the impact of central place hierarchies on measured location quotients. It examines the relationship between location quotients and hierarchical position and posits an explanation of how changes in the value of a location quotient may be indicative of differences in the nature of trade and the degree of agglomeration.

Isard (1956, 1960) noted that position within the central place hierarchy alters the interpretation of location quotients, and that it alters, in particular, the use of the location quotient to distinguish basic from nonbasic production To our knowledge, however, the relationship between central place theory and the location quotient has not been explicitly and exactly developed. In several recent papers the authors have suggested systematic shifts in the base of the location quotient as a means of "correcting" economic base theory when applied in the context of a hierarchy of places (Keil and Mack 1986; Gilmer, Keil, and Mack 1987, 1989; Groshen, 1987 and others have adopted these techniques). The arguments presented in these papers are intuitively appealing and, in application, they produce interesting and seemingly useful results. Our attempts to provide a better theoretical foundation for this technique have led to this current systematic examination of the location quotient/central place relationship. After a review of the algebra and assumptions behind the traditional use of the location quotient to identify basic/nonbasic relationships, location quotients for each level of a simple hierarchy of places are generated. Next we examine the attributes of location quotients for industries located at each level of the place hierarchy and propose measures to correct for biases generated by central place position. Finally, conclusions are drawn and the implications of our results for applied research are discussed.

The Location Quotient and Nonbasic Production

Economic base studies place primary emphasis on the exports of a local area. Basic exports are goods and services produced locally but sold outside the local area. Nonbasic goods and services are produced locally for local consumption. The basic sector's importance stems from its provision of the means of payment for imports and nonbasic production. Gilmer, Keil, and

Mack (1989) modify the basic-nonbasic terminology to define "basic imports and exports" to be those that cross the boundaries of the economic hinterlands of their place of origin in the case of exports or destination in the case of imports. The remaining activities, non-basic or local in the sense that they are traded only among the places within these hinterlands, were termed agglomerative activities if traded up or down the place hierarchy and residential if traded only within a given place. As will be seen, it is trade in the agglomerative activities that give rise to non-unity location quotients for nonbasic activities that are sensitive to the base chosen for measurement.

In this study we use the location quotient is that based on employment. It is the ratio of a local industry's share of total local employment to this same share in a larger region.

$$LQ_{ij}=\frac{e_{ij}/e_{oj}}{E_{io}/E_{oo}}$$

where: $i = 1, \ldots, n$; $j = 1, \ldots, m$; and

e_{ij} = local employment in industry i and place j

e_{oj} = total location employment in place j

E_{io} = regiowide employment in industry i

E_{oo} = regionwide employment in all industries

The rationale underlying the use of the location quotient as a means of separating basic and nonbasic production is this: measured across a number of places the variance of location quotients for basic production will be large, while location quotients for nonbasic production will have small variances and a central value of one. For example, assume basic employment (b_j) varies widely from place to place, and that nonbasic employment in industry i (n_{ij}) is proportional to the economic base.

$$n_{ij} = a_i * b_j$$

Then the location quotient is always 1.0 in all nonbasic industries and in all places. This can be quickly seen by noting that

e_{oj} = total employment, basic and nonbasic, in place j

$$= b_j(1 + \sum_{i=1}^{n} a_i)$$

n_{io} = total nonbasic employment, regionwide in industry i

$$= a_i \sum_{j=1}^{m} b_j$$

E_{oo} = regionwide employment, basic and nonbasic

$$= b_j(1 + \sum_{i=1}^{n} a_i) \sum_{j=1}^{m} b_j$$

Some algebraic manipulation quickly shows that:

$$LQ_{ij} = \frac{n_{ij}/e_{oj}}{n_{io}/E_{oo}} = 1$$

Thus the dividing line between basic and nonbasic industries is made on the value of the location quotient measured across a number of places. A large variance indicates basic activity; a small variance and a location quotient with a value typically close to one indicate nonbasic activity.

