MEASURING SPATIAL FOCUSING IN A MIGRATION SYSTEM*

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Equality indexes used in other geographical contexts may be used to gauge the degree of spatial focusing in an entire migration system or within the gross in- and out-migration fields of specific regions. They provide useful indicators of overall shifts in the patterns of interregional migration and can help give insight into the population redistributive roles played by specific regions. Perhaps the most common equality index used to measure income distribution is the Gini coefficient, yet it appears almost never to have been applied in migration research. In this paper we set forth a variety of Gini indexes to be used for different migration analyses and illustrate their application with recent data on U.S. interstate movements. We argue that the Gini index provides some singularly useful insights that differ from those afforded by other measures more commonly found to date in the migration analyst's toolkit.

Interest in the structure of interregional migration systems arises, in part, because of the differing relative volumes of migrants in various population movement streams. Migration systems tend to exhibit greater or lesser degrees of "spatial focusing" in different periods. In this paper we use the term *spatial focusing* to mean the inequality that exists in the relative volumes of a set of origin-destination-specific migration flows. A high degree of spatial focusing means that most in-migrants are moving selectively to only a few destinations while most out-migrants are leaving only a few origins. A low degree of spatial focusing means that migrants are moving among all the possible origins and destinations in relatively equal numbers. The extent to which in- and out-migration patterns are spatially focused for a particular state or locality has implications for the future course of population growth in that area: Compared to a state with broad migration fields, a state with highly focused sources of in-migration or highly focused destinations of out-migration will be more strongly affected by economic and societal events in other specific regions.

In any interregional migration system the various regions probably have different populations, and it is likely that the various potential migration destinations will be located at different distances from each possible origin. Because of these structural factors we, of course, would never expect all streams to have equal volumes of migrant flow. One use for an index of spatial concentration is to give an indication of *shifts* in the overall geographic patterns of flow in a migration system. Whereas the geographic patterns of migration can change rather dramatically over the course of even a short business cycle, the relative population sizes of regions and the relevant distance of one population centroid to another population centroid changes only slowly over time.

Even more useful, and probably the primary reason to include it in the migration analyst's toolkit, spatial concentration is a summary measure of the differences between the patterns of movement in any region's in- and out-migration fields. The extent to which the volumes of flows coming into a region differ in their degree of concentration from the volumes of flows leaving the region is of particular interest because net migration is one of the components of population change. A region that draws its migrants from a set of origin regions different from the destination regions to which it sends out-migrants may have a zero overall net migration (total gross in-migration equals total gross out-migration), but it nonetheless may play a significant role as a *redistributor* of the population in the migration system. The specific streams of in- and out-movement may differ in their degrees of spatial concentration. A measure of the spatial concentration of in-migration fields and out-migration fields, in conjunction with other measures of migration, can aid our understanding of the spatial linkages that exist between population change in any single region and that taking place in all other regions of the system. An interesting question to explore is whether some regions have persistently focused (highly concentrated) in- or out-migration fields while others have persistently broad (unconcentrated) fields.

In this paper we argue that the Gini index of concentration, which has been most widely applied by economists in studying income distribution, provides a useful and revealing accounting framework for examining the nature of spatial focusing in a migration system. In the next section we set forth the Gini coefficient and its decomposition into several useful subcomponents based on the structure of migration matrices. We illustrate the calculation of the various terms involved using hypothetical (3 × 3) matrices. In the third section of the paper we apply the concepts to actual U.S. migration matrices during the last decade. In the concluding section we compare the insights provided by the Gini

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index to those afforded by several other measures, including entropy statistics, the demographic effectiveness index, and transaction flow analysis (which uses the Hoover index of concentration). We highlight the purposes for which the Gini index seems to have the most potential for researching substantive migration questions.

THE GINI INDEX FOR MIGRATION SYSTEM ANALYSIS

Measuring spatial focusing in a system of region-to-region migration flows is analogous to measuring equality in any distribution of numerical values. In the geographical analysis of population these equality measures have been employed most commonly in measuring (a) the diversity or heterogeneity of a population for comparison over time or across geographic areas, and (b) segregation—the extent to which the various subgroups of a population are clustered within certain geographic subareas.

Social scientists have devised measures of inequality to address a wide range of issues: Is the income distribution in a nation less equal today than in the past? Is the age distribution of the population in a region becoming increasingly equal with high volumes of elderly in-migration? Are crime rates becoming more concentrated in a few regions of the nation? Are public facilities becoming less and less equally accessible to citizens?

In all of these cases analysts must make a choice among a range of measures or statistics that capture the degree of inequality or concentration in the variate values of a distribution. The most common measures include the range, the relative mean deviation (which equals twice the Hoover index), the variance, the coefficient of variation, the standard deviation of logarithms, the Gini index, Theil's entropy index, and Atkinson's index (see Atkinson 1970; Duncan and Duncan 1955; Griffith and Amrhein 1991; Isard 1960; Kendall 1958; King 1969; Sen 1970; Smith 1975). Of course, the most appropriate measure depends upon the actual purposes of the study.

Economists have preferred certain measures over others because of the different welfare implications underlying each of these distributions—a point Dalton (1920) emphasized over 75 years ago. For example, some indexes have the Pigou-Dalton property of being sensitive to (income) transfers for all (income) levels—an extremely attractive property when measuring longitudinal change in (income) inequality. In general, other social scientists have not been especially concerned about these underlying welfare implications when they have examined inequality; but White (1986), in a very useful review of the application of equality measures to examine population diversity or heterogeneity and segregation, spells out a number of desirable properties and evaluates each measure according to such criteria.

Many of the measures commonly employed in the social sciences possess either arbitrary or nonintuitive properties that are rarely addressed. For instance, why should the different values of some variate be compared to the mean value when this mean value might not itself exist? Or, why should procedures such as squaring the differences or making logarithmic transformations be adopted when these have very definite consequences for the resulting values taken on by the measures?

