Migration Data and Matrix Methods: Deriving the Network of U.S. Central Places.

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Abstract

Inter-county flows of commuters have long been used by the Bureau of the Census to identify MSAs and by the BEA to identify its Economic Areas. This paper looks at U.S. interregional flows of commuters, population, and goods in an effort to identify broader patterns of relationships among U.S. regions. A region's primary flow up the central place hierarchy is found using tools commonly employed in Social Network Analysis. The results allow classification of regions in two ways: 1) as levels in a hierarchy; or 2) as a member of a group of regions all tied to the same member of the next-highest level of the hierarchy.

Key words: Central Place Theory, Network Analysis, Migration, Trade

JEL category: R1, R12

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1. Introduction

Regions are integrated in the national and global economies through a web of interregional exchanges of goods, services, capital, and labor. Theoretical views on how regions are interrelated fall roughly into two classes. First, regions can be seen as hierarchically organized, with each level of the hierarchy fulfilling a particular kind of role, so that different places at the same hierarchical level are equivalent. Walter Christaller's (1933) Central Place Theory may be the best known variant of this view, though the voluminous "world systems" literature also falls into this class. Second, regions can be seen as specialized units in an interregional division of labor; each region has a unique comparative advantage, and each region exchanges with every other region, rather than up or down a local hierarchical gradient. Export Base models (Richardson 1979: 84ff) fall into this second class.

Empirical work on interregional exchange networks dates back at least to the 1940s in the U.S. (Isard 1960: Chapter 5). With one notable exception, interregional exchange data have not been used to derive the hierarchical relations among regions. That one exception is the use of county-to-county commuting flows to produce *Metropolitan Statistical Areas* (U.S. Bureau of the Census 2002) and Bureau of Economic Analysis *Economic Areas* (Johnson 1995). The delineation of an MSA or EA begins with the *a priori* designation of hub counties, and then employs commuting data to find spoke counties. The derived hierarchy is incomplete, since the exercise simply produces the bottom level of the hierarchy—the cluster of counties reliant on a node county—and does not then array the delineated MSAs or EAs into a hierarchy. Thus, one can learn that Oldham County, Kentucky is a spoke for the hub Jefferson County, Kentucky and therefore a member of the Louisville EA. But one does not learn to which EA the Louisville EA is subordinate—is it Cincinnati, or Chicago, or Atlanta?

A particularly useful set of tools for empirical work on network data is found in *social network analysis*, a set of techniques based on graph theory and matrix algebra, employed primarily by sociologists, anthropologists, and psychologists (Wasserman and Faust 1994; Scott 2001).

Examples of the application of social network analysis to interregional flows are not plentiful, but one can find work on trade flows among nations (Snyder and Kick 1979; Kick and Davis 2001) or among major world cities (Shin and Timberlake 2000; Smith and Timberlake 2001). As will be shown, network analysis provides tools that can be used to delineate the hierarchical relations among regions.

The following section introduces some ideas from social network analysis. The next section then discusses three data sources for interregional flows of labor and goods in the U.S. The paper then presents a technique for singling out from the myriad of interregional flows those that represent a region's position in the central place hierarchy. The technique is then applied to six data matrices, and the results compared to determine the degree of congruence among the six derived hierarchies. The paper concludes with discussion of potential uses of the method.

2. Interregional Flows as Graphs and Matrices

Interregional exchange networks can be presented as graphs. Figure 1 presents a view of how the interregional exchanges posited by Walter Christaller's (1933) Central Place Theory would appear in graph format. Each node or vertex of the graph represents a region; each line or link represents a flow of goods or people; the system of regions has three levels, and each level is characterized by a hub and spoke structure. The single node at the center of the graph is the highest order center.

Figure 2 presents a graph in which all of the regions exchange directly with each other. There is no hierarchical structure in this graph: each region has a comparative advantage and produces for exchange with every other region. Of course, both central place models and export base models are true, both describe some part of the reality of how regions are interrelated. In practice, this suggests that empirical graphs of interregional flows will look like Figure 2, and one must have some method of singling out those lines which constitute the central place structure.

When lines have a direction, the graph is called a *directed graph* or digraph. When lines have a value, as they would when representing the volume of trade from one node to another, the graph is called a *valued graph*. The number of lines one must traverse to move from one node to another is the *path length*. If there is a path from node i to node j, then node i is *reachable* from node j. The shortest path length between any two nodes is the *geodesic distance* connecting those two nodes. Figure 1 shows the largest geodesic distance for each of the nodes; thus, for example, from the node in the center of the graph (representing the highest order central place) one can reach any other node in the graph by traversing at most two lines. From the peripheral nodes, on the other hand, one must traverse four lines in order to reach the most distant nodes. One can readily see that the maximum geodesic distance provides a measure of hierarchy within the central place system: higher order central places will have a lower maximum geodesic distance.

Centrality is a node-level property, where a node with high centrality is in some way better connected to other nodes. A node's *degree* (the number of lines incident to the node) is often used as a measure of centrality, since nodes with many links to other nodes are especially well connected. A node's *indegree* is the number of directed lines that enter the node; a node's *outdegree* is the number of directed lines that leave the node. Intuitively, centrality seems to provide a measure of hierarchy, though one can see in Figure 1 that the highest order center has the same number of indegrees and outdegrees as the centers immediately below it in the hierarchy.

Graphs can be represented algebraically with an *adjacency matrix*. Each element a_{ij} in adjacency matrix **A** gives the value of the link from node i to node j; the unvalued version of the adjacency matrix contains a '1' in each element a_{ij} where there exists a link from node i to node j, and a '0' when there is no link. Presented in matrix form, a graph can then easily be studied using computational software such as MatLab, Mathematica, or SAS-IML.

3. Interregional Flows in the United States

Data are available for the interregional movement of labor and goods in the U.S. The 1993 Consolidated Freight Survey (CFS), produced by the Bureau of Transportation Statistics, provides data on the interregional exchange of goods. The regional level of analysis in the CFS is the National Transportation Analysis Region (NTAR). NTARs are either coterminous with BEA Economic Areas (EA) or aggregations of two or more EAs (using the boundaries as they stood in 1993). There are 89 NTARs. The CFS presents data on flows by commodity type and by mode of transportation, and it gives both weight and value for these flows. Nevertheless, disclosure restrictions lead to the suppression of portions of all the disaggregated data, so that only aggregate data are complete.

Data for interregional labor exchanges come from two sources. Commuting flows are detailed in the decennial census Journey to Work data. The data are at the county level, and can be aggregated up to the NTAR level to make them compatible with the CFS data. Journey to Work data are available from the Censuses of 1970, 1980, and 1990. Short-distance or short-term movement of labor would be well represented by commuting data, but longer distance or longer term movements would appear predominantly as migration of working age persons. The STP-28 file from the 1990 census gives inter-county migration counts for persons by age, sex, race, educational attainment, nativity, and poverty status. Thus, working age migrants can be singled out, as well as migrants with high education levels. These data can be aggregated to identify migration patterns at the NTAR level.

Six directed, valued adjacency matrices are created from these data. Each matrix depicts the flows among 89 NTAR regions, where the flow from the row NTAR to the column NTAR is given by each element. Two matrices are of commuting data: Journey to Work 1980, and Journey to Work 1990. Two matrices are of migration data: all 1990 migrants from ages 25 to 69, and those 1990 migrants from ages 25 to 59 who have educational attainment of at least a Bachelor's degree. Two matrices are of trade data: 1993 value of shipments, and 1993 weight of all shipments.

Do these matrices represent graphs that look more like Figure 1 or Figure 2? One way to answer this question is to calculate graph *density*. A graph's density is the number of lines between nodes divided by the number of pairs of nodes; it gives the percent of possible lines actually present in the graph. The density of Figure 1 is about 5%, and of Figure 2 100%. The density of the six graphs are given in Table 1. For a graph like Figure 1—with a single upward link for each node—the density of a network with 89 nodes would be 88/(89*88) = 1.12%. All of the matrices in fact represent graphs much denser than that, with the migration matrices having a density very close to 100%. Thus, the raw data clearly resemble Figure 2, but as we noted above, we would expect empirical relationships to resemble Figure 2 in a world where regions *both* fill a role on a central place hierarchy *and* exchange as a specialized unit with every other region. The task is to tease out from the myriad of links those links that represent the central place hierarchy.

4. A Method for Identifying the Central Place Hierarchy

Flows among n regions can be depicted in an n x n matrix **F**, where the flow from region i to region j is given by each element f_{ij}. Flows can be converted to percentages, to dampen the effect of differential region sizes, in an n x n matrix **P**, where the flow from region i to region j is given by each element $p_{ij} = f_{ij} / \sum_j f_{ij}$. The element-wise geometric mean of **P** and its transpose creates a symmetric matrix **A**, where each element $a_{ij}=(p_{ij}p_{ji})^{½}$. Setting the diagonal equal to zero, one can use **A** to calculate a centrality vector **c**:

$$\lambda c = Ac \tag{1}$$

where λ is an eigenvalue and **c** is an eigenvector of matrix **A** (Strang 1980: 181). The first principal eigenvector from equation (1) has long been used by network analysts to calculate network centrality scores (Wasserman and Faust 1994: 207; Bonacich 1987). The centrality score for any region i is given below:

$$c_i = \frac{1}{\lambda} \sum_{j=1}^{n} a_{ij} c_j \ , \qquad a_{ii} = 0 \ , \ \forall i \tag{2}$$

Tam (1989) describes this specification as *endogenous* centrality, since the centrality of a region i is a function not only of the magnitude of the flows a_{ij} between i and j, but also of the centrality of the regions j to which it is connected. A peripheral region will have flows directed primarily at regions with low centrality—it will lie low on the hierarchy, with upward connections primarily to centers that themselves are not particularly high on the hierarchy. A central region will have flows directed primarily toward regions with high centrality.

The centrality score in equation 2 can be used as a basis for selecting each region's single most important upward link, presented in an unvalued adjacency matrix **Δ**, with elements δ_{ij}:

$$\delta_{ij} = 1 \ \textit{if} \ a_{ij} c_j = \max_{\forall (j \mid c_j > c_i)} (a_{ij} c_j), \ \delta_{ij} = 0 \ \textit{otherwise} \qquad \forall i \tag{3}$$

For the set of links for which the destination node j has higher centrality than the source node i, find the link with the highest product $a_{ij}c_j$ –this link is then region i's most important upward link. Note that the link to the selected region provides the single largest contribution to region i's own centrality score, and thus is the single greatest source of connectedness to the network of regions.

The method detailed above is *atheoretical*, in that the determination of higher levels on the hierarchy is entirely dependent upon the centrality scores—a feature of the data—and not on *a priori* considerations. Theoretical approaches could, however, be implemented. One might expect lower order centers to produce bulky commodities and higher order centers to produce goods with high value to weight ratios. One could thus use differences in value to weight ratios to assign different regions to different levels of the central place hierarchy. Likewise, one might expect labor in higher order centers to have more command and control functions, while labor in lower order centers might engage in more routine activities. Thus, one would expect more educated labor to migrate to higher order centers, and one could use this differential migration to assign different regions to different hierarchical levels. The fact that the present method is atheoretical would be particularly convenient in cases where one wishes to *test* theoretical assumptions used to delineate a central place hierarchy.

5. Results

The procedure detailed above is applied to each of the six data matrices. The results are summarized in Figures 3 through 8 and in Tables 4.1 through 4.6. Each of the figures is a NTAR-level map with lines pointing from a lower-order center to the higher order center to which it is most attached. The tables report the single most important upward link for each region in column one—i.e., the tables tell which elements of matrix **Δ** are equal to one. The *centrality* score is also reported, as well as the number of other regions the region *reaches to* and is *reached by*.[1] The tables are sorted by descending *reached by*, so that the apex of the hierarchy is at the top. Results for each of the six matrices are detailed separately below.