Note, however, that our algebraic proof that the nonbasic location quotient is always one assumes that places arise independently of each other. This is not true in a system of central places, and in the next section we show that: for a high-order central place, nonbasic location quotients may be one, greater than one, or zero. They will be zero if the place is not large enough to achieve required threshold effects, otherwise they are:

$$LQ_{ij} = 1.0 + \frac{P'_{io}}{P_j}$$

where

P_j = population of the central place

P'_{io} = population of all lower-order places that purchase nonbasic product i from the central place.

For central places large enough to provide services to a surrounding hinterland, the nonbasic location quotient is greater than one. This is a result that certainly obviates the traditional rules on the division of basic and nonbasic production, as both kinds of production can generate location quotients greater than one.

The Nonbasic Location Quotient for a Central Place

Here we employ an elementary version of the central place model (King, 1984) to develop a system of location quotients within a hierarchy. The model is similar in essential aspects to those presented by Christaller (1966), Losch (1954), and Beckman and McPherson (1970), as it assumes:

- Factor endowments are distributed uniformly across a homogeneous plane.

- Agriculture is the only basic product and farmers are uniformly distributed across the plane.

- Transportation costs are positive. Self-interest and perfect competition are assumed.

- Higher-order places arise to provide nonbasic goods and services, locating in space in such a way to most easily provide services to the surrounding hinterland.

- The threshold requirement for a nonbasic good is expressed in terms of population:

  s_i = Number of people served with good or service i per employee engaged at level j of the hierarchy, $j \geq i$

- If population is large enough, good i is introduced into the model. The larger the value of s_i the higher the order of the good or service.

- A nested hierarchy, i.e., each higher-order place also serves as a center for each lower-order activity. For our example we assume four higher-order, nonbasic activities (i = 1, . . ., 4) undertaken by four levels of place (j = 1, . . ., 4) defined by each activity.

- The nested hierarchy, in conjunction with positive transportation costs and perfect competition, gives rise to the well-known hexagonal pattern of interlocking market areas. Table 1 summarizes the number of places served with each activity, according to the level of place that produces the good or service.

[Table One here]

To compute location quotients throughout the hierarchy we require only one further assumption: the ratio of population to employment (r) is the same in all places. In some models, threshold effects may be stated in terms of income or purchasing power (Tinbergen 1967), which then require the assumption of a uniform wage rate in each place. Denoting the exogenously given population in rural areas as (P_R) and the consequent populations (given the s_i's) in

Table 1

Number of Places Served with Nonbasic Production:

By Level of Place Served

Activity Delivered	Level of Place 4	3	2	1	Number of Places Served
4	27	0	0	0	27
3	9	9	0	0	27
2	3	3	3	0	27
1	1	1	1	1	27
No. of Cities in Hierarchy	1	2	6	18	27

higher-order places as P_j (j = 1, . . ., 4), Table 2 summarizes employment in each activity and each place. The nonbasic employment at higher-order places (e_{ij}) results from a simple counting exercise where P_j/s_i is employment in activity i and place j. For example, the 18 Level 1 places serve themselves plus their adjacent rural areas with Activity 1. Level 2 places provide themselves with Activity 2, each services two Level 1 places, and each provides Activity 2 to rural areas adjacent to themselves and to the Level 1 places. In addition, each Level 2 place is a Level 1 center for itself. This continues for Levels 3 and 4. Of course, lower-order places never provide higher-order goods; this gives rise to the pattern of zeros above the diagonal.

[Table 2 here]

Total employment by industry (E_{io}) is given in the rightmost column of Table 2, requiring that the entire population (P) be served with each activity. Total employment by place (e_{oj}) is given in the bottom row of the table, assuming a uniform ratio of population to employment. The bottom right corner of the table gives regionwide employment ($P/r = E_{oo}$). As we move sequentially from a lower-order place to the next higher-order place, the standard formulation of the urban multiplier is implicit (Beckmann and McPherson 1970). Multipliers are completely defined by s_i and r, assuring us of a solution for employment and population in higher-level places. These multipliers are presented in the appendix.