It seems to us that the Gini index, which carries out direct comparisons between every pair of variate values, simply makes more sense than the other inequality measures. This index not only has the attractive feature of being directly related to the Lorenz curve, but also satisfies the Pigou-Dalton condition for transfers. Also, the Gini index and the Hoover index, which both vary between 0 and 1, have an intimate but little-known relationship. If variate values are ranked from highest to lowest and then appropriately differenced and summed, the Gini index weights the largest (smallest) variate values the most (least), whereas the Hoover index weights all the ranked variate differences equally. Consequently the Gini index is always at least as large as the Hoover index (see Mulligan 1991).

With Glasser's (1962) estimates of the sample mean and variance for the Gini index, we could construct a test statistic for the index, where sampling is without replacement and there are at least 20 observations. We see no use for this test for the applications given in this paper, however, because we are only measuring the annual values for interstate migration inequality at four points over a short period. If our study were extended over a longer period, perhaps more than two decades, it would be interesting to test whether certain years were significantly different from the average year in migration inequality.

The only previous application of the Gini index to migration that we have found is that by Watkins (1986:113–27), who plots Lorenz curves and calculates coefficient values based on the destination-specific percentages of each U.S. state's age-specific gross migraproduction rates (i.e., the average expected number of lifetime moves). He thereby demonstrates that out-migration by persons in younger age groups tends to be more spatially dispersed than the highly concentrated or focused streams of the elderly.

The special structure of a migration (or other interaction) matrix—one with elements associated with particular origin and destination regions—makes it desirable to examine spatial focusing with a measure of equality that can be decomposed into constituent terms related to the rows, columns, and paired (*ij* and *ji*) elements that correspond to gross out-migration, gross in-migration, and net migration exchange among regions. For this purpose we suggest the Gini index, which is the only common measure that involves a comparison of *each* flow to *every other* flow in the system. It is sufficiently (1) *comprehensive* to capture in a single measure all possible pairwise exchanges in a migration system (e.g., to include all possible interregional flows in a national system); (2) *specific* to compare directly the differences between any possible pair of these flows; (3) *useful* to capture any intertemporal changes in the pattern of systemwide exchanges (i.e., amenable to measuring changes in flow differences from one period to another); (4) *adaptable* to capture the differences in these flows at various geographic scales (so that demographic accounting conforms to all properties of spatial aggregation); (5) *flexible* to portray trends in region-specific in-migration and out-migration differences, as well as direct exchange differences between regions; and (6) *modifiable* to allow the various region-level trends (noted in point 5) to be standardized by the systemwide trend (point 1) to permit more useful intertemporal comparisons (per point 3).

A general formula for computing a Gini Index for a set of n numbers is:

$$G=\left[\sum_{a=1}^{n}\sum_{b=1}^{n}\left|y_a-y_b\right|\right]\Big/2n^2\mu\ , \tag{1}$$

where y_a, y_b represent two of the observations, and μ is the (observed) mean of all n numbers.

The Total Flows Gini Index

For application to interregional migration flows, we shall compute a total Gini coefficient based on the migration flows $\{m_{ij}\}$ between n regions represented in an $(n \times n)$ matrix $\mathbf{M}$, ignoring the diagonal elements $\{m_{ii}\}$ (which might contain nonmovers as well as within-region migrants). Thus the general formula may be rewritten such that the Gini coefficient is based on comparing every interregional flow to every other interregional flow:

$$^{T}G(t)=\frac{\displaystyle\sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n}\sum_{g=1}^{n}\sum_{\substack{h=1\\ h\neq g}}^{n}\left|m_{ij}-m_{gh}\right|}{2\left[n\left(n-1\right)\right]^{2}\left(\displaystyle\sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n}m_{ij}\right)\Big/\left[n\left(n-1\right)\right]}\ . \tag{2}$$

The Gini index is interpretable as one-half the relative mean absolute difference, which can be described as the arithmetic average of the absolute value of the differences between all pairs of exchanges. Note that the numerator term is simply the sum of all the absolute differences between each of the $n(n-1)$ migration flows and every other flow; the denominator is simply the product of twice the total number of such comparisons, $2[n(n-1)]^2$, and the mean value of all the flows. The denominator can be simplified and the formula rewritten more compactly as:

$$^{T}G(t)=\frac{\sum_{i}\sum_{j\neq i}\sum_{g}\sum_{h\neq g}\left|m_{ij}-m_{gh}\right|}{2n\left(n-1\right)T}\ , \tag{3}$$

where T is the total number of interregional migrants in the system. Note that we have added a left superscript T to indicate that this index, as distinct from others that we shall propose, is based on all the migration flows in the system. We have also shown G as a function of time (t) to emphasize that the primary usefulness of this total index will be to make intertemporal comparisons. Although we think there is utility in examining how the values of this total index change over time, the accounting framework that it affords suggests some even more useful and more interpretable subindexes.

TABLE 1. HYPOTHETICAL MIGRATION MATRICES FOR PERIODS t_1 AND t_2, WITH ROW (OUT-MIGRATION) AND COLUMN (IN-MIGRATION) TOTALS

	$\mathbf{M}(t_1)$				$\mathbf{M}(t_2)$			
	$j=1$	$j=2$	$j=3$	O_i	$j=1$	$j=2$	$j=3$	O_i
$i=1$	0	10	10	20	0	20	20	40
$i=2$	20	0	20	40	30	0	50	80
$i=3$	30	30	0	60	20	20	0	40
I_j	50	40	30	$T=120$	50	40	70	$T=160$

Graphically speaking, the Gini index represents the ratio between (1) the areal difference between the line of absolute equivalents (diagonal) and the Lorenz curve, and (2) the area of the triangular region under the diagonal. The index varies from 0, when all cumulated observed frequencies would fall on the Lorenz curve itself (i.e., when all flows are of equal size) to 1, when all migrants are found in a single interregional flow.