Additional information is supplied by Tables 2 and 3. Table 2 presents the matrix correlation coefficient (Wasserman and Faust 1994: 686) among the six data matrices **A**. All matrices **A** are positively and significantly correlated, though they vary in the strength of that correlation. Table 3 shows the modified matrix match coefficient (Wasserman and Faust 1994: 686) among the six final matrices **Δ**. The match coefficient shows how often—as a percentage of 88 possible occurrences—that the matrices **Δ** have the same non-zero elements δ_{ij}.

5.1 Commuting 1980.

From Table 4.1 one can see that the final matrix **Δ** for 1980 commuting data contains two unconnected components. For 56 regions, Raleigh-Durham, NC serves as the apex; for the other 31 regions, Lansing-Kalamazoo, MI serves as the apex. From Figure 3, one can observe that there are relatively few local hub and spoke patterns. Regions often find a quite distant region as their most important upward link, and that distant region is often one that seems implausible. For example, one would not expect Lansing-Kalamazoo to serve as an apex of the hierarchy of US regions. The results suggest that commuting, while serving well to delineate the relationship of hierarchical relations among counties for MSAs and EAs, is a short distance phenomenon that does not provide accurate information about the long distance relationships among regions.

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[1] To calculate reachability, one takes advantage of the fact that the unvalued, directed adjacency matrix **Δ** taken to the second power gives a matrix $\mathbf{\Delta}^2$, where each cell gives the number of paths of length 2 between the row node and the column node. The number of paths of length three can be found by taking **Δ** to the third power, and so forth. If the number of nodes is g, then all nodes reachable from any other node must have a path length $(g\text{-}1)$ or shorter (Wasserman and Faust 1994: 159-163). Thus, if matrix $\mathbf{Z} = \mathbf{\Delta}^1 + \mathbf{\Delta}^2 + \mathbf{\Delta}^3 \ldots + \mathbf{\Delta}^{(g-1)}$, and element $z_{ij}>0$ then node i is reachable from node j. The number of regions *reached by* region k is the number of non-zero elements in the k^{th} column of matrix **Z**. Region k *reaches to* a number of regions equal to the number of non-zero elements in the k^{th} row of matrix **Z**.

5.2 Commuting 1990.

Table 2 shows that the matrix correlation between commuting flows in 1980 and commuting flows in 1990 is quite high (0.986). The match coefficient in Table 3 shows that 64% of the links singled out in matrix **Δ** are the same for commuting 1980 and commuting 1990. Thus, unsurprisingly, the results shown in Table 4.2 and Figure 4 repeat some of the absurdities seen with commuting flows in 1980: Lansing-Kalamazoo is the apex of the hierarchy of central places, and many of the flows are over very long distances, with relatively few local hub and spoke patterns. These results further confirm that commuting flows do not accurately depict long distance relations among regions.

5.3 Value of Commodity Freight Flows, 1993.

Table 4.3 and Figure 5 show that the final matrix **Δ** places New York at the apex, with three regions serving as regional hubs: Chicago, Atlanta, and Los Angeles. The assignments appear much more plausible than did the assignments in the two final commuting matrices.

5.4 Weight of Commodity Freight Flows, 1993.

Table 2 shows that the matrix correlation between *value* of freight flows and *weight* of freight flows is 0.842—a high figure, but not as high as the correlation between migration flows on the one side and value of freight flows on the other. This pattern is repeated in Table 3, which shows that 54% of the links singled out in matrix **Δ** are the same for value of freight flows and weight of freight flows. Here, too, the final matrix for value of freight flows has a greater resemblance to migration flows than it has to weight of freight flows. Table 4.4 and Figure 6 show that the final matrix **Δ** for weight has Columbia, SC at the apex, with Columbia itself serving as the regional hub for the southeast and Chicago serving as the hub for the remaining 68 regions. One possible interpretation of these results is that weight flows may not be particularly accurate representations of hierarchical relationships among regions.

5.5 Migration of Persons Ages 25 through 69, 1990.

Table 4.5 and Figure 7 show that the final matrix **Δ** places Los Angeles at the apex, with Chicago, Dallas, and Washington, DC serving as regional hubs. A few of the results do not appear reasonable; the most striking anomaly is that Tampa serves as the regional hub for Cleveland, Detroit, and Buffalo. Apparently, migration of retired persons distorts what was intended to be the migration of working age persons.

5.6 Migration of Persons Ages 25 through 59, with a Four Year College Degree or Higher, 1990.

Table 2 shows that the matrix correlation between the two labor migration matrices is 0.975—almost as high as the correlation between the two commuting matrices. In Table 3, one can see that 74% of the links singled out in matrix **Δ** are the same for the two labor migration matrices, the highest match coefficient of any pair of matrices. One can also see that the matrix **Δ** for migration of college educated persons ages 25 through 59 has a higher match coefficient with the commuting matrices and the goods matrices than does the matrix **Δ** for migration of persons ages 25 through 69. Table 4.6 and Figure 8 show that the final matrix **Δ** places Washington, DC at the apex, with New York, Dallas, Los Angeles, Raleigh, and Atlanta serving as regional hubs. These results seem more reasonable than those of the matrix for all migrants ages 25 through 69. Since educated persons are often specialized labor, and must enter national labor markets, this particular matrix of flows might be representative of long distance connections among regions. In addition, selecting only migrants younger than 60 serves to eliminate the distortion of retiree migration.

6. Summary and Conclusions

Interregional flow data are available for freight shipments, for labor commuting, and for labor migration. The graphs of these flows are quite dense, and resemble the kind of pattern predicted by export base models, where each region specializes in its comparative advantage and trades with every other region. If, however, one wishes to identify each region's position in the central place hierarchy, one must somehow prune away the least important links, so that one finds the single most important upward link for each region.

The method used here to identify the single most important upward link is based on endogenous centrality measures employed in social network analysis. The method is applied to six different data matrices: two commuting matrices, two freight shipment matrices, and two labor migration matrices. The results indicate that commuting flows are not suitable for identifying the long distance relationships linking a region with its higher order center. Migration flows fare much better, but here it appears that the best information is given by the flows of relatively young and well-educated migrants—flows that do not contain retirees, and that contain specialized labor that typically enters national labor markets. Freight shipments also seem to work reasonably well, but the results for shipments by weight seem counter-intuitive, while the results for shipments by value seem consistent with expectations. Thus, the two best flows—best in the non-rigorous sense that they produce patterns consistent with expectations—are value of freight shipments and migration of persons ages 25 through 59 with at least a four year college degree. When comparing the central place hierarchies produced by these two flows, one finds that they overlap for 58 percent of the links.

This exercise shows that for highly aggregated regions such as NTARs, flow data can provide a reasonable picture of the hierarchical relations among regions. Nevertheless, the results are not highly robust—there is only 58 percent agreement between the two most informative data matrices used here. Of course, there is no reason to believe that the central place hierarchy of freight shipments is identical to the central place hierarchy of labor migration. After all, we accept that different cities may occupy the apex for different kinds of functions in the U.S. economy: New York is the apex of the financial system, Washington D.C. is the apex of public policy, Nashville is the apex of country music, and so on. The current approach for delineating MSAs and EAs is to consider labor markets, based on commuting flows, as the most informative way of demarcating regions. It may be most promising to continue along these lines, and to delineate broader labor market relationships, using migration flows. Figure 9 provides an example of what such an effort might produce. Working age migration among Labor Market Areas (Killian and Tolbert 1993) is used to produce the single most important upward link for each LMA. The resulting patterns of affiliation seem reasonable.

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FIGURES

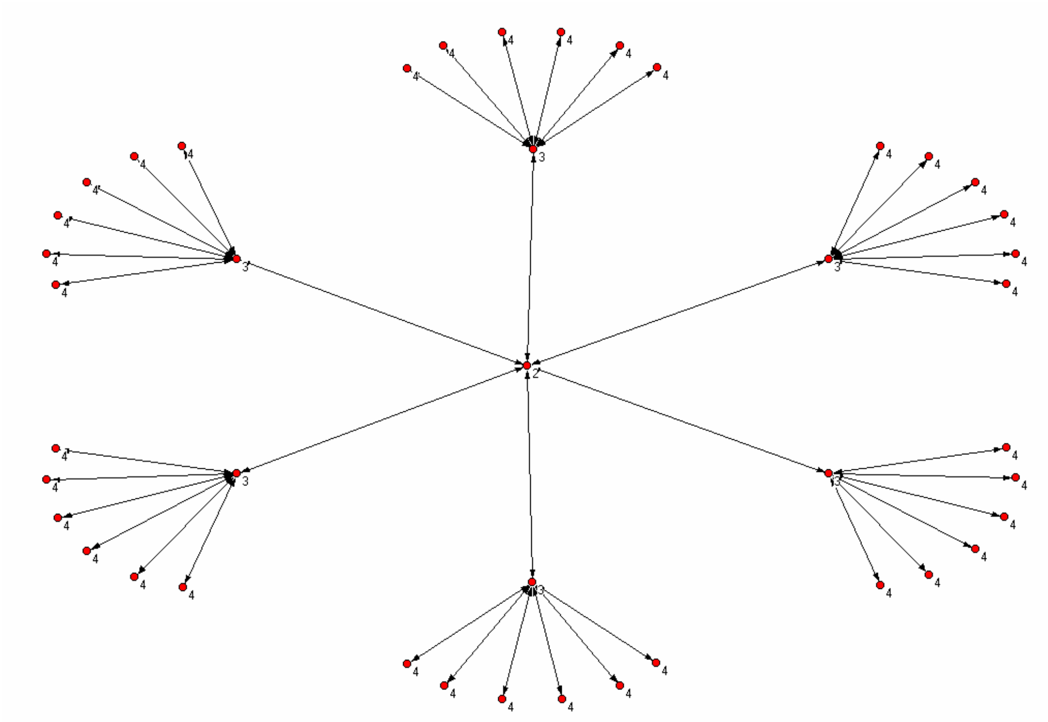

Figure 1: Unvalued directed graph with 43 vertices, representing Christaller's Central Place Theory, with three levels in the regional hierarchy. The numbers at each vertex indicate the geodesic distance to the most distant vertex. Density=0.048675.

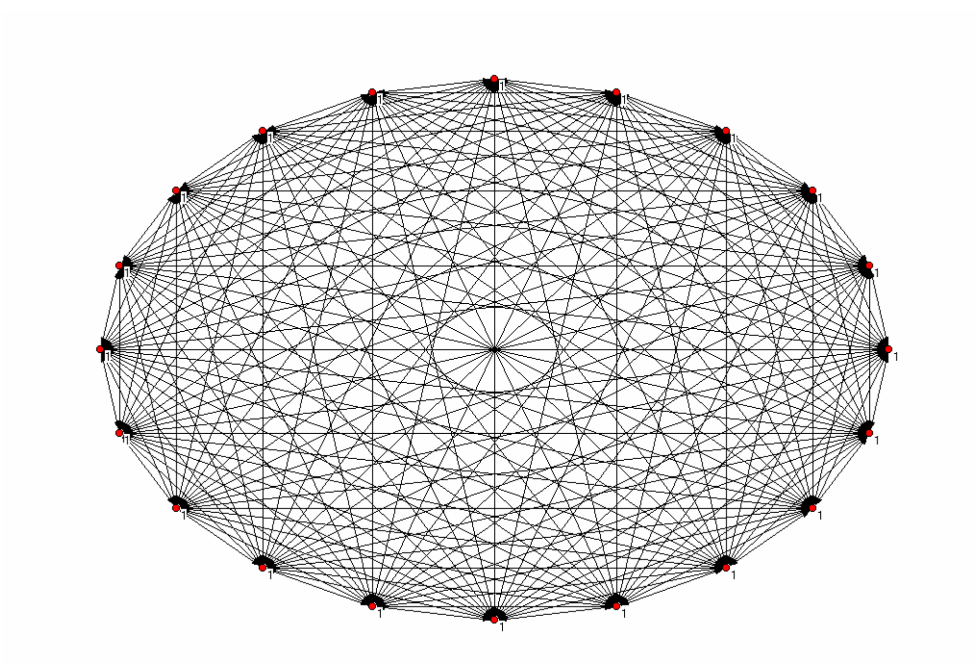

Figure 2: Unvalued directed graph with 20 vertices, all interconnected. There is a geodesic distance of one from any vertex to any other vertex. Density=1.0.