Table 2

Employment in a Hierarchy of Central Places

Activity	Employment Engaged in Each Activity PLACE				
	4	3	2	1	Total(Eio)
4	$\frac{P_4+2P_3+6P_2+18P_1+27P_R}{s_4}$	0	0	0	$\frac{P}{s_4}$
3	$\frac{P_4+2P_2+6P_1+9P_R}{s_3}$	$\frac{P_3+2P_2+6P_1+9P_R}{s_3}$	0	0	$\frac{P}{s_3}$
2	$\frac{P_4+2P_1+3P_R}{s_2}$	$\frac{P_3+2P_1+3P_R}{s_2}$	$\frac{P_2+2P_1+3P_R}{s_2}$	0	$\frac{P}{s_2}$
1	$\frac{P_4+P_R}{s_1}$	$\frac{P_3+P_R}{s_1}$	$\frac{P_2+P_R}{s_1}$	$\frac{P_1+P_R}{s_1}$	$\frac{P}{s_1}$
Urban	$\frac{P_4}{r}$	$\frac{P_3}{r}$	$\frac{P_2}{r}$	$\frac{P_1}{r}$	$\frac{P_{urb}}{r}$
Rural	$\frac{P_R}{r}$	$\frac{P_R}{r}$	$\frac{P_R}{r}$	$\frac{P_R}{r}$	$\frac{27P_R}{r} =$
Total (e_{oj})	$\frac{P_4+P_R}{r}$	$\frac{P_3+P_R}{r}$	$\frac{P_2+P_R}{r}$	$\frac{P_1+P_R}{r}$	$\frac{P}{r} = E$

Location quotients for nonbasic activities are given in Table 3. If a nonbasic good is produced at a particular level, i.e., if the location quotient is nonzero, then its value is the ratio of total population served by that place with activity i (including the central place itself) to the population of the central place. This results in location quotients that are typically greater than one for higher-order places.

[table 3 here]

Corrections at the Top of the Hierarchy

The preceding section has shown that nesting and threshold effects lead to nonbasic location quotients that are greater than one for large central places. This, then, creates the problem in using location quotients to distinquish basic exports and imports from those we have termed agglomerative imports and exports. Keil and Mack (1986) argue that the way out of this dilemma is to shift the location quotient to a metropolitan or urban base. The adjusted location quotient is computed as follows:

$$LQ^{*}_{iu} = \frac{e_{iu}/e_{ou}}{(E_{io}-e_{ir})/(E_{oo}-e_{or})}$$

e_{iu} = employment in industry i in a metropolitan or urban place

e_{ou} = total employment in a metropolitan or urban place

e_{ir} = employment in industry i in all lower-order or rural places

e_{or} = total employment in lower-order or rural places

E_{io}, E_{oo} = as defined above

Table 3

Location Quotients for Nonbasic Production on the Total Employment Base

	PLACE			
Activity	4	3	2	1
4	$1+\frac{2P_3+6P_2+18P_1+26P_R}{P_4+P_R}$	0	0	0
3	$1+\frac{2P_2+6P_1+8P_R}{P_4+P_R}$	$1+\frac{2P_2+6P_1+8P_R}{P_3+P_R}$	0	0
2	$1+\frac{2P_1+2P_R}{P_4+P_R}$	$1+\frac{2P_1+2P_R}{P_3+P_R}$	$1+\frac{2P_1+2P_R}{P_2+P_R}$	0
1	1	1	1	1

Keil and Mack claim that the shift in base acts as a filter, removing the influence of lower-order places on metropolitan areas that stand at the very top of the hierarchy. Their argument hinges on how the metropolitan location quotient changes in value when we shift the base. They show:

$$\Delta LQ_{iu} = LQ_{iu} - LQ'_{iu}$$

$$= k\{LQ_{iu}(1 - LQ_{ir})\}$$

where $$k = \frac{E_{oo}}{e_{or}}\left(1 - \frac{e_{ir}}{E_{io}}\right) \geq 0$$

where LQ_{iu} and LQ_{ir} are the location quotients for industry i in metro and rural areas respectively. Given $k > 0$ (and this is the typical case), the sign of ΔLQ_{iu} depends strictly on whether LQ_{ir} <,> or = 1.0.