Of course, in reality we would never expect to find equality in the sizes of migration flows among a set of regions of different population sizes, economic vitality, amenity endowment, and so forth, that are separated from one another by different distances. For purposes of *intertemporal* comparisons across the same set of regions, however, the total flows index suggests the overall extent to which migration is becoming more or less spatially focused. An alternative to using the complete absolute equality of flows as the benchmark for a spatial focusing measure would be to examine the deviations between actual flow volumes and some level of "expected" flow based on, for instance, the population sizes of origin and destination regions (as in Ledent's 1991 concept of "natural" migration) or the flow level predicted by a gravity model (as in Plane's 1984b concept of "migration space"). Any model of expected flow, however, is arguable; thus we think the straightforward application of the Gini index to absolute flow volumes is of interest.

Sample Calculations

To illustrate the calculation of the total flows Gini index, $^{T}G(t)$, and to make more apparent the various components of it that we shall present later, we consider the hypothetical migration matrices for two time periods shown in Table 1.

For these matrices there are $[n(n-1)]^2 = 36$ absolute differences to be computed. Of these, $n(n-1) = 6$ are trivial in the sense that they are comparisons of each migration flow to itself, which necessarily result in zero absolute differences. We shall find it useful to account for the remaining 30 differences in four different categories: (1) differences between flows in the same row of the matrix (i.e., $|m_{ij} - m_{ih}|$); (2) differences between flows in the same column (i.e., $|m_{ij} - m_{gj}|$); (3) differences in the diagonally opposite elements in the matrix (i.e., $|m_{ij} - m_{ji}|$); and (4) all other differences (i.e., $|m_{ij} - m_{gh}|$, where $i \neq g$, *or* $j \neq h$, *or* $i \neq h$ *and* $j \neq g$).

For instance, for period 1:

$$(1)\quad \left.\begin{aligned} &\text{Row 1: } |10-10|+|10-10|=0\\ &\text{Row 2: } |20-20|+|20-20|=0\\ &\text{Row 3: } |30-30|+|30-30|=0 \end{aligned}\right\} = 0$$

$$(2)\quad \left.\begin{aligned} &\text{Column 1: } |20-30|+|30-20|=20\\ &\text{Column 2: } |10-30|+|30-10|=40\\ &\text{Column 3: } |10-20|+|20-10|=20 \end{aligned}\right\} = 80$$

$$(3)\quad \left.\begin{aligned} &12{,}21\text{: } |10-20|+|20-10|=20\\ &13{,}31\text{: } |10-30|+|30-10|=40\\ &23{,}32\text{: } |20-30|+|30-20|=20 \end{aligned}\right\} = 80$$

$$(4)\quad \left.\begin{aligned} &12\text{, Other: } |10-20|+|10-30|=30\\ &13\text{, Other: } |10-20|+|10-30|=30\\ &21\text{, Other: } |20-10|+|20-30|=20\\ &23\text{, Other: } |20-10|+|20-30|=20\\ &31\text{, Other: } |30-10|+|30-20|=30\\ &32\text{, Other: } |30-10|+|30-20|=30 \end{aligned}\right\} = 160.$$

Therefore the numerator term overall is 0 + 80 + 80 + 160 = 320, and the total flows index is:

$$^{T}G(t_1) = 320\big/\left[2\times 36\times(120/6)\right] = 320/1440 = 0.2222 \;.$$

Carrying out the corresponding calculations for period 2:

$$\begin{aligned} ^{T}G(t_2) &= (40+80+80+160)\big/\left[2\times 36\times(160/6)\right]\\ &= 360/1920 = 0.1875 \;. \end{aligned}$$

Thus for these hypothetical matrices we would conclude that migration had become *less* spatially focused from t_1 to t_2.

This then illustrates the first use of the Gini index: for intertemporal comparisons for entire migration systems. It would be interesting to examine whether, over the longterm, systemwide patterns of movement become more dispersed or more concentrated. Another interesting question is whether there are more spatially specialized channels of movement in existence during short-term upturns or downturns in the economic cycle. As suggested by the four constituent elements into which we grouped the calculations of the absolute differences for the numerators, however, it is also of interest to examine the contributions to the total flows index for particular subsets of flows.

The Rows and Columns Gini Indexes

To study the relative extent to which the destination selections of out-migrants are spatially focused we can use simply the $n(n-1)(n-2)$ Group 1 differences to derive a *rows* index:

$$^{T}G_{R\bullet}(t) = \frac{\sum_{i}\sum_{j\neq i}\sum_{h\neq i,j}|m_{ij}-m_{ih}|}{2n(n-1)T} \;. \tag{4}$$

Similarly, the spatial focusing represented by the relative proportions of in-migrants coming from all the various origins to each of the destinations is given by a *columns* index based on the $n(n-1)(n-2)$ Group 2 differences:

$$^{T}G_{\bullet C}(t) = \frac{\sum_{j}\sum_{i\neq j}\sum_{g\neq j,i}|m_{ij}-m_{gj}|}{2n(n-1)T} \;. \tag{5}$$

The two measures may be used to compare the relative extensiveness or focusing of all out-migration versus all in-migration fields. Note, however, that these are summary measures for the *entire* migration system (hence we retain the left superscript, *T*) rather than measures computed for specific regions.

To facilitate comparisons from one period to the next of the rows and columns indexes it is useful to standardize their values by dividing by the total flows index value and expressing the results as percentages. That is:

$$\begin{aligned} ^{T}G_{R\bullet}^{*}(t) &= 100\times{}^{T}G_{R\bullet}(t)/{}^{T}G(t)\\ ^{T}G_{\bullet C}^{*}(t) &= 100\times{}^{T}G_{\bullet C}(t)/{}^{T}G(t) \;. \end{aligned} \tag{6}$$

These standardized indexes will range from 0%–100% depending on the extent to which the Group 1 or Group 2 differences contribute to all the differences included in the total flows index. Again, as with the total flows index, the actual values of these subindexes will reflect structural properties of the interregional system examined; because the same origin-destination pairs are examined for in- and out-migration, however, their relative values tell us whether out- or in-migration is the more spatially focused.