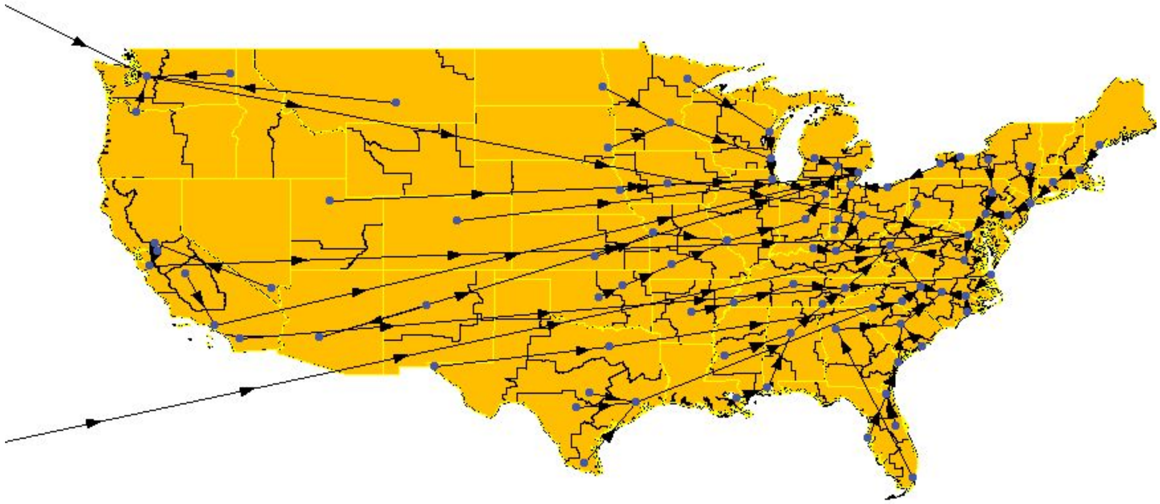

Figure 3: Single most important upward link for each NTAR, based on commuting flows from 1980.

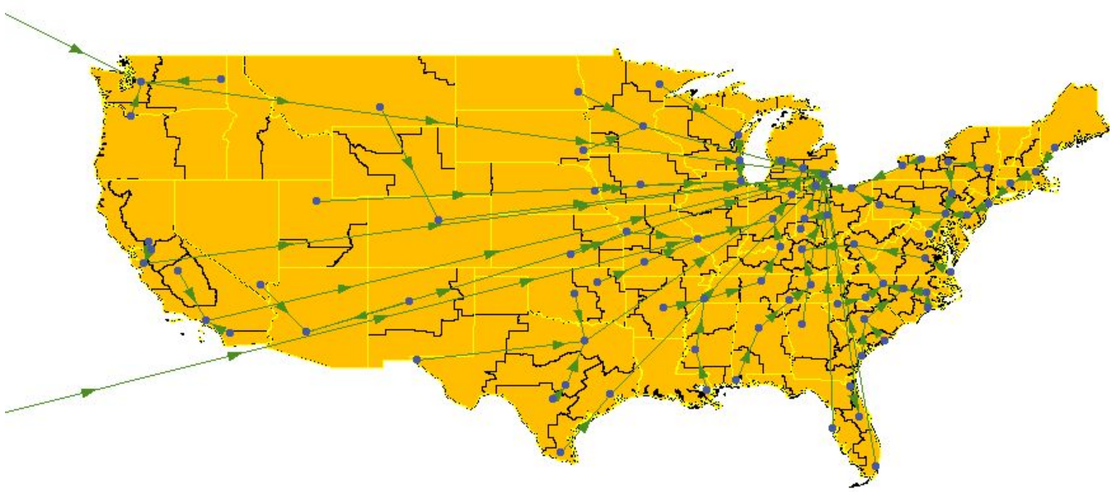

Figure 4: Single most important upward link for each NTAR, based on commuting flows from 1990.

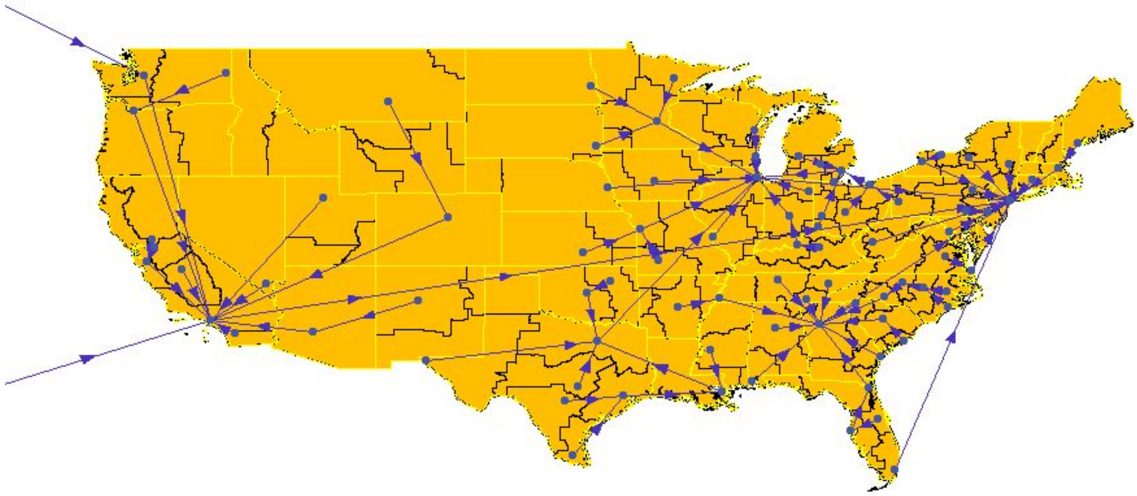

Figure 5: Single most important upward link for each NTAR, based on the *value* of commodity freight flows from 1993.

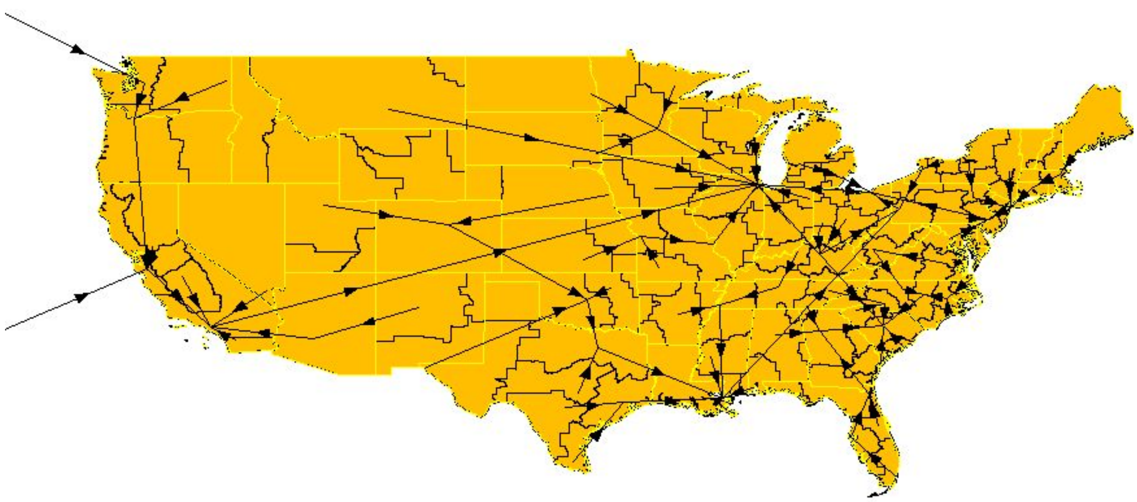

Figure 6: Single most important upward link for each NTAR, based on the *weight* of commodity freight flows from 1993.

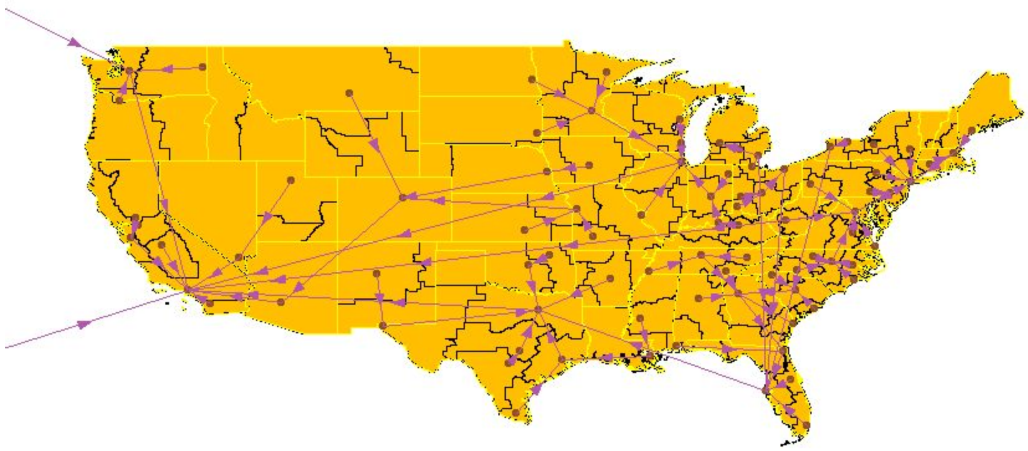

Figure 7: Single most important upward link for each NTAR, based on migration flows of persons ages 25 through 69.

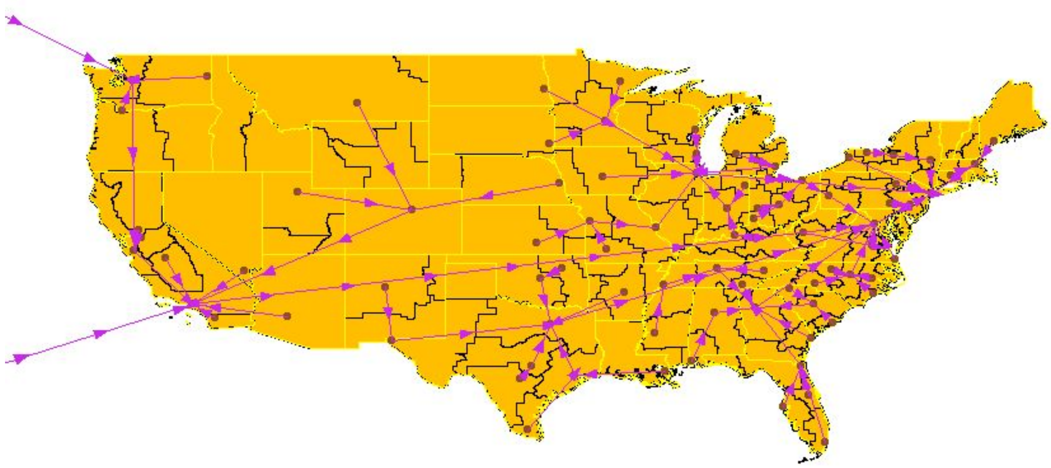

Figure 8: Single most important upward link for each NTAR, based on migration flows of persons ages 25 through 59, with at least a four-year college degree.