Keil and Mack replace the nesting and threshold assumptions with the more intuitive notion of agglomeration effects. Urban agglomeration or clustering occurs to facilitate buyer convenience (proximity of shops selling similar merchandise), to draw from pools of specialized labor, or to draw from pools of other specialized inputs. With agglomeration, the typical case for any place in the hierarchy with $j \geq 2$ will be $LQ_{ir} < 1$, and that place's location quotient will fall in value after the base is shifted. Thus nonbasic location quotients should-- with the effects of their hinterlands now filtered out--return to a value close to one.

In the simple central place model, shifting the base of the location quotient in this way will return every nonbasic location quotient to exactly one. In Table 3, if metropolitan areas are represented by Level 4 places, the shift easily--trivially--makes each nonbasic location quotient equal to one. That is, by noting

$e_{iu} = E_{io} - e_{ir} = e_{ij}$ and

$e_{ou} = E_{oo} - e_{or} = e_{oj}$ it is readily seen that

$LQ'_{iu} = 1.0$

However, this is the answer we sought in that it gives us a means to remove the ambiguity of location quotients above one in the case of threshold or agglomerative activities.

To see how the technique can be made operational, consider an economy with a set of large metropolitan places each standing at the top of its own hierarchy. This is the case of the level 4 place in Table 3 (see Figure 1). The base (E_{io} and E_{oo}) for the entire economy includes the large metropolitan places and all of the smaller places in each of their hierarchies. To the extent that industry i is characterized by agglomerative economies, the location quotients for this industry in the large metropolitan areas will be greater than one but there is no implication of trade between like size places. However, if the location quotient for this industry in the metropolitian areas does not uniformily change to one when the base is modified to remove all lower order places, it is likely that this good is traded among these places for reasons that violate the assumptions made in developing the simple hierarchy. Practically speaking, nonbasic location quotients can once more be identified as those with small variance and with average values close to one when measured across a base consisting only of metropolitan places.

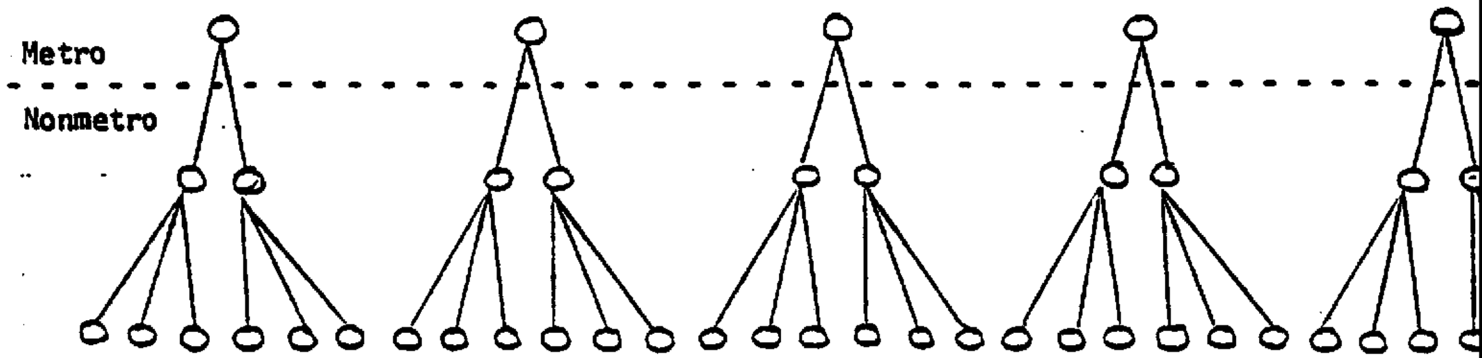

Figure 1

Metropolitan Areas and Their Hinterlands

Gilmer, Keil, and Mack (1987) provide an example. They examined 41 metropolitan areas in a seven-state region of the Southeast. They computed the location quotients for service industries in these 41 cities, shifted to a metropolitan base, and examined means and variances of the location quotients. Those services with large variances were assumed to be basic, and a subset of eight metropolitan areas located in the Tennessee Valley was examined closely to see if the areas were exporters or importers of services. Table 4 shows the service exports for these cities (large variance and a location quotient greater than 1.2) and imports (location quotient < 0.8).