For the hypothetical migration matrices shown in Table 1, the out-migration flows to various destinations are more uniform than the in-migration flows from the various origins. For the first period, $^{T}G_{R\bullet}^{*}(t_1) = 0$ because both off-diagonal elements in each of the rows are identical in size. For the second time period, however, the out-migration destination fields become a little more spatially focused: $^{T}G_{R\bullet}^{*}(t_2) = 100 \times 0.0208 / 0.1875 = 11.1\%$. On the other hand, standardized columns indexes disclose that the distribution of source regions for in-migration are more spatially concentrated, but that the level of this concentration is decreasing over this time span: ${}^{T}G_{.C}{}^{*}(t_1) = 100 \times 0.0555 / 0.2222 = 25.0\%$, and ${}^{T}G_{.C}{}^{*}(t_2) = 100 \times 0.0417 / 0.1875 = 22.2\%$.

The Exchanges Gini Index

We calculate a final subindex analogous to the rows and columns Ginis based on the Group (3) comparisons of the flow, m_{ij}, in each migration stream to the flow in the counter-stream, m_{ji}. The *exchanges* index indicates the contribution to spatial focusing represented by the $n(n-1)$ net interchanges in the system. It is calculated with the formula:

$$ {}^{T}G_{RC,CR}(t) = \frac{\sum_{i}\sum_{j\neq i}\left|m_{ij} - m_{ji}\right|}{2n(n-1)T} \ . \tag{7} $$

As with the rows and columns indexes it is best used in standardized form:

$$ {}^{T}G_{RC,CR}{}^{*}(t) = 100 \times {}^{T}G_{RC,CR}(t) / {}^{T}G(t) \ . \tag{8} $$

For the sample matrices of Table 1 the reader may verify that the standardized exchanges index values are 25.0% and 22.2%.

The remaining differences included in the total Gini index are those in Group 4. Although we envision no use for migration analysis of interpreting this fourth constituent element of ${}^{T}G(t)$, we designate it ${}^{T}G_{\text{Other}}(t)$ so as to be able to state the accounting relationships:

$$ \begin{aligned} {}^{T}G(t) &= {}^{T}G_{R\bullet}(t) + {}^{T}G_{\bullet C}(t) + {}^{T}G_{RC,CR}(t) + {}^{T}G_{\text{Other}}(t) \\ 100 &= {}^{T}G_{R\bullet}{}^{*}(t) + {}^{T}G_{\bullet C}{}^{*}(t) + {}^{T}G_{RC,CR}{}^{*}(t) + {}^{T}G_{\text{Other}}{}^{*}(t) \ . \end{aligned} \tag{9} $$

Before using the measures to examine the empirical evidence on spatial focusing of the U.S. migration system during the 1980s, we present two even more disaggregate Gini indexes which may prove to be the most practical for substantive analyses.

The Out- and In-migration Field Gini Indexes

Both the rows and the columns indexes can be decomposed further to represent the contributions of each region's row or column to the total index. These, however, are not necessarily directly comparable to one another due to the possibly very large differences in the population sizes of each region in the system. We suggest, therefore, the calculation of indexes for each specific region k's out-migration destination field and for its in-migration source field:

$$ {}^{O}G_{k\bullet}(t) = \frac{\sum_{j\neq k}\sum_{h\neq k}\left|m_{kj} - m_{kh}\right|}{2(n-1)^2 \sum_{j\neq k} m_{kj} \Big/ (n-1)} = \frac{\sum_{j\neq k}\sum_{h\neq k}\left|m_{kj} - m_{kh}\right|}{2(n-1)O_k} , \tag{10} $$

$$ {}^{I}G_{\bullet k}(t) = \frac{\sum_{i\neq k}\sum_{g\neq k}\left|m_{ik} - m_{gk}\right|}{2(n-1)^2 \sum_{i\neq k} m_{ik} \Big/ (n-1)} = \frac{\sum_{i\neq k}\sum_{g\neq k}\left|m_{ik} - m_{gk}\right|}{2(n-1)I_k} \ . \tag{11} $$

Here the left superscript is either O or I, rather than T as in the measures presented earlier, indicative of the smaller number of total comparisons on which their denominators are based.

These out-migration and in-migration field Gini indexes vary on the interval [0,1]. Without further standardization they may be directly compared to one another and to indexes for other regions in the system. To facilitate interpretation, however, we present them as z-scores (i.e., by subtracting their average values across all regions in the system and dividing by their standard deviation). We now examine applications of these measures to actual migration matrices for several periods and for several geographic scales during the 1980s, thereby highlighting the ways in which they can provide insights for practical analyses of the geographic patterns of migration.

SPATIAL FOCUSING OF THE U.S. MIGRATION SYSTEM IN THE 1980s

1985–1990 Decennial Census Interstate Flow Matrix and a Typology of States

We first applied the various Gini index measures to the (51 × 51) matrix of state-to-state migration flows from the 1990 decennial census question on place of residence in 1985.[1] Shown in Table 2 are both the raw and standardized coefficients for the four components of the total flows index.

Note that the rows (or out-migration destinations) index is higher than the columns (or in-migration sources) index, a result we found for all 1980s matrices that we examined. These differences, however, are fairly small. This is not unexpected given the property of migration systems, well known since Ravenstein's (1885) seminal paper, that every migration stream tends to beget an opposite and *almost* equal counterstream. Structural properties also would lead us to expect relatively close rows and columns index values: The flows in both directions between large states generally will be larger than those between pairs of smaller states, and these expected differences in the flow volumes will result in the same contribution to the rows and the columns index.

Note also the relatively small contribution of the exchange flows to the total flows index value. This is an expected result given (a) the well-known fact that the demographic effectiveness of U.S. migration (the ratio of net to gross interchange) is low; and (b) that when working with a (51 × 51) matrix there are only 2,550 absolute differences included in the computation of the exchange measure, whereas there are 124,950 nontrivial comparisons for each

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[1] All matrices examined included the District of Columbia in addition to the 50 states. Diagonal elements (inclusive of nonmovers and within-state movers) were excluded from the analyses.