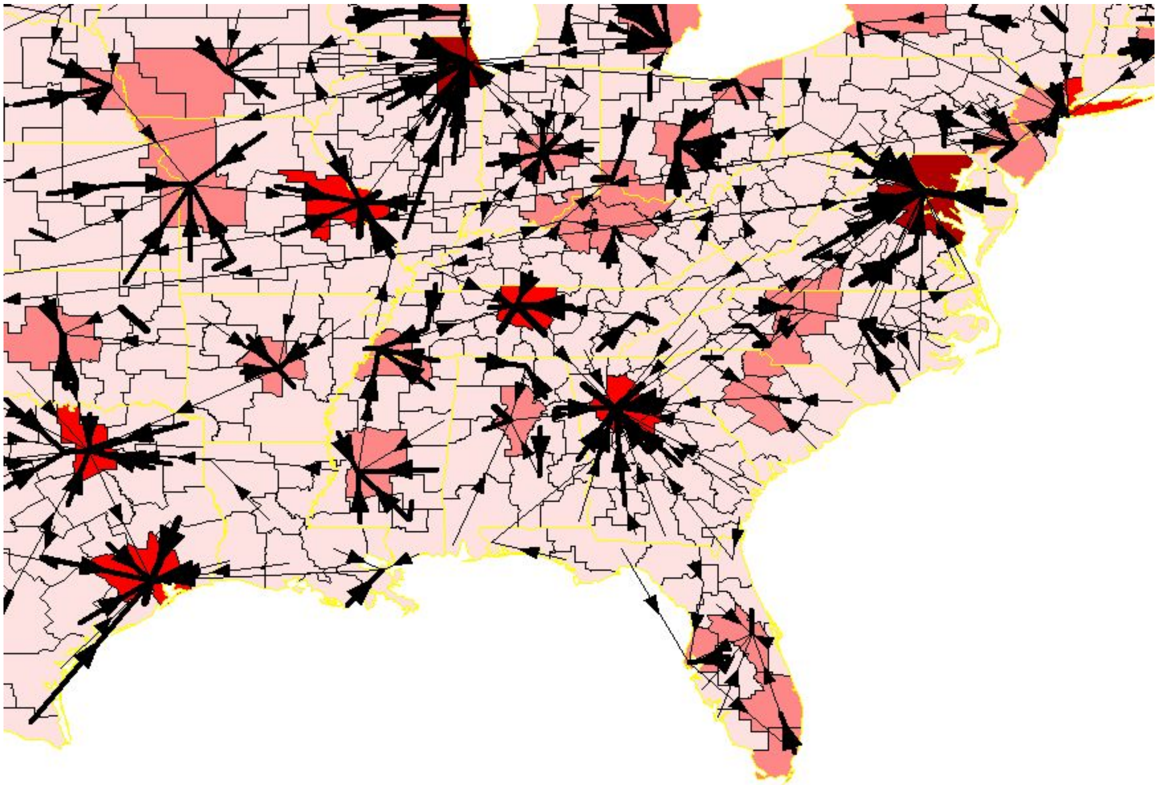

Figure 9: Labor Market Area-Level Working Age Population Nominations. Thicker line indicates higher percent of sender's total outflows. The darker the LMA, the higher its *reachability*.

TABLES

TABLE 1. DENSITY OF SIX DATA MATRICES

Data Matrix	Density
Journey to Work 1980	22.8%
Journey to Work 1990	25.7%
Migration 1990 age 25-69	99.9%
Migration, college+ 1990 age 25-59	99.2%
Goods 1993 weight	76.0%
Goods 1993 value	86.5%

Notes: Density is the number of interregional flows, divided by the number of pairs of nodes (89*88).

TABLE 2. MATRIX CORRELATION AMONG SIX DATA MATRICES *A*

Matrix	Journey to Work 1980	Journey to Work 1990	Migration 1990 age 25-69	Migration, college+ 1990 age 25-59	Goods 1993 weight	Goods 1993 value
Journey to Work 1980	1.000	0.986	0.727	0.729	0.782	0.699
Journey to Work 1990	0.986	1.000	0.727	0.726	0.772	0.700
Migration 1990 age 25-69	0.727	0.727	1.000	0.975	0.799	0.860
Migration, college+ 1990 age 25-59	0.729	0.726	0.975	1.000	0.801	0.877
Goods 1993 weight	0.782	0.772	0.799	0.801	1.000	0.842
Goods 1993 value	0.699	0.700	0.860	0.877	0.842	1.000

Notes: Matrix correlation coefficient (Wasserman and Faust 1994: 686). All coefficients significantly different from zero with p-values<.01 (from permutation test).

TABLE 3. MATRIX MATCH COEFFICIENT AMONG SIX FINAL MATRICES *Δ*

Matrix	Journey to Work 1980	Journey to Work 1990	Migration 1990 age 25-69	Migration, college+ 1990 age 25-59	Goods 1993 weight	Goods 1993 value
Journey to Work 1980	100%	64%	24%	28%	40%	28%
Journey to Work 1990	64%	100%	28%	31%	34%	32%
Migration 1990 age 25-69	24%	28%	100%	74%	41%	56%
Migration, college+ 1990 age 25-59	27%	31%	74%	100%	47%	58%
Goods 1993 weight	40%	34%	41%	47%	100%	52%
Goods 1993 value	27%	32%	56%	58%	52%	100%

Notes: Modification of the matrix match coefficient (Wasserman and Faust 1994: 686). Since each final matrix has one upward link for each row, and the apex of the hierarchy has no upward link, then there are 88 non-zero elements in each of the 89 x 89 final matrices. The match coefficient reports the percent of time that a pair of matrices have the same non-zero elements.

TABLE 4.1. FINAL MATRIX: SINGLE MOST IMPORTANT UPWARD LINK FOR COMMUTING 1980

Region	Upward Link	Reached by	Reaches to	Centrality
Raleigh-Durham-Fayetteville,NC		56	0	4.711
Greensboro-Winston-Salem-HighPoint,NC	Raleigh-Durham-Fayetteville,NC	43	1	3.566
Roanoke-Lynchburg,VA-Charleston,WV	Greensboro-Winston-Salem-HighPoint,NC	34	2	2.117
Lansing-Kalamazoo,MI		31	0	1.188
Richmond-Petersburg,VA	Roanoke-Lynchburg,VA-Charleston,WV	20	3	1.080
Baltimore,MD-Washington,DC	Richmond-Petersburg,VA	19	4	0.429
FortWayne-SouthBend,IN	Lansing-Kalamazoo,MI	17	1	0.671
Detroit,MI	Lansing-Kalamazoo,MI	11	1	0.949
Chicago-Rockford-Peoria,IL-Davenport,IA	FortWayne-SouthBend,IN	9	2	0.111
Knoxville-JohnsonCity,TN-Bristol,TN-VA	Roanoke-Lynchburg,VA-Charleston,WV	8	3	0.798
Harrisburg-York-Williamsport,PA	Baltimore,MD-Washington,DC	8	5	0.224
Columbia-Florence,SC-Augusta,GA	Raleigh-Durham-Fayetteville,NC	7	1	1.457
Charlotte,NC	Greensboro-Winston-Salem-HighPoint,NC	7	2	1.994
Indianapolis-Kokamo,IN-Champaign,IL	FortWayne-SouthBend,IN	6	2	0.237
Toledo,OH	Detroit,MI	5	2	0.871
St.Louis-Columbia,MO-Quincy-Springfield,IL	Indianapolis-Kokamo,IN-Champaign,IL	5	3	0.049
Milwaukee-Madison,WI-Dubuque,IA	Chicago-Rockford-Peoria,IL-Davenport,IA	5	3	0.032
Philadelphia,PA	Harrisburg-York-Williamsport,PA	5	6	0.209
Greenville-Spartanburg,SC-Asheville,NC	Charlotte,NC	4	3	1.032
Chattanooga,TN	Knoxville-JohnsonCity,TN-Bristol,TN-VA	4	4	0.255
Seattle,WA	Baltimore,MD-Washington,DC	4	5	0.005
NewYork,NY	Philadelphia,PA	4	7	0.137
RockyMount-Wilson-Greenville,NC	Raleigh-Durham-Fayetteville,NC	3	1	4.122
Savannah,GA	Columbia-Florence,SC-Augusta,GA	3	2	0.335
Houston-Beaumont,TX	Greenville-Spartanburg,SC-Asheville,NC	3	4	0.010
SanFrancisco-Oakland-Eureka,CA	Baltimore,MD-Washington,DC	3	5	0.005
Birmingham-Montogomery-Huntsville,AL	Chattanooga,TN	3	5	0.118
Lexington,KY-Huntington,WV	Roanoke-Lynchburg,VA-Charleston,WV	2	3	0.989
Jacksonville-Tallahassee,FL-Albany,GA	Savannah,GA	2	3	0.108
Cleveland-Youngstown,OH	Toledo,OH	2	3	0.318
Nashville,TN-Paducah,KY	Knoxville-JohnsonCity,TN-Bristol,TN-VA	2	4	0.132
Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	Milwaukee-Madison,WI-Dubuque,IA	2	4	0.005
Springfield,MO-Fayetteville,AR	St.Louis-Columbia,MO-Quincy-Springfield,IL	2	4	0.005
Hartford-NewHaven,CT-Springfield,MA	NewYork,NY	2	8	0.062
Norfolk-VirginiaBeach-NewportNews,VA	RockyMount-Wilson-Greenville,NC	1	2	1.047
Atlanta-Columbus-Macon,GA	Columbia-Florence,SC-Augusta,GA	1	2	0.286
LosAngeles,CA	Detroit,MI	1	2	0.011
Phoenix-Tucson,AZ	Detroit,MI	1	2	0.004
Dallas-FortWorth-Abilene,TX	Charlotte,NC	1	3	0.008
Dayton-Springfield-Lima,OH	Toledo,OH	1	3	0.596
DesMoines-CedarRapids-Waterloo,IA	Chicago-Rockford-Peoria,IL-Davenport,IA	1	3	0.009
Buffalo,NY-Erie,PA	Cleveland-Youngstown,OH	1	4	0.095
Appleton-GreenBay-Wausau,WI	Milwaukee-Madison,WI-Dubuque,IA	1	4	0.018
KansasCity,MO-Topeka,KS	St.Louis-Columbia,MO-Quincy-Springfield,IL	1	4	0.004
Memphis,TN	Nashville,TN-Paducah,KY	1	5	0.038
Tulsa,OK-FortSmith,AR	Springfield,MO-Fayetteville,AR	1	5	0.002
Binghamton-Elmira,NY-Scranton,PA	Harrisburg-York-Williamsport,PA	1	6	0.122
Mobile,AL-Pensacola,FL	Birmingham-Montogomery-Huntsville,AL	1	6	0.038
Sacramento-Redding,CA	SanFrancisco-Oakland-Eureka,CA	1	6	0.003
Boston,MA-Providence-Warwick,RI	Hartford-NewHaven,CT-Springfield,MA	1	9	0.031
GrandRapids-Saginaw,MI	Lansing-Kalamazoo,MI	0	1	0.920
Wilmington,NC	RockyMount-Wilson-Greenville,NC	0	2	3.885
Charleston,SC	Columbia-Florence,SC-Augusta,GA	0	2	0.540
Denver-GrandJuction,CO-Cheyenne,WY-Scottsbluf	Detroit,MI	0	2	0.001
Pittsburgh,PA-Morgantown-Wheeling,WV	Roanoke-Lynchburg,VA-Charleston,WV	0	3	0.328