[Table 4 here]

The results depict a region with a relatively weak service sector, where only Memphis and Nashville stand out as service exporters. Memphis shows strength as a regional distribution center with exports of transportation services and wholesale trade; Nashville's entertainment industry stands out (communications, hotels, amusements) as well as its exports of insurance and private education.

Exports from Smaller Places

Suppose our interest centers on communities smaller than metropolitan areas. For example, in Figure 1, focus attention on the exports of the level immediately below the broken line. Gilmer, Keil, and Mack (1989) suggest that higher-level places be dropped from the base. In this case we would drop metropolitan

Table 4

Services Traded Among Cities in the Tennessee Valley

EXPORTS

Memphis: Transportation, wholesale, insurance agents and brokers, holding and investment companies, misc. business services, government

Nashville: Communications, wholesale, education, insurance carriers, insurance agents, holding and investment companies, membership organizations, hotels and lodging, amusements

Knoxville: Wholesale, museums, government enterprise

Tri-Cities: Combined real estate and insurance

Chattanooga: Combined real estate and insurance, credit agencies, insurance carriers, holding and investment companies

Huntsville: Government

Clarksville-Hopkinsville: Combined real estate and insurance, government

Florence: Government

IMPORTS

Memphis: Misc. professional services, museums, insurance carriers

Nashville: Brokerage, social services, misc. repair, museums

Knoxville: Brokerage, insurance carriers, insurance agents, holding and investment companies

Tri-Cities: Wholesale, credit agencies, brokerage, insurance carriers, insurance agents, holding and investment companies, misc. professional services, hotels and lodging, amusements, museums

Chattanooga: Brokerage, insurance agents, misc. professional services, amusements, museums

Huntsville: Wholesale, credit agencies, brokerage, insurance agents, holding and investment companies, membership organizations, misc. professional services, hotels and lodging, amusements, museums

Clarksville-Hopkinsville: Transportation
Florence: Transportation, combined real estate and investment, hotels and lodging

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From Gilmer/Keil/Mack (1987).

areas, and the new base would be composed of all nonmetropolitan areas. If we were interested in even smaller places (i.e., at levels further down the hierarchy) we would remove all higher-level places from the base, and have a new base of lower-order places.

This transformation once more acts as a filter, removing higher-order agglomeration or clustering, and allowing us to see lower-order places as if higher-order places do not exist. Algebraically we have the same result seen earlier when lower-order places were removed from the location quotient base, but with a switch in subscripts.

Before: Drop lower-order places from the location quotient base

$$\Delta LQ_{iu} = k\{LQ_{iu}(1 - LQ_{ir})\} \qquad k > 0$$

Now: Drop higher-order places from the location quotient base

$$\Delta LQ_{ir} = k'\{LQ_{ir}(1 - LQ_{iu})\} \qquad k' > 0$$

The "typical" case, following up on our earlier urban example, would be higher-order urban agglomeration. That is, $LQ_{iu} > 1$ and $\Delta LQ_{ir} < 0$. After adjustment, the new lower-order location quotient will increase in value. We see smaller places in relation to those places that lie below them in the hierarchy, but with the influence of higher-order agglomeration removed.

If smaller places achieve economies of scale or agglomeration relative to their hinterland, their location quotient may shift upward and become greater than one. It is more difficult to think of agglomeration as working in smaller places, but auto and farm implement dealers are obvious examples. The success of

WalMart stores, mostly operating in nonmetropolitan areas, suggests that strong economies exist in retailing at this sub-metro level.