TABLE 2. TOTAL FLOWS GINI INDEX VALUES FOR 1985–1990 INTERSTATE MIGRATION

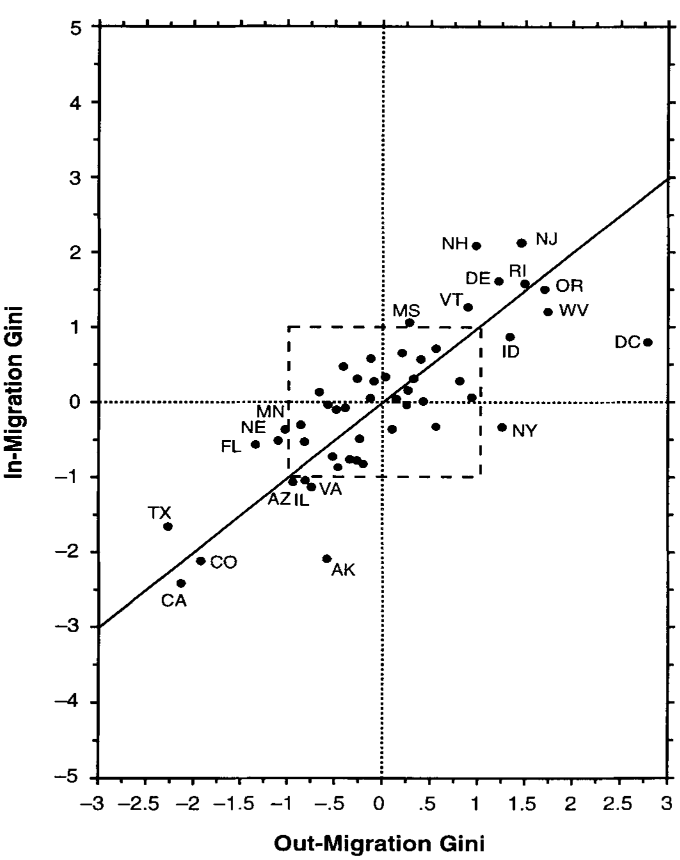
Component	Raw Index Value	Standardized Value (%)
Rows (Out-Migration)	.012028	1.684
Columns (In-Migration)	.011683	1.635
Exchanges	.000089	0.012
Other Flows	.690644	96.669
Overall Total Flows	.714443	

of the rows and columns indexes and 6,247,500 for the "other flows" index.

We next computed the out- and in-migration field indexes for the 1985–1990 (51 × 51) matrix. The states' $^{O}G_{k}(t)$ and $^{I}G_{k}(t)$ z-score standardized indexes are plotted graphically in Figure 1. A positive z-score indicates that a state's migration field is more spatially focused than average, perhaps indicating its role in a strong regional migration subsystem.[2] Negative z-scores indicate that a state's field is broader, or less focused. Negative z-scores for in-migration indicate that migrants are attracted from diverse areas of the nation, whereas negative out-migration values suggest that migrants move to widely dispersed destinations.

The results of our application of the Gini index to raw migration flow data do not simply reflect population size effects. The adjusted R^2 values for simple regressions of the out-migration and in-migration field indexes with 1990 state population are 0.134 and 0.187, respectively. Furthermore, the relationships are inverse, with larger states having a very slight tendency toward lower Gini indexes indicating broader migration fields. Because the calculation of each state's coefficients is based on its respective total gross out- and in-migration, we essentially control for the state's own population size. Further, we are comparing the distribution of flows to the other potential destinations or from the same potential origins so that the population sizes at the other end of the migration streams similarly do not determine the results. Were this method to be used on transition probabilities rather than on raw flow data, the results would be identical for the out-migration field indexes; the in-migration field measures, however, would have no useful interpretation.

FIGURE 1. MIGRATION FIELD GINI INDEX VALUES, 1985–1990 U.S. INTERSTATE FLOWS



Just as Roseman and McHugh (1982) use the Hoover index for transaction flow analysis, we compare the relative magnitudes of the standardized out- and in-migration field indexes for perspective on the redistributive role that states play in the overall migration system. States with larger in-migration than out-migration field indexes—those plotted above the 45° line in Figure 1—are similar to what Roseman and McHugh would term outward redistributors; those with larger out-migration measures—those lying below the 45-degree line—are inward redistributors. Roseman and McHugh, however, also measure distance or the spatial extent of the migration fields. From the perspective of their transaction flow analysis, an inward redistributor would be a state attracting in-migrants from long distances and from throughout the migration system, but sending a high percentage of out-migrants to a small number of nearby states. In our use of the Gini index there is no necessary connection between the typical distances that in- and out-migrants travel; a state that is an inward redistributor is one where in-migration is relatively uniform across all origins, whereas out-migration is more highly focused on selective destinations—wherever they might be.

Perhaps the most notable aspect of Figure 1 is the high positive correlation between the in– and out-migration field measures (R = .793). In- and out-migration fields for particular states are, in fact, in most cases rather similar. Of particular interest are states with index values greater than