Region	Upward Link	Reached by	Reaches to	Centrality
SanDiego,CA	Norfolk-VirginiaBeach-NewportNews,VA	0	3	0.009
Miami-FortLauderdale,FL	Atlanta-Columbus-Macon,GA	0	3	0.029
SaltLakeCity,UT-IdahoFalls,ID	Chicago-Rockford-Peoria,IL-Davenport,IA	0	3	0.000
Albuquerque,NM	Phoenix-Tucson,AZ	0	3	0.001
Fresno-Bakersfield,CA	LosAngeles,CA	0	3	0.002
Tampa-St.Petersburg,FL	Jacksonville-Tallahassee,FL-Albany,GA	0	4	0.027
Orlando-Melbourne-DaytonaBeach,FL	Jacksonville-Tallahassee,FL-Albany,GA	0	4	0.027
Columbus,OH	Lexington,KY-Huntington,WV	0	4	0.452
Louisville,KY-Evansville,IN	Lexington,KY-Huntington,WV	0	4	0.275
Cincinnati,OH	Dayton-Springfield-Lima,OH	0	4	0.512
Omaha-GrandIsland,NE-SiouxCity,IA	DesMoines-CedarRapids-Waterloo,IA	0	4	0.001
ElPaso-Lubbock-Odessa,TX	Dallas-FortWorth-Abilene,TX	0	4	0.000
Rochester,NY	Buffalo,NY-Erie,PA	0	5	0.054
Honolulu,HI	Baltimore,MD-Washington,DC	0	5	0.001
Duluth,MN	Appleton-GreenBay-Wausau,WI	0	5	0.002
RapidCity-SiouxFalls-Aberdeen,SD	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	5	0.001
Minot-Fargo-GrandForks-Bismark,ND	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	5	0.000
Wichita-Salina,KS	KansasCity,MO-Topeka,KS	0	5	0.001
Austin-Waco-SanAngelo,TX	Houston-Beaumont,TX	0	5	0.002
SanAntonio,TX	Houston-Beaumont,TX	0	5	0.002
Brownsville-CorpusChristi,TX	Houston-Beaumont,TX	0	5	0.001
Jackson,MS	Birmingham-Montogomery-Huntsville,AL	0	6	0.020
LittleRock-NorthLittleRock,AR	Memphis,TN	0	6	0.005
OklahomaCity-Lawton,OK-Amarillo,TX	Tulsa,OK-FortSmith,AR	0	6	0.001
Portland-Eugene,OR	Seattle,WA	0	6	0.001
BoiseCity,ID-Spokane-Yakima,WA	Seattle,WA	0	6	0.000
Anchorage,AK	Seattle,WA	0	6	0.000
GreatFalls-Missoula-Billings,MT	Seattle,WA	0	6	0.000
Stockton-Modesto,CA	SanFrancisco-Oakland-Eureka,CA	0	6	0.002
Syracuse-Utica,NY	Binghamton-Elmira,NY-Scranton,PA	0	7	0.050
NewOrleans-BatonRouge-Shreveport,LA	Mobile,AL-Pensacola,FL	0	7	0.017
LasVegas-Reno,NV	Sacramento-Redding,CA	0	7	0.002
Albany,NY-Burlington,VT	NewYork,NY	0	8	0.032
Portland-Bangor,ME	Boston,MA-Providence-Warwick,RI	0	10	0.016

Notes: Lower order center in the first column; its single most important higher order center in the second column. The *centrality* score from Equation (2). *Reached by* gives the number of nodes that can reach the region in the first column by any path in the directed, unvalued graph given by **Δ**. *Reaches to* gives the number of nodes that the region in the first column can reach by any path in the directed, unvalued graph given by **Δ**.

TABLE 4.2. FINAL MATRIX: SINGLE MOST IMPORTANT UPWARD LINK FOR COMMUTING 1990

Region	Upward Link	Reached by	Reaches to	Centrality
Lansing-Kalamazoo,MI		88	0	5.356
Detroit,MI	Lansing-Kalamazoo,MI	65	1	4.134
Toledo,OH	Detroit,MI	34	2	3.241
FortWayne-SouthBend,IN	Lansing-Kalamazoo,MI	20	1	2.542
Dayton-Springfield-Lima,OH	Toledo,OH	19	3	1.918
Columbus,OH	Dayton-Springfield-Lima,OH	17	4	0.899
Lexington,KY-Huntington,WV	Columbus,OH	16	5	0.330
Cleveland-Youngstown,OH	Toledo,OH	13	3	0.823
Indianapolis-Kokamo,IN-Champaign,IL	FortWayne-SouthBend,IN	12	2	0.744
Roanoke-Lynchburg,VA-Charleston,WV	Lexington,KY-Huntington,WV	11	6	0.140
Pittsburgh,PA-Morgantown-Wheeling,WV	Cleveland-Youngstown,OH	10	4	0.233
Harrisburg-York-Williamsport,PA	Pittsburgh,PA-Morgantown-Wheeling,WV	9	5	0.069
Greensboro-Winston-Salem-HighPoint,NC	Roanoke-Lynchburg,VA-Charleston,WV	8	7	0.075
Chicago-Rockford-Peoria,IL-Davenport,IA	FortWayne-SouthBend,IN	6	2	0.366
Louisville,KY-Evansville,IN	Indianapolis-Kokamo,IN-Champaign,IL	5	3	0.263
Raleigh-Durham-Fayetteville,NC	Greensboro-Winston-Salem-HighPoint,NC	5	8	0.059
Dallas-FortWorth-Abilene,TX	Detroit,MI	4	2	0.010
St.Louis-Columbia,MO-Quincy-Springfield,IL	Indianapolis-Kokamo,IN-Champaign,IL	4	3	0.092
Nashville,TN-Paducah,KY	Louisville,KY-Evansville,IN	4	4	0.056
Philadelphia,PA	Harrisburg-York-Williamsport,PA	4	6	0.058
Seattle,WA	Detroit,MI	3	2	0.003
Memphis,TN	Nashville,TN-Paducah,KY	3	5	0.017
Knoxville-JohnsonCity,TN-Bristol,TN-VA	Lexington,KY-Huntington,WV	3	6	0.116
NewYork,NY	Philadelphia,PA	3	7	0.044
LosAngeles,CA	Detroit,MI	2	2	0.015
Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	Detroit,MI	2	2	0.013
Phoenix-Tucson,AZ	Detroit,MI	2	2	0.007
SanFrancisco-Oakland-Eureka,CA	Detroit,MI	2	2	0.005
Milwaukee-Madison,WI-Dubuque,IA	Chicago-Rockford-Peoria,IL-Davenport,IA	2	3	0.100
Binghamton-Elmira,NY-Scranton,PA	Harrisburg-York-Williamsport,PA	2	6	0.047
Chattanooga,TN	Knoxville-JohnsonCity,TN-Bristol,TN-VA	2	7	0.034
Hartford-NewHaven,CT-Springfield,MA	NewYork,NY	2	8	0.019
Columbia-Florence,SC-Augusta,GA	Raleigh-Durham-Fayetteville,NC	2	9	0.017
Houston-Beaumont,TX	Detroit,MI	1	2	0.009
Orlando-Melbourne-DaytonaBeach,FL	Detroit,MI	1	2	0.008
Denver-GrandJuction,CO-Cheyenne,WY-Scottsbluf	Detroit,MI	1	2	0.002
DesMoines-CedarRapids-Waterloo,IA	Chicago-Rockford-Peoria,IL-Davenport,IA	1	3	0.024
Austin-Waco-SanAngelo,TX	Dallas-FortWorth-Abilene,TX	1	3	0.002
Buffalo,NY-Erie,PA	Cleveland-Youngstown,OH	1	4	0.095
Appleton-GreenBay-Wausau,WI	Milwaukee-Madison,WI-Dubuque,IA	1	4	0.046
Springfield,MO-Fayetteville,AR	St.Louis-Columbia,MO-Quincy-Springfield,IL	1	4	0.008
KansasCity,MO-Topeka,KS	St.Louis-Columbia,MO-Quincy-Springfield,IL	1	4	0.007
Jackson,MS	Memphis,TN	1	6	0.005
Syracuse-Utica,NY	Binghamton-Elmira,NY-Scranton,PA	1	7	0.022
Richmond-Petersburg,VA	Roanoke-Lynchburg,VA-Charleston,WV	1	7	0.043
Charlotte,NC	Greensboro-Winston-Salem-HighPoint,NC	1	8	0.030
Birmingham-Montogomery-Huntsville,AL	Chattanooga,TN	1	8	0.014
Boston,MA-Providence-Warwick,RI	Hartford-NewHaven,CT-Springfield,MA	1	9	0.010
RockyMount-Wilson-Greenville,NC	Raleigh-Durham-Fayetteville,NC	1	9	0.043
GrandRapids-Saginaw,MI	Lansing-Kalamazoo,MI	0	1	4.268
Atlanta-Columbus-Macon,GA	Detroit,MI	0	2	0.020
Miami-FortLauderdale,FL	Detroit,MI	0	2	0.014
Tampa-St.Petersburg,FL	Detroit,MI	0	2	0.008
Jacksonville-Tallahassee,FL-Albany,GA	Orlando-Melbourne-DaytonaBeach,FL	0	3	0.005
Honolulu,HI	Indianapolis-Kokamo,IN-Champaign,IL	0	3	0.003
SaltLakeCity,UT-IdahoFalls,ID	Chicago-Rockford-Peoria,IL-Davenport,IA	0	3	0.000
RapidCity-SiouxFalls-Aberdeen,SD	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	3	0.001
Minot-Fargo-GrandForks-Bismark,ND	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	3	0.001
Brownsville-CorpusChristi,TX	Houston-Beaumont,TX	0	3	0.001

Region	Upward Link	Reached by	Reaches to	Centrality
OklahomaCity-Lawton,OK-Amarillo,TX	Dallas-FortWorth-Abilene,TX	0	3	0.001
ElPaso-Lubbock-Odessa,TX	Dallas-FortWorth-Abilene,TX	0	3	0.000
GreatFalls-Missoula-Billings,MT	Denver-GrandJuction,CO-Cheyenne,WY-Scottsbluf	0	3	0.000
LasVegas-Reno,NV	Phoenix-Tucson,AZ	0	3	0.002
Albuquerque,NM	Phoenix-Tucson,AZ	0	3	0.001
Portland-Eugene,OR	Seattle,WA	0	3	0.000
Anchorage,AK	Seattle,WA	0	3	0.000
BoiseCity,ID-Spokane-Yakima,WA	Seattle,WA	0	3	0.000
Stockton-Modesto,CA	SanFrancisco-Oakland-Eureka,CA	0	3	0.003
Sacramento-Redding,CA	SanFrancisco-Oakland-Eureka,CA	0	3	0.003
SanDiego,CA	LosAngeles,CA	0	3	0.009
Fresno-Bakersfield,CA	LosAngeles,CA	0	3	0.003
Cincinnati,OH	Dayton-Springfield-Lima,OH	0	4	1.360
Omaha-GrandIsland,NE-SiouxCity,IA	DesMoines-CedarRapids-Waterloo,IA	0	4	0.002
SanAntonio,TX	Austin-Waco-SanAngelo,TX	0	4	0.002
Rochester,NY	Buffalo,NY-Erie,PA	0	5	0.042
Duluth,MN	Appleton-GreenBay-Wausau,WI	0	5	0.003
Wichita-Salina,KS	KansasCity,MO-Topeka,KS	0	5	0.001
Tulsa,OK-FortSmith,AR	Springfield,MO-Fayetteville,AR	0	5	0.002
Baltimore,MD-Washington,DC	Harrisburg-York-Williamsport,PA	0	6	0.046
LittleRock-NorthLittleRock,AR	Memphis,TN	0	6	0.002
NewOrleans-BatonRouge-Shreveport,LA	Jackson,MS	0	7	0.004
Albany,NY-Burlington,VT	Syracuse-Utica,NY	0	8	0.012
Norfolk-VirginiaBeach-NewportNews,VA	Richmond-Petersburg,VA	0	8	0.021
Greenville-Spartanburg,SC-Asheville,NC	Charlotte,NC	0	9	0.015
Mobile,AL-Pensacola,FL	Birmingham-Montogomery-Huntsville,AL	0	9	0.003
Portland-Bangor,ME	Boston,MA-Providence-Warwick,RI	0	10	0.003
Wilmington,NC	RockyMount-Wilson-Greenville,NC	0	10	0.035
Charleston,SC	Columbia-Florence,SC-Augusta,GA	0	10	0.006
Savannah,GA	Columbia-Florence,SC-Augusta,GA	0	10	0.005

Notes: Lower order center in the first column; its single most important higher order center in the second column. The *centrality* score from Equation (2). *Reached by* gives the number of nodes that can reach the region in the first column by any path in the directed, unvalued graph given by $\mathbf{\Delta}$. *Reaches to* gives the number of nodes that the region in the first column can reach by any path in the directed, unvalued graph given by $\mathbf{\Delta}$.