By dropping higher-order places, filtering them out of the lower-order location quotients, and effectively placing a group of smaller communities at the top of the hierarchy, we return to the original metropolitan-export problem. That is, after we compute LQ'_{ij} and find it is greater than one, is this because the industry is a basic export or simply because the location quotients elevated by agglomerative economies? Fortunately, we can solve this problem by using a second piece of information--the change in the value of the location quotient when we shift the base.

Table 5 gives an example. Suppose (as in Figure 1) we are interested in the largest nonmetropolitan communities. If we divide the hierarchy there and compute location quotients, we might find results like those at the top of the table. Industries 1 and 5 are predominately nonmetropolitan, and industries 2, 3, and 4 are metropolitan. Essentially this tells us that, broken at this level, the dominant flow of goods is upward for industries 1 and 5 and downward for 2, 3, and 4. The sign of ΔLQ_{ir} also contains this same information.

[Table 5 here]

Thus we have the two-way classification scheme as presented at the bottom of Table 5. If the adjusted location quotient is greater than one, and the overall flow is downward, we are

Table 5

Location Quotients and the Classification of Goods and Services in a Lower-Order Place

	Industry				
	1	2	3	4	5
Metro	.38	1.32	1.30	1.12	0.55
Nonmetro	1.95	0.51	0.53	0.81	1.69
ΔLQ_{ir}	>0	<0	<0	<0	>0
Flow	up	down	down	down	up

<u>Two-Way Classification</u>

	$LQ' > 1$	$LQ' < 1$
$\Delta LQ < 0$ flow down	Exports Agglomerative	Imports Agglomerative
$\Delta LQ > 0$ flow up	Exports Basic	Imports Basic

dealing with communities that achieve economies of agglomeration relative to places below them. If the adjusted location quotient is less than one, and the flow is downward, these communities are dominated by agglomeration economies achieved at places above them. If the flow is upward, to larger places in the hierarchy, basic exports are indicated. These communities may export or import these basic goods and services.

Gilmer, Keil, and Mack (1989) applied this methodology to nonmetropolitan counties in seven southeastern states. Their results indicate that counties with 25-70,000 population primarily act as service centers for smaller surrounding counties. Of 49 service industries, 33 or more fell into the agglomerative export category in these larger nonmetro counties. Smaller counties were dominated by agglomerative imports. Basic exports and imports were rare, and when they did occur they were predictably tied to tourism, transportation services, or remotely-sited energy facilities.

Central Place Theory and Low-Order Places

Central place theory provides a very nice interpretation of this shift in the location quotient base. Looking back at Table 3 and our solution for location quotients in central places, what happens if we drop the highest-level places (Level 4) from the base of the Level 3 places? Table 6 presents the algebra for Activity 2 at Level 3. The essential result, shown at the bottom of the table, is:

[Table 6 here]

$$LQ'_{23} = LQ_{23} \frac{P_r}{P'_r}$$

P_r is the population of all places at Level 3 or smaller; P'_r is the population of these places that buy Activity 2 from Level 3 or smaller places. First, note that $LQ'_{23} > 1$ and ΔLQ_{23} is negative. Agglomeration and a downward flow are indicated, as they must be for this model. Second, the LQ'_{23} is the location quotient for the hypothetical case where no higher-order nesting or threshold effects exist. With nesting, metropolitan areas at Level 4 reach down to serve $P_r - P'_r$ individuals in smaller, lower-order places. Without nesting, each central place serves itself (i.e., P_r). This is the sense in which LQ′ adjusts for higher-order agglomeration, and lets us see lower-order places as if higher-order places do not exist.

Qualifications and Conclusions

The qualifications associated with these corrections for the central place hierarchy are many and stem from several sources. First, as we indicated earlier, the literature provides a wide range of qualifications concerning the location quotient approach. We dealt at length with only one of many potential deficiencies, the role of the central place concept in economic base theory. A second source of weakness in our approach is the use of central place theory as a standard for correctness. The elementary version of the model employed in this paper has never been successful as a description of the real world. However, more realistic versions, particularly those that include basic

Table 6

Dropping Higher-Order Places from the Location Quotient Base for a Lower Order Place