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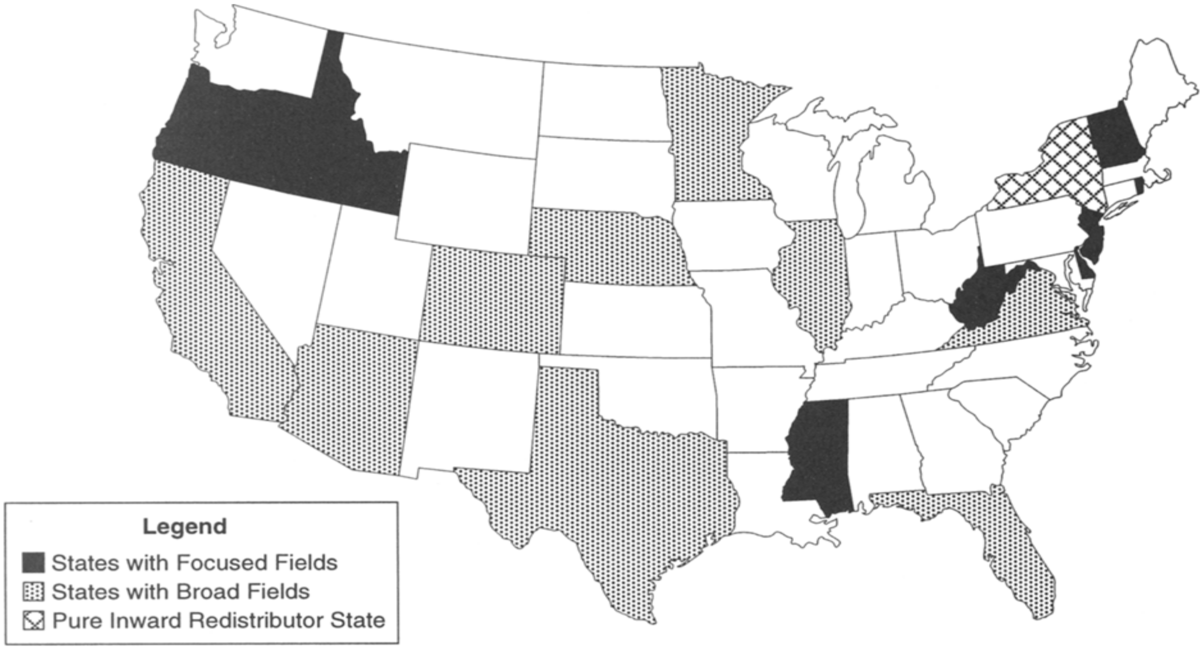
[2] For discussion of subsystems in U.S. interstate migration see, for example, Clayton (1977, 1982); Ellis, Barff, and Renard (1993); Pandit (1994); and Plane and Isserman (1983).

FIGURE 2. STATES WITH HIGHLY FOCUSED OR ESPECIALLY BROAD INTERSTATE MIGRATION FIELDS, 1985–1990



one standard deviation above or below the mean. As highlighted by the box drawn with a dashed line on the figure, 21 states have one or both index values above +1.0 or under −1.0. We can then derive a typology of these states. Ten states are classified as having focused fields: Both indexes are positive, implying spatially focused destinations for their out-migrants and spatially focused source regions for their in-migrants. As shown on the map in Figure 2, small New England and northeastern states for which short-distance intraregional or even intrametropolitan flows are quite large (New Hampshire, Vermont, Delaware, and Washington D.C.) and rural states in other regions isolated from major metropolitan areas (Oregon, West Virginia, Idaho, and Mississippi) are found in this group. Ten states have distinctively broad or spatially extensive fields. These states with substantially below-average spatial focusing include several in the west with high rates of in- and out-migration (California, Colorado, Texas, Alaska, and Arizona). Florida is also included because it draws elderly migrants from large sections of the nation. Virginia, as part of the national capital district has the lure of federal government employment; thus it draws substantial numbers of in-migrants from (and sends out-migrants back to) all other states. One state is a special case. New York has strongly focused destinations for out-migrants (particularly its elderly stream to Florida) but a moderately broad in-migration field. Thus it can be called a "pure" inward redistributor of population.

Annual IRS/Census Matrices: Trends and Geographic Scales in Spatial Focusing

To study the temporal trends in spatial focusing over the course of the 1980s and to examine such trends at different geographic scales, we also computed all the Gini index measures for four selected one-year migration matrices representing moves made in the periods 1981–1982, 1983–1984, 1985–1986, and 1987–1988. Based on the addresses and number of exemptions claimed on matched personal income tax returns filed in the first quarters of consecutive years, these IRS/Census Bureau migration matrices are extremely useful for studies of the temporal evolution of the U.S. migration system (see Engels and Healy 1981; Isserman, Plane, and McMillen 1982).

Table 3 shows the total flows index values and the standardized constituent elements for each of the four one-year time periods and for each of three geographic scales: interstate flows (51 × 51), interdivisional (9 × 9), and interregional (4 × 4).

As is the case with other applications of the Gini index, the values go down with increasing geographic aggregation. Despite the differences between one-year and five-year mi-

TABLE 3. OVERALL TOTAL FLOWS AND STANDARDIZED COMPONENT GINI INDEX VALUES FOR ONE-YEAR PERIODS AND DIFFERENT GEOGRAPHIC SCALES DURING THE 1980s

	1981–1982	1983–1984	1985–1986	1987–1988
Interstate (51 × 51)				
Overall total flows	.70489	.70219	.70716	.71149
Rows (out-migration)	1.70	1.68	1.70	1.67
Columns (in-migration)	1.62	1.64	1.62	1.65
Exchanges	0.010	0.008	0.009	0.010
Interdivisional (9 × 9)				
Overall total flows	.41464	.39959	.40735	.41616
Rows (out-migration)	9.23	9.22	9.35	9.24
Columns (in-migration)	8.52	8.67	8.86	8.71
Exchanges	0.69	0.46	0.52	0.52
Interregional (4 × 4)				
Overall total flows	.30891	.28559	.28804	.27561
Rows (out-migration)	20.41	19.98	19.94	19.59
Columns (in-migration)	13.65	14.98	15.26	16.01
Exchanges	5.84	4.35	4.09	2.97

gration data, the IRS interstate matrices result in index values very similar to those previously reported from 1985–1990 decennial census data. As also was found for the 1985–1990 period, throughout the decade the row (or out-migration destination) indexes are higher than the corresponding column (or in-migration source) indexes. This result holds at all three geographic scales.

The temporal trends in the total flows index, however, are quite different at the three scales. Over the course of the decade, interstate flows became increasingly spatially focused, whereas interregional flows became less focused. At the intermediate, interdivisional scale, the index first decreased from the 1981–1982 to the 1983–1984 period, and then began to climb, reaching a higher level in the period 1987–1988 than in the first period. Thus the importance of areal unit definition and of spatial scale for migration analysis is highlighted. Because these types of measures are sensitive to the level of aggregation, they can be used (as, for instance, in the application of the Hoover index by Vining and Strauss 1977) to highlight differences or similarities in population distribution trends at various geographic scales.