TABLE 4.3. FINAL MATRIX: SINGLE MOST IMPORTANT UPWARD LINK FOR VALUE OF COMMODITY SHIPMENTS 1993

Region	Upward Link	Reached by	Reaches to	Centrality
NewYork,NY		88	0	2.260
Chicago-Rockford-Peoria,IL-Davenport,IA	NewYork,NY	35	1	2.216
Atlanta-Columbus-Macon,GA	NewYork,NY	19	1	1.782
LosAngeles,CA	NewYork,NY	16	1	1.693
Dallas-FortWorth-Abilene,TX	Chicago-Rockford-Peoria,IL-Davenport,IA	9	2	1.332
Detroit,MI	Chicago-Rockford-Peoria,IL-Davenport,IA	8	2	1.650
Charlotte,NC	Atlanta-Columbus-Macon,GA	4	2	1.245
NewOrleans-BatonRouge-Shreveport,LA	Dallas-FortWorth-Abilene,TX	4	3	1.005
Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	Chicago-Rockford-Peoria,IL-Davenport,IA	3	2	1.186
Greensboro-Winston-Salem-HighPoint,NC	Charlotte,NC	3	3	0.988
Philadelphia,PA	NewYork,NY	2	1	1.803
Indianapolis-Kokamo,IN-Champaign,IL	Chicago-Rockford-Peoria,IL-Davenport,IA	2	2	1.352
SanFrancisco-Oakland-Eureka,CA	LosAngeles,CA	2	2	1.323
KansasCity,MO-Topeka,KS	Chicago-Rockford-Peoria,IL-Davenport,IA	2	2	1.076
Jacksonville-Tallahassee,FL-Albany,GA	Atlanta-Columbus-Macon,GA	2	2	0.980
Cleveland-Youngstown,OH	Detroit,MI	2	3	1.483
Houston-Beaumont,TX	NewOrleans-BatonRouge-Shreveport,LA	2	4	0.984
Raleigh-Durham-Fayetteville,NC	Greensboro-Winston-Salem-HighPoint,NC	2	4	0.929
Boston,MA-Providence-Warwick,RI	NewYork,NY	1	1	1.472
Buffalo,NY-Erie,PA	NewYork,NY	1	1	1.062
Norfolk-VirginiaBeach-NewportNews,VA	NewYork,NY	1	1	0.841
Memphis,TN	Atlanta-Columbus-Macon,GA	1	2	1.210
Milwaukee-Madison,WI-Dubuque,IA	Chicago-Rockford-Peoria,IL-Davenport,IA	1	2	1.169
Columbia-Florence,SC-Augusta,GA	Atlanta-Columbus-Macon,GA	1	2	1.051
Denver-GrandJuction,CO-Cheyenne,WY-Scottsbluf	LosAngeles,CA	1	2	0.900
Phoenix-Tucson,AZ	LosAngeles,CA	1	2	0.782
Seattle,WA	LosAngeles,CA	1	2	0.643
Portland-Eugene,OR	LosAngeles,CA	1	2	0.579
Louisville,KY-Evansville,IN	Indianapolis-Kokamo,IN-Champaign,IL	1	3	1.100
Dayton-Springfield-Lima,OH	Detroit,MI	1	3	1.094
Tampa-St.Petersburg,FL	Jacksonville-Tallahassee,FL-Albany,GA	1	3	0.956
OklahomaCity-Lawton,OK-Amarillo,TX	Dallas-FortWorth-Abilene,TX	1	3	0.817
Hartford-NewHaven,CT-Springfield,MA	NewYork,NY	0	1	1.265
Roanoke-Lynchburg,VA-Charleston,WV	NewYork,NY	0	1	1.001
Miami-FortLauderdale,FL	NewYork,NY	0	1	0.964
Binghamton-Elmira,NY-Scranton,PA	NewYork,NY	0	1	0.883
Albany,NY-Burlington,VT	NewYork,NY	0	1	0.799
Syracuse-Utica,NY	NewYork,NY	0	1	0.721
Baltimore,MD-Washington,DC	Philadelphia,PA	0	2	1.426
St.Louis-Columbia,MO-Quincy-Springfield,IL	Chicago-Rockford-Peoria,IL-Davenport,IA	0	2	1.315
Harrisburg-York-Williamsport,PA	Philadelphia,PA	0	2	1.251
Birmingham-Montogomery-Huntsville,AL	Atlanta-Columbus-Macon,GA	0	2	1.103
Nashville,TN-Paducah,KY	Atlanta-Columbus-Macon,GA	0	2	1.068
Greenville-Spartanburg,SC-Asheville,NC	Atlanta-Columbus-Macon,GA	0	2	1.054
FortWayne-SouthBend,IN	Chicago-Rockford-Peoria,IL-Davenport,IA	0	2	1.034
Knoxville-JohnsonCity,TN-Bristol,TN-VA	Atlanta-Columbus-Macon,GA	0	2	0.883
Richmond-Petersburg,VA	Norfolk-VirginiaBeach-NewportNews,VA	0	2	0.829
DesMoines-CedarRapids-Waterloo,IA	Chicago-Rockford-Peoria,IL-Davenport,IA	0	2	0.802
Omaha-GrandIsland,NE-SiouxCity,IA	Chicago-Rockford-Peoria,IL-Davenport,IA	0	2	0.785
Chattanooga,TN	Atlanta-Columbus-Macon,GA	0	2	0.747
SanDiego,CA	LosAngeles,CA	0	2	0.708
Mobile,AL-Pensacola,FL	Atlanta-Columbus-Macon,GA	0	2	0.680
Savannah,GA	Atlanta-Columbus-Macon,GA	0	2	0.663
SaltLakeCity,UT-IdahoFalls,ID	LosAngeles,CA	0	2	0.650
LasVegas-Reno,NV	LosAngeles,CA	0	2	0.608
Fresno-Bakersfield,CA	LosAngeles,CA	0	2	0.580

Region	Upward Link	Reached by	Reaches to	Centrality
Rochester,NY	Buffalo,NY-Erie,PA	0	2	0.568
Portland-Bangor,ME	Boston,MA-Providence-Warwick,RI	0	2	0.519
Honolulu,HI	LosAngeles,CA	0	2	0.066
GrandRapids-Saginaw,MI	Detroit,MI	0	3	0.962
Toledo,OH	Detroit,MI	0	3	0.927
Appleton-GreenBay-Wausau,WI	Milwaukee-Madison,WI-Dubuque,IA	0	3	0.841
Lansing-Kalamazoo,MI	Detroit,MI	0	3	0.789
LittleRock-NorthLittleRock,AR	Memphis,TN	0	3	0.741
Springfield,MO-Fayetteville,AR	KansasCity,MO-Topeka,KS	0	3	0.738
Austin-Waco-SanAngelo,TX	Dallas-FortWorth-Abilene,TX	0	3	0.710
Sacramento-Redding,CA	SanFrancisco-Oakland-Eureka,CA	0	3	0.677
ElPaso-Lubbock-Odessa,TX	Dallas-FortWorth-Abilene,TX	0	3	0.670
Charleston,SC	Columbia-Florence,SC-Augusta,GA	0	3	0.599
Stockton-Modesto,CA	SanFrancisco-Oakland-Eureka,CA	0	3	0.594
Wichita-Salina,KS	KansasCity,MO-Topeka,KS	0	3	0.534
BoiseCity,ID-Spokane-Yakima,WA	Portland-Eugene,OR	0	3	0.480
RapidCity-SiouxFalls-Aberdeen,SD	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	3	0.441
Albuquerque,NM	Phoenix-Tucson,AZ	0	3	0.377
Minot-Fargo-GrandForks-Bismark,ND	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	3	0.368
GreatFalls-Missoula-Billings,MT	Denver-GrandJuction,CO-Cheyenne,WY-Scottsbluf	0	3	0.309
Duluth,MN	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	3	0.247
Anchorage,AK	Seattle,WA	0	3	0.071
Columbus,OH	Cleveland-Youngstown,OH	0	4	1.119
Pittsburgh,PA-Morgantown-Wheeling,WV	Cleveland-Youngstown,OH	0	4	1.113
Cincinnati,OH	Dayton-Springfield-Lima,OH	0	4	1.073
Lexington,KY-Huntington,WV	Louisville,KY-Evansville,IN	0	4	0.822
Tulsa,OK-FortSmith,AR	OklahomaCity-Lawton,OK-Amarillo,TX	0	4	0.728
Orlando-Melbourne-DaytonaBeach,FL	Tampa-St.Petersburg,FL	0	4	0.717
Jackson,MS	NewOrleans-BatonRouge-Shreveport,LA	0	4	0.638
SanAntonio,TX	Houston-Beaumont,TX	0	5	0.764
RockyMount-Wilson-Greenville,NC	Raleigh-Durham-Fayetteville,NC	0	5	0.692
Wilmington,NC	Raleigh-Durham-Fayetteville,NC	0	5	0.435
Brownsville-CorpusChristi,TX	Houston-Beaumont,TX	0	5	0.419

Notes: Lower order center in the first column; its single most important higher order center in the second column. The *centrality* score from Equation (2). *Reached by* gives the number of nodes that can reach the region in the first column by any path in the directed, unvalued graph given by **Δ**. *Reaches to* gives the number of nodes that the region in the first column can reach by any path in the directed, unvalued graph given by **Δ**.