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By definition

$$LQ_{ij} = \frac{e_{ij}/e_{oj}}{E_{io}/E_{oo}} \qquad LQ'_{ij} = \frac{e_{ij}/e_{oj}}{(E_{io}-e_{iu})/(E_{oo}-e_{ou})}$$

Location Quotient for Activity 2, Level 3, dropping level 4

$$e_{23} = \frac{P_3+2P_1+3P_R}{s_2}$$

$$e_{03} = \frac{P_3+P_R}{r}$$

$$E_{oo}-e_{o4} = \frac{2P_3+6P_2+18P_1+26P_R}{r}$$

$$E_{2o}-e_{24} = \frac{2P_3+6P_2+16P_1+24P_R}{s_3}$$

A little algebraic manipulation readily shows that

$$LQ'_{23} = LQ_{23}\left(\frac{2P_3+6P_2+18P_1+26P_R}{2P_3+6P_2+16P_1+24P_R}\right)$$

$$= LQ_{23}(P_r/P_r')$$

where

P_r = Total population of lower-order places

P_r' = Total population of lower-order places that receive Activit produced in Level 3 or lower-order places

~~include basic~~ exports at all levels of the model, quickly become analytically intractable (Ahn and Nourse 1988). The result is that central place theory rarely contributes much to applied regional and urban economics. Another example of this enormous gap between central place theory and practice is the shift from nesting and threshold effects to the more intuitive, less well-defined concept of agglomeration. The necessary shift to goods and services defined by the Standard Industrial Classification, and not by threshold effects and the extent of the market is yet another manifestation. Although the insights derived from theory aid and abet intuition at every step, there is little formalism left in actual practice.

Thus, central place theory provides limited theoretical support for systematic shifts in the base of location quotients as a means of correcting for a hierarchy of places. The effects of these shifts on the location quotients match prior intuition. Most importantly, application of the approach provides interesting and practical empirical insights into the way rural and urban places relate to one another. The results can be achieved at minimal cost and with widely available data. We need to know much more about the gap between theory and practice, but it is likely that as much responsibility for closing the gap falls on the side of augmenting theory as it does on improving empirical methods.

APPENDIX

Population and employment throughout the central place hierarchy are determined once we set the population of rural places (P_R) and the number of people served by each employee working in an industry (s_R, s_i; $i = 1,\ldots,4$). First, the ratio of employment to population is technologically determined assuming a long run competitive equilibrium. The column on the right side of Table 2 for total employmnent gives us the following identity:

$$1/r = 1/s_1 + 1/s_2 + 1/s_3 + 1/s_4 + 1/s_R$$

Further, the population of all higher level places is determined by a hierarchial multiplier similar to that discussed by Beckman and McPherson (1970). Population at each level, P_i, $i = 1,\ldots,4$, is determined by known parameters and the counting rules of Table 2. Use the counting rules to divide employment at each level as follows:

$$D_i = m_i P_i = L_i$$

$$P_i = L_i/m_i \qquad i = 1,\ldots,4$$

where D_i = employment at level i devoted to production for domestic or local purchase and consumption of goods and services.

L_i = employment at level i devoted to production for lower-order places to purchase and consume.

and m_i = multiplier for known parameters.

For example, total employment at level 1 of the hierarchy (P_1/r) can be divided into components as:

$$P_1/r = D_1 + L_1 = P_1/s_1 + P_R/s_1.$$

Solving for P_1 we have

$$P_1 = \frac{P_R}{s_1 m_1} = \frac{L_1}{m_1}$$

where $m_1 = \frac{1}{r} - \frac{1}{s_1}$.

At higher levels of the hierarchy we can solve for the following multipliers:

$$m_2 = \frac{1}{r} - \frac{1}{s_1} - \frac{1}{s_2} ;$$

$$m_3 = \frac{1}{r} - \frac{1}{s_1} - \frac{1}{s_2} - \frac{1}{s_3} ;$$

and $$m_4 = \frac{1}{r} - \frac{1}{s_1} - \frac{1}{s_2} - \frac{1}{s_3} - \frac{1}{s_4} .$$

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