The final computations we carried out with the IRS data set were for the in- and out-migration field indexes at each of the three geographic scales for each of the four one-year time periods. The results at the interstate scale are summarized in Table 4, in which out-migration destination and in-migration source fields are classified according to the same typology we used for 1985–1990 decennial census flows illustrated in Figures 1 and 2.

The most apparent aspect of the table is the relatively high stability that exists in the classification of states over the four periods of the decade. For those states with one or both Gini index values more than one standard deviation above or below their respective means, there are none with focused fields in one period and broad fields in a later period. The relative level of spatial focusing of a state's in- and out-migration fields is reflective of various historical, social, and economic structure factors, as well as of certain "spatial structure" aspects of the geographic units used for the analysis. As such, it appears to be a property that endures over time—at least over the short or medium term. Although certain structural properties (such as the physical location of a state with respect to all other states) could be expected to influence its in- and out-migration fields equally, other characteristics may result in asymmetries. For example, in Florida, in-migration is dominated by elderly retirees moving in from the Northeast, whereas out-migration is influenced most heavily by labor force flows to other states of the South.

As we reported for 1985–1990 decennial census data, the IRS matrices also result in highly correlated out- and in-migration Ginis, implying that many of the structural properties have rather symetrical effects. The correlation is, in fact, even higher for the shorter migration interval they represent (*R* equals .902 for 1981–1982, .936 for 1983–1984, .917 for 1985–1986, and .899 for 1987–1988, versus .793 for 1985–1990). There is also high correlation over time among both the out-migration and the in-migration field measures. These correlations (*R*) are presented in Table 5.

TABLE 4. TYPOLOGY OF FOCUSING OF INTERSTATE IN- AND OUT-MIGRATION FIELDS FOR SELECTED YEARS IN THE 1980s

	1981–1982	1983–1984	1985–1986	1987–1988
A. States with Focused Fields				
1. Outward redistributors	NH	NJ	NH	NJ
	NJ	NH	NJ	NH
	OR	OR	RI	OR
	VT	DE	DE	RI
	DE	WV		DE
	WV			MS
	RI			VT
	ID			
2. Inward redistributors	DC	DC	DC	DC
	AR	RI	OR	WV
	NM	VT	WV	ID
			VT	
			ID	
B. States with Broad Fields				
1. Outward redistributors	CO	AK	TX	TX
	AK	FL	FL	FL
	FL	MN	MN	MN
	VA			
	MN			
2. Inward redistributors	CA	CA	CA	CA
	TX	CO	CO	CO
	IL	TX	AK	AK
	WY	VA	VA	VA
		IL	IL	IL
		AZ	AZ	
C. "Pure" Inward Redistributor			NY	NY

Note: States listed in each grouping are ranked in descending order of the size of the larger of their two Gini indexes.

TABLE 5. CORRELATIONS OVER TIME FOR OUT-MIGRATION AND IN-MIGRATION FIELD MEASURES

	Out-Migration	In-Migration
1981–1982 and 1983–1984	.969	.979
1983–1984 and 1985–1986	.990	.987
1985–1986 and 1987–1988	.986	.988
1981–1982 and 1985–1986	.953	.971
1983–1984 and 1987–1988	.971	.976
1981–1982 and 1987–1988	.915	.923

There was slightly more change in the geographic focusing of out-migration destinations than of in-migration sources over this period.

In Table 4 no state over the decade switches between the list of focused fields and the list of broad fields, although some states change in classification as outward or inward redistributors. For example, among the focused states West Virginia switches from an outward redistributor (i.e., one with more focused sources of in-migration than destinations of out-migration) to an inward redistributor, and Oregon, Rhode Island, and Vermont switch twice during the decade.

New Jersey remains an outward redistributor across all four periods, with an increasing focus of its in-migration source regions as indicated by a rise in its $^{I}\mathrm{G}_{.k}(t)$ value from 1.60 in 1981–1982 to 2.03 in 1987–1988. The District of Columbia has the highest standardized $^{O}G_{k.}(t)$ z-scores for all four periods, exceeding three standard deviations above the mean. As previously mentioned, moves to the Maryland and Virginia suburbs are an extremely significant aspect of Washington D.C.'s out-migration field.

Among the states with broad migration fields, the Gini index discloses Florida and Minnesota to be consistent outward redistributors (i.e., with more spatially extensive out- than in-migration fields). The result for Florida is interesting. Pandit (1994), for instance, notes that Florida's in-migration field is more spatially extensive (with heavy volumes of flow particularly from New York), whereas its out-migration field is more typical of southern states. The Gini index results reflect the extreme concentration represented by New York–Florida movements, whereas the maps of migration regions derived by Pandit through principal component and cluster analysis show the greater contiguity of out-migration destinations than of in-migration sources. The Gini index shows California holding its position as the state with the broadest fields during all four periods—receiving migrants widely from across the entire nation, but sowing out-migrants somewhat less broadly. Examination of the actual migration flows matrices shows that California's out-migration is heavily focused on selected other western states (e.g., Oregon, Washington, Nevada, and Arizona). The Gini index thus can be used as a "flag" or indicator to direct migration researchers to explore certain state's unusual migration fields.