TABLE 4.4. FINAL MATRIX: SINGLE MOST IMPORTANT UPWARD LINK FOR WEIGHT OF COMMODITY SHIPMENTS 1993

Region	Upward Link	Reached by	Reaches to	Centrality
Columbia-Florence,SC-Augusta,GA		88	0	2.475
Chicago-Rockford-Peoria,IL-Davenport,IA	Columbia-Florence,SC-Augusta,GA	68	1	1.749
Cleveland-Youngstown,OH	Chicago-Rockford-Peoria,IL-Davenport,IA	39	2	1.661
Pittsburgh,PA-Morgantown-Wheeling,WV	Cleveland-Youngstown,OH	24	3	1.484
NewOrleans-BatonRouge-Shreveport,LA	Pittsburgh,PA-Morgantown-Wheeling,WV	17	4	1.258
LosAngeles,CA	Chicago-Rockford-Peoria,IL-Davenport,IA	13	2	0.461
Philadelphia,PA	Cleveland-Youngstown,OH	9	3	1.568
SanFrancisco-Oakland-Eureka,CA	LosAngeles,CA	7	3	0.388
Dallas-FortWorth-Abilene,TX	NewOrleans-BatonRouge-Shreveport,LA	7	5	0.870
Raleigh-Durham-Fayetteville,NC	Columbia-Florence,SC-Augusta,GA	6	1	2.087
Atlanta-Columbus-Macon,GA	Columbia-Florence,SC-Augusta,GA	6	1	1.556
NewYork,NY	Philadelphia,PA	6	4	1.451
OklahomaCity-Lawton,OK-Amarillo,TX	Dallas-FortWorth-Abilene,TX	5	6	0.697
Jacksonville-Tallahassee,FL-Albany,GA	Atlanta-Columbus-Macon,GA	3	2	1.125
St.Louis-Columbia,MO-Quincy-Springfield,IL	Chicago-Rockford-Peoria,IL-Davenport,IA	3	2	1.245
Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	Chicago-Rockford-Peoria,IL-Davenport,IA	3	2	0.794
Lexington,KY-Huntington,WV	Pittsburgh,PA-Morgantown-Wheeling,WV	3	4	1.245
Portland-Eugene,OR	SanFrancisco-Oakland-Eureka,CA	3	4	0.190
Memphis,TN	NewOrleans-BatonRouge-Shreveport,LA	3	5	1.201
Charlotte,NC	Columbia-Florence,SC-Augusta,GA	2	1	2.002
Greensboro-Winston-Salem-HighPoint,NC	Raleigh-Durham-Fayetteville,NC	2	2	1.910
RockyMount-Wilson-Greenville,NC	Raleigh-Durham-Fayetteville,NC	2	2	1.876
Detroit,MI	Cleveland-Youngstown,OH	2	3	1.296
KansasCity,MO-Topeka,KS	St.Louis-Columbia,MO-Quincy-Springfield,IL	2	3	0.779
Hartford-NewHaven,CT-Springfield,MA	NewYork,NY	2	5	0.776
Houston-Beaumont,TX	NewOrleans-BatonRouge-Shreveport,LA	2	5	0.845
Denver-GrandJuction,CO-Cheyenne,WY-Scottsbluf	OklahomaCity-Lawton,OK-Amarillo,TX	2	7	0.665
Milwaukee-Madison,WI-Dubuque,IA	Chicago-Rockford-Peoria,IL-Davenport,IA	1	2	0.881
Roanoke-Lynchburg,VA-Charleston,WV	Greensboro-Winston-Salem-HighPoint,NC	1	3	1.255
Tampa-St.Petersburg,FL	Jacksonville-Tallahassee,FL-Albany,GA	1	3	0.643
Phoenix-Tucson,AZ	LosAngeles,CA	1	3	0.203
Buffalo,NY-Erie,PA	Pittsburgh,PA-Morgantown-Wheeling,WV	1	4	1.119
Binghamton-Elmira,NY-Scranton,PA	NewYork,NY	1	5	0.850
Cincinnati,OH	Lexington,KY-Huntington,WV	1	5	1.205
Seattle,WA	Portland-Eugene,OR	1	5	0.111
Boston,MA-Providence-Warwick,RI	Hartford-NewHaven,CT-Springfield,MA	1	6	0.469
Nashville,TN-Paducah,KY	Memphis,TN	1	6	1.037
Charleston,SC	Columbia-Florence,SC-Augusta,GA	0	1	1.650
Savannah,GA	Columbia-Florence,SC-Augusta,GA	0	1	1.081
Greenville-Spartanburg,SC-Asheville,NC	Charlotte,NC	0	2	1.546
Knoxville-JohnsonCity,TN-Bristol,TN-VA	Charlotte,NC	0	2	1.047
Birmingham-Montogomery-Huntsville,AL	Atlanta-Columbus-Macon,GA	0	2	1.113
Chattanooga,TN	Atlanta-Columbus-Macon,GA	0	2	0.916
Indianapolis-Kokamo,IN-Champaign,IL	Chicago-Rockford-Peoria,IL-Davenport,IA	0	2	1.115
FortWayne-SouthBend,IN	Chicago-Rockford-Peoria,IL-Davenport,IA	0	2	0.929
DesMoines-CedarRapids-Waterloo,IA	Chicago-Rockford-Peoria,IL-Davenport,IA	0	2	0.626
GreatFalls-Missoula-Billings,MT	Chicago-Rockford-Peoria,IL-Davenport,IA	0	2	0.103
Norfolk-VirginiaBeach-NewportNews,VA	RockyMount-Wilson-Greenville,NC	0	3	1.226
Wilmington,NC	RockyMount-Wilson-Greenville,NC	0	3	1.206
Orlando-Melbourne-DaytonaBeach,FL	Jacksonville-Tallahassee,FL-Albany,GA	0	3	0.535
Toledo,OH	Cleveland-Youngstown,OH	0	3	1.156
Appleton-GreenBay-Wausau,WI	Milwaukee-Madison,WI-Dubuque,IA	0	3	0.743
RapidCity-SiouxFalls-Aberdeen,SD	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	3	0.406

Region	Upward Link	Reached by	Reaches to	Centrality
Minot-Fargo-GrandForks-Bismark,ND	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	3	0.287
Duluth,MN	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	3	0.214
Fresno-Bakersfield,CA	LosAngeles,CA	0	3	0.271
SanDiego,CA	LosAngeles,CA	0	3	0.178
LasVegas-Reno,NV	LosAngeles,CA	0	3	0.145
Harrisburg-York-Williamsport,PA	Philadelphia,PA	0	4	1.233
Baltimore,MD-Washington,DC	Philadelphia,PA	0	4	1.069
Richmond-Petersburg,VA	Roanoke-Lynchburg,VA-Charleston,WV	0	4	0.798
Miami-FortLauderdale,FL	Tampa-St.Petersburg,FL	0	4	0.309
GrandRapids-Saginaw,MI	Detroit,MI	0	4	0.919
Lansing-Kalamazoo,MI	Detroit,MI	0	4	0.853
Springfield,MO-Fayetteville,AR	KansasCity,MO-Topeka,KS	0	4	0.658
Wichita-Salina,KS	KansasCity,MO-Topeka,KS	0	4	0.548
Albuquerque,NM	Phoenix-Tucson,AZ	0	4	0.080
Stockton-Modesto,CA	SanFrancisco-Oakland-Eureka,CA	0	4	0.266
Sacramento-Redding,CA	SanFrancisco-Oakland-Eureka,CA	0	4	0.235
Honolulu,HI	SanFrancisco-Oakland-Eureka,CA	0	4	0.010
Rochester,NY	Buffalo,NY-Erie,PA	0	5	0.567
Albany,NY-Burlington,VT	NewYork,NY	0	5	0.571
Columbus,OH	Lexington,KY-Huntington,WV	0	5	1.107
Jackson,MS	NewOrleans-BatonRouge-Shreveport,LA	0	5	0.913
Mobile,AL-Pensacola,FL	NewOrleans-BatonRouge-Shreveport,LA	0	5	0.902
BoiseCity,ID-Spokane-Yakima,WA	Portland-Eugene,OR	0	5	0.126
Syracuse-Utica,NY	Binghamton-Elmira,NY-Scranton,PA	0	6	0.590
LittleRock-NorthLittleRock,AR	Memphis,TN	0	6	0.677
Dayton-Springfield-Lima,OH	Cincinnati,OH	0	6	0.930
SanAntonio,TX	Houston-Beaumont,TX	0	6	0.472
Brownsville-CorpusChristi,TX	Houston-Beaumont,TX	0	6	0.341
Austin-Waco-SanAngelo,TX	Dallas-FortWorth-Abilene,TX	0	6	0.439
Anchorage,AK	Seattle,WA	0	6	0.011
Portland-Bangor,ME	Boston,MA-Providence-Warwick,RI	0	7	0.251
Louisville,KY-Evansville,IN	Nashville,TN-Paducah,KY	0	7	1.024
Tulsa,OK-FortSmith,AR	OklahomaCity-Lawton,OK-Amarillo,TX	0	7	0.627
ElPaso-Lubbock-Odessa,TX	OklahomaCity-Lawton,OK-Amarillo,TX	0	7	0.359
Omaha-GrandIsland,NE-SiouxCity,IA	Denver-GrandJunction,CO-Cheyenne,WY-Scottsbluf	0	8	0.585
SaltLakeCity,UT-IdahoFalls,ID	Denver-GrandJunction,CO-Cheyenne,WY-Scottsbluf	0	8	0.158

Notes: Lower order center in the first column; its single most important higher order center in the second column. The *centrality* score from Equation (2). *Reached by* gives the number of nodes that can reach the region in the first column by any path in the directed, unvalued graph given by **Δ**. *Reaches to* gives the number of nodes that the region in the first column can reach by any path in the directed, unvalued graph given by **Δ**.

Table 4.5. Final Matrix: Single Most Important upward Link for Migration of Persons Aged 25-69, 1990

Region	Upward Link	Reached by	Reaches to	Centrality
LosAngeles,CA		88	0	1.911
Dallas-FortWorth-Abilene,TX	LosAngeles,CA	36	1	1.711
Tampa-St.Petersburg,FL	Dallas-FortWorth-Abilene,TX	24	2	1.642
Baltimore,MD-Washington,DC	LosAngeles,CA	18	1	1.570
Chicago-Rockford-Peoria,IL-Davenport,IA	LosAngeles,CA	11	1	1.273
Jacksonville-Tallahassee,FL-Albany,GA	Tampa-St.Petersburg,FL	11	3	1.509
Atlanta-Columbus-Macon,GA	Jacksonville-Tallahassee,FL-Albany,GA	9	4	1.479
NewYork,NY	Baltimore,MD-Washington,DC	8	2	1.436
Phoenix-Tucson,AZ	LosAngeles,CA	7	1	1.504
Denver-GrandJuction,CO-Cheyenne,WY-Scottsbluf	Phoenix-Tucson,AZ	6	2	1.499
Raleigh-Durham-Fayetteville,NC	Baltimore,MD-Washington,DC	4	2	1.170
Seattle,WA	LosAngeles,CA	3	1	1.303
Indianapolis-Kokamo,IN-Champaign,IL	Chicago-Rockford-Peoria,IL-Davenport,IA	3	2	0.896
Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	Chicago-Rockford-Peoria,IL-Davenport,IA	3	2	0.857
Houston-Beaumont,TX	Dallas-FortWorth-Abilene,TX	3	2	1.412
Detroit,MI	Tampa-St.Petersburg,FL	3	3	0.909
Cleveland-Youngstown,OH	Tampa-St.Petersburg,FL	3	3	0.822
SanFrancisco-Oakland-Eureka,CA	LosAngeles,CA	2	1	1.723
Boston,MA-Providence-Warwick,RI	NewYork,NY	2	3	1.060
KansasCity,MO-Topeka,KS	Denver-GrandJuction,CO-Cheyenne,WY-Scottsbluf	2	3	0.995
Columbus,OH	Cleveland-Youngstown,OH	2	4	0.750
Columbia-Florence,SC-Augusta,GA	Atlanta-Columbus-Macon,GA	2	5	1.019
Nashville,TN-Paducah,KY	Atlanta-Columbus-Macon,GA	2	5	0.872
LasVegas-Reno,NV	LosAngeles,CA	1	1	1.198
Milwaukee-Madison,WI-Dubuque,IA	Chicago-Rockford-Peoria,IL-Davenport,IA	1	2	0.732
Austin-Waco-SanAngelo,TX	Dallas-FortWorth-Abilene,TX	1	2	1.301
OklahomaCity-Lawton,OK-Amarillo,TX	Dallas-FortWorth-Abilene,TX	1	2	1.064
ElPaso-Lubbock-Odessa,TX	Dallas-FortWorth-Abilene,TX	1	2	1.052
Philadelphia,PA	NewYork,NY	1	3	1.097
Buffalo,NY-Erie,PA	Tampa-St.Petersburg,FL	1	3	0.573
Louisville,KY-Evansville,IN	Indianapolis-Kokamo,IN-Champaign,IL	1	3	0.676
NewOrleans-BatonRouge-Shreveport,LA	Houston-Beaumont,TX	1	3	1.019
Omaha-GrandIsland,NE-SiouxCity,IA	Denver-GrandJuction,CO-Cheyenne,WY-Scottsbluf	1	3	0.753
GrandRapids-Saginaw,MI	Detroit,MI	1	4	0.738
SanDiego,CA	LosAngeles,CA	0	1	1.433
Honolulu,HI	LosAngeles,CA	0	1	1.001
Fresno-Bakersfield,CA	LosAngeles,CA	0	1	0.878
Norfolk-VirginiaBeach-NewportNews,VA	Baltimore,MD-Washington,DC	0	2	1.216
Pittsburgh,PA-Morgantown-Wheeling,WV	Baltimore,MD-Washington,DC	0	2	0.821
Richmond-Petersburg,VA	Baltimore,MD-Washington,DC	0	2	0.807
Roanoke-Lynchburg,VA-Charleston,WV	Baltimore,MD-Washington,DC	0	2	0.792
St.Louis-Columbia,MO-Quincy-Springfield,IL	Chicago-Rockford-Peoria,IL-Davenport,IA	0	2	0.971
LittleRock-NorthLittleRock,AR	Dallas-FortWorth-Abilene,TX	0	2	0.694
SaltLakeCity,UT-IdahoFalls,ID	LasVegas-Reno,NV	0	2	0.948
Portland-Eugene,OR	Seattle,WA	0	2	1.104
BoiseCity,ID-Spokane-Yakima,WA	Seattle,WA	0	2	1.032
Anchorage,AK	Seattle,WA	0	2	0.854
Sacramento-Redding,CA	SanFrancisco-Oakland-Eureka,CA	0	2	1.273
Stockton-Modesto,CA	SanFrancisco-Oakland-Eureka,CA	0	2	0.880
Albany,NY-Burlington,VT	NewYork,NY	0	3	0.709
Binghamton-Elmira,NY-Scranton,PA	NewYork,NY	0	3	0.659
Syracuse-Utica,NY	NewYork,NY	0	3	0.602
Charlotte,NC	Raleigh-Durham-Fayetteville,NC	0	3	0.875
Wilmington,NC	Raleigh-Durham-Fayetteville,NC	0	3	0.871