Among the other noteworthy states picked out by the Gini indexes is Illinois, which appears on all four lists of broad inward redistributors. Alaska switches from being an outward redistributor in the first two periods to serving as an inward redistributor in the final two. Colorado makes the same change, but one time period earlier, whereas Texas moves in the opposite direction. Although its out- and in-migration fields are both quite broad in all time periods, Texas's in-migration source field is broader than its out-migration destination field during the first two periods; but

TABLE 6. STANDARDIZED OUT-MIGRATION AND IN-MIGRATION FIELD COEFFICIENTS FOR U.S. REGIONS AND DIVISIONS IN THE 1980s

	1981–1982		1983–1984		1985–1986		1987–1988	
	Out	In	Out	In	Out	In	Out	In
REGION								
Northeast	.67	.54	.86	.22	.90	.31	1.09	.42
Midwest	.83	1.33	.70	1.33	.68	1.26	.59	1.08
South	–1.68	–1.25	–1.66	–1.47	–1.65	–1.52	–1.56	–1.63
West	.18	–.62	.10	–.08	.07	–.05	–.12	.13
DIVISION								
New England	.68	1.23	1.04	1.11	1.13	1.21	1.13	.82
Middle Atlantic	.70	.68	1.09	.42	1.34	.53	1.43	.40
East North Central	–.62	–1.44	–.67	–1.34	–.66	–1.39	–.69	–1.35
West North Central	.12	–.14	–.36	.29	–.41	.29	–.77	.08
South Atlantic	–1.74	–.31	–1.53	–.40	–1.21	–.08	–1.25	–.54
East South Central	1.42	1.55	1.30	1.51	1.26	1.33	1.23	1.62
West South Central	–1.35	–1.13	–1.23	–1.53	–1.36	–1.53	–1.03	–1.57
Mountain	.88	.51	.71	.64	.43	.55	.45	.90
Pacific	–.09	–.95	–.35	–.72	–.50	–.90	–.51	–.37

its out-migration is broader than its in-migration during the latter two periods.

As in the 1985–1990 typology, New York stands out as the only strong, "pure" inward redistributor. For the final two periods, when out-migration—particularly to the South Atlantic states—speeded up dramatically, New York has a focused out-migration field (z-scores of +1.02 for the period 1985–1986 and +1.11 for the period 1987–1988); but it retains a somewhat cosmopolitan pattern of in-migration (z-scores equal –0.15 for both periods).

Aggregating the (51 × 51) matrix to the interregional (4 × 4) and interdivisional (9 × 9) levels allows us to report in a single, comprehensible table all the standardized $^{O}G_{k.}(t)$ and $^{I}G_{.k}(t)$ Gini indexes for the four periods (see Table 6). At the interregional scale the South has the broadest fields, whereas the Midwest has the most focused field for in-migration (and for out-migration in the period 1981–1982). The Northeast has the most spatially focused out-migration for all except the first period. The West has values close to the mean, and switches from being a fairly strong inward redistributor in the first period to being somewhat of an outward redistributor by the last period.

The z-scores for the interdivisional scale highlight that aggregation can mask more specific trends. In particular, whereas the South Atlantic and West South Central divisions have broad fields (as was noted for the South as a whole), the East South Central fields are highly focused. Within the West region, the Mountain division has focused fields, whereas the Pacific has quite broad fields.

CONCLUSIONS

In this paper we have proposed a set of Gini index measures for use in examining the degree of spatial focusing found in systems of interregional migration. The measures appear to have utility both for examining systemwide properties and for studying the out-migration destination and in-migration source fields of particular regional units. The measures are based on comparing all flows in the system or in a selected subsection of the system to all other such flows.

Our initial experiments in applying the measures have resulted in some useful insights on the structure of the U.S. migration system during the 1980s. At a later stage of research we plan to study longer-term trends in the measures, comparing the 1985–1990 results reported here to Gini indexes computed from the interstate, interdivisional, and interregional flow tables from the 1940, 1960, 1970, and 1980 decennial censuses.

Gini indexes have not been applied routinely in the analysis of migration systems. We suggest that population analysts add them to their basic toolkit. They should prove useful in the continuing quest to expose the underlying structure of human migration. We have argued that the Gini index has advantages over, for instance, variance and entropy measures (whose use in migration analysis is discussed in Plane and Rogerson 1994:105–106).

The concept of spatial focusing advanced in this paper differs significantly from the concept of demographic effectiveness (or efficiency) first suggested by Thomas (1941). As specified by Shryock (1959, 1964) and used by, for instance, Long (1988), McHugh and Gober (1992), Plane (1984a, 1992, 1994), and Plane and Rogerson (1991), its systemwide value may be derived as:

$$E = 100\sum_j |N_j| / \sum_j T_j \ , \tag{12}$$

where N_j is net migration to each region j and T_j is total migration (i.e., the sum of gross in- and out-migration). Migration effectiveness measures the unidirectionality of migration streams, the extent to which flows of in-migrants are matched by the flows of out-migrants. Thus it is conceptually different than the Gini index of spatial focusing, which reflects how the sizes of each of the migration streams in the system differ from all the other streams. As Rogers and Hemez-Descryve (1993) pointed out using an example for the period 1935–1980, increasing demographic effectiveness does not necessarily mean that other measures will suggest geographic focusing.

The application of the Gini index here also differs from previous applications of the Hoover index to migration analysis (e.g., Flowerdew and Salt 1979; Roseman 1971; Roseman and McHugh 1982). We suggest no standardization of the rows or columns of the flow matrix: We are simply comparing the size of every gross flow to the size of every other flow that occupies the same row or column. The transaction flow analysis method set forth by Roseman and McHugh is useful for separating out size effects to focus particularly on the role of distance in affecting the volumes of migration streams. Our method, in contrast, allows a more general definition of focusing. Embedded in the relative volumes of flows in a migration system are surely origin- and destination-size effects as well as a strong empirical regularity relating the volumes of flow to distance. In addition, the relative flow volumes contain a "spatial structure" effect such as that explored by Fotheringham (1983), Fik (1988), Fik and Mulligan (1990), and Amey, Fik, and Mulligan (1992). The purpose of our accounting framework of Gini indexes is not to sort out effects that make migration a spatially focused phenomenon. Rather, we propose the Gini index as simply a descriptive statistic useful for making comparisons among flow matrices observed for the same interregional system, and for comparing the in- and out-migration fields of specific regions within those systems.

In summary, we suggest the following rules of thumb for choosing from among the various measures for particular applications:

(1) If attention is on the ability of migration to lead to population change in origin and destination regions, use the demographic effectiveness measure.

(2) If the focus of analysis is on the spatial extent or distances moved by in- or out-migrants, use the transaction flow analysis measure.

(3) If the motivation for study is simply to compare the degree to which the sources of in-migration versus the destinations of out-migration are spatially focused, use the Gini index measures set forth in this paper.

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