Region	Upward Link	Reached by	Reaches to	Centrality
Greensboro-Winston-Salem-HighPoint,NC	Raleigh-Durham-Fayetteville,NC	0	3	0.803
RockyMount-Wilson-Greenville,NC	Raleigh-Durham-Fayetteville,NC	0	3	0.789
Orlando-Melbourne-DaytonaBeach,FL	Tampa-St.Petersburg,FL	0	3	1.447
Miami-FortLauderdale,FL	Tampa-St.Petersburg,FL	0	3	1.403
FortWayne-SouthBend,IN	Indianapolis-Kokamo,IN-Champaign,IL	0	3	0.618
Appleton-GreenBay-Wausau,WI	Milwaukee-Madison,WI-Dubuque,IA	0	3	0.552
RapidCity-SiouxFalls-Aberdeen,SD	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	3	0.532
Minot-Fargo-GrandForks-Bismark,ND	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	3	0.524
Duluth,MN	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	3	0.360
Brownsville-CorpusChristi,TX	Houston-Beaumont,TX	0	3	0.717
SanAntonio,TX	Austin-Waco-SanAngelo,TX	0	3	1.013
Albuquerque,NM	ElPaso-Lubbock-Odessa,TX	0	3	0.822
Tulsa,OK-FortSmith,AR	OklahomaCity-Lawton,OK-Amarillo,TX	0	3	0.903
GreatFalls-Missoula-Billings,MT	Denver-GrandJuction,CO-Cheyenne,WY-Scottsbluf	0	3	0.689
Hartford-NewHaven,CT-Springfield,MA	Boston,MA-Providence-Warwick,RI	0	4	0.852
Portland-Bangor,ME	Boston,MA-Providence-Warwick,RI	0	4	0.537
Rochester,NY	Buffalo,NY-Erie,PA	0	4	0.480
Harrisburg-York-Williamsport,PA	Philadelphia,PA	0	4	0.694
Mobile,AL-Pensacola,FL	Jacksonville-Tallahassee,FL-Albany,GA	0	4	1.055
Lexington,KY-Huntington,WV	Louisville,KY-Evansville,IN	0	4	0.633
Toledo,OH	Detroit,MI	0	4	0.490
Springfield,MO-Fayetteville,AR	KansasCity,MO-Topeka,KS	0	4	0.872
Wichita-Salina,KS	KansasCity,MO-Topeka,KS	0	4	0.673
Jackson,MS	NewOrleans-BatonRouge-Shreveport,LA	0	4	0.537
DesMoines-CedarRapids-Waterloo,IA	Omaha-GrandIsland,NE-SiouxCity,IA	0	4	0.677
Birmingham-Montogomery-Huntsville,AL	Atlanta-Columbus-Macon,GA	0	5	0.934
Savannah,GA	Atlanta-Columbus-Macon,GA	0	5	0.829
Chattanooga,TN	Atlanta-Columbus-Macon,GA	0	5	0.507
Cincinnati,OH	Columbus,OH	0	5	0.649
Dayton-Springfield-Lima,OH	Columbus,OH	0	5	0.643
Lansing-Kalamazoo,MI	GrandRapids-Saginaw,MI	0	5	0.674
Charleston,SC	Columbia-Florence,SC-Augusta,GA	0	6	0.811
Greenville-Spartanburg,SC-Asheville,NC	Columbia-Florence,SC-Augusta,GA	0	6	0.795
Memphis,TN	Nashville,TN-Paducah,KY	0	6	0.791
Knoxville-JohnsonCity,TN-Bristol,TN-VA	Nashville,TN-Paducah,KY	0	6	0.731

Notes: Lower order center in the first column; its single most important higher order center in the second column. The *centrality* score from Equation (2). *Reached by* gives the number of nodes that can reach the region in the first column by any path in the directed, unvalued graph given by $\mathbf{\Delta}$. *Reaches to* gives the number of nodes that the region in the first column can reach by any path in the directed, unvalued graph given by $\mathbf{\Delta}$.

TABLE 4.6. FINAL MATRIX: SINGLE MOST IMPORTANT UPWARD LINK FOR MIGRATION OF PERSONS WITH AT LEAST A FOUR-YEAR COLLEGE DEGREE, AGED 25-59, 1990

Region	Upward Link	Reached by	Reaches to	Centrality
Baltimore,MD-Washington,DC		88	0	1.934
NewYork,NY	Baltimore,MD-Washington,DC	29	1	1.632
Chicago-Rockford-Peoria,IL-Davenport,IA	NewYork,NY	18	2	1.459
LosAngeles,CA	Baltimore,MD-Washington,DC	16	1	1.665
Atlanta-Columbus-Macon,GA	Baltimore,MD-Washington,DC	15	1	1.720
Dallas-FortWorth-Abilene,TX	Baltimore,MD-Washington,DC	10	1	1.787
SanFrancisco-Oakland-Eureka,CA	LosAngeles,CA	6	2	1.550
Pittsburgh,PA-Morgantown-Wheeling,WV	Baltimore,MD-Washington,DC	5	1	0.964
Raleigh-Durham-Fayetteville,NC	Baltimore,MD-Washington,DC	4	1	1.387
Cleveland-Youngstown,OH	Pittsburgh,PA-Morgantown-Wheeling,WV	4	2	0.927
Jacksonville-Tallahassee,FL-Albany,GA	Atlanta-Columbus-Macon,GA	3	2	1.355
Nashville,TN-Paducah,KY	Atlanta-Columbus-Macon,GA	3	2	0.986
Denver-GrandJuction,CO-Cheyenne,WY-Scottsbluf	LosAngeles,CA	3	2	1.395
St.Louis-Columbia,MO-Quincy-Springfield,IL	Chicago-Rockford-Peoria,IL-Davenport,IA	3	3	1.125
Indianapolis-Kokamo,IN-Champaign,IL	Chicago-Rockford-Peoria,IL-Davenport,IA	3	3	1.077
Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	Chicago-Rockford-Peoria,IL-Davenport,IA	3	3	0.949
Seattle,WA	SanFrancisco-Oakland-Eureka,CA	3	3	1.114
Boston,MA-Providence-Warwick,RI	NewYork,NY	2	2	1.307
Albany,NY-Burlington,VT	NewYork,NY	2	2	0.813
Columbia-Florence,SC-Augusta,GA	Atlanta-Columbus-Macon,GA	2	2	1.115
Houston-Beaumont,TX	Dallas-FortWorth-Abilene,TX	2	2	1.505
Columbus,OH	Cleveland-Youngstown,OH	2	3	0.899
Detroit,MI	Chicago-Rockford-Peoria,IL-Davenport,IA	2	3	1.001
KansasCity,MO-Topeka,KS	St.Louis-Columbia,MO-Quincy-Springfield,IL	2	4	1.049
Richmond-Petersburg,VA	Baltimore,MD-Washington,DC	1	1	1.007
Philadelphia,PA	NewYork,NY	1	2	1.331
Birmingham-Montogomery-Huntsville,AL	Atlanta-Columbus-Macon,GA	1	2	1.059
Austin-Waco-SanAngelo,TX	Dallas-FortWorth-Abilene,TX	1	2	1.276
ElPaso-Lubbock-Odessa,TX	Dallas-FortWorth-Abilene,TX	1	2	0.947
OklahomaCity-Lawton,OK-Amarillo,TX	Dallas-FortWorth-Abilene,TX	1	2	0.918
Syracuse-Utica,NY	Albany,NY-Burlington,VT	1	3	0.660
Memphis,TN	Nashville,TN-Paducah,KY	1	3	0.873
Milwaukee-Madison,WI-Dubuque,IA	Chicago-Rockford-Peoria,IL-Davenport,IA	1	3	0.881
Louisville,KY-Evansville,IN	Indianapolis-Kokamo,IN-Champaign,IL	1	4	0.792
Norfolk-VirginiaBeach-NewportNews,VA	Baltimore,MD-Washington,DC	0	1	1.128
Binghamton-Elmira,NY-Scranton,PA	NewYork,NY	0	2	0.732
Buffalo,NY-Erie,PA	NewYork,NY	0	2	0.621
Roanoke-Lynchburg,VA-Charleston,WV	Richmond-Petersburg,VA	0	2	0.927
Charlotte,NC	Raleigh-Durham-Fayetteville,NC	0	2	1.117
Greensboro-Winston-Salem-HighPoint,NC	Raleigh-Durham-Fayetteville,NC	0	2	1.030
RockyMount-Wilson-Greenville,NC	Raleigh-Durham-Fayetteville,NC	0	2	0.807
Wilmington,NC	Raleigh-Durham-Fayetteville,NC	0	2	0.738
Savannah,GA	Atlanta-Columbus-Macon,GA	0	2	0.753
Chattanooga,TN	Atlanta-Columbus-Macon,GA	0	2	0.555
LittleRock-NorthLittleRock,AR	Dallas-FortWorth-Abilene,TX	0	2	0.649
Phoenix-Tucson,AZ	LosAngeles,CA	0	2	1.211
SanDiego,CA	LosAngeles,CA	0	2	1.130
Honolulu,HI	LosAngeles,CA	0	2	0.772
LasVegas-Reno,NV	LosAngeles,CA	0	2	0.737
Fresno-Bakersfield,CA	LosAngeles,CA	0	2	0.601
Hartford-NewHaven,CT-Springfield,MA	Boston,MA-Providence-Warwick,RI	0	3	0.995
Portland-Bangor,ME	Boston,MA-Providence-Warwick,RI	0	3	0.558
Harrisburg-York-Williamsport,PA	Philadelphia,PA	0	3	0.849
Greenville-Spartanburg,SC-Asheville,NC	Columbia-Florence,SC-Augusta,GA	0	3	1.007
Charleston,SC	Columbia-Florence,SC-Augusta,GA	0	3	0.769

Region	Upward Link	Reached by	Reaches to	Centrality
Tampa-St.Petersburg,FL	Jacksonville-Tallahassee,FL-Albany,GA	0	3	1.345
Miami-FortLauderdale,FL	Jacksonville-Tallahassee,FL-Albany,GA	0	3	1.272
Orlando-Melbourne-DaytonaBeach,FL	Jacksonville-Tallahassee,FL-Albany,GA	0	3	1.194
Mobile,AL-Pensacola,FL	Birmingham-Montogomery-Huntsville,AL	0	3	0.980
Knoxville-JohnsonCity,TN-Bristol,TN-VA	Nashville,TN-Paducah,KY	0	3	0.843
Toledo,OH	Cleveland-Youngstown,OH	0	3	0.547
DesMoines-CedarRapids-Waterloo,IA	Chicago-Rockford-Peoria,IL-Davenport,IA	0	3	0.763
NewOrleans-BatonRouge-Shreveport,LA	Houston-Beaumont,TX	0	3	1.077
Brownsville-CorpusChristi,TX	Houston-Beaumont,TX	0	3	0.650
SanAntonio,TX	Austin-Waco-SanAngelo,TX	0	3	1.044
Albuquerque,NM	ElPaso-Lubbock-Odessa,TX	0	3	0.785
Tulsa,OK-FortSmith,AR	OklahomaCity-Lawton,OK-Amarillo,TX	0	3	0.815
SaltLakeCity,UT-IdahoFalls,ID	Denver-GrandJuction,CO-Cheyenne,WY-Scottsbluf	0	3	0.815
Omaha-GrandIsland,NE-SiouxCity,IA	Denver-GrandJuction,CO-Cheyenne,WY-Scottsbluf	0	3	0.768
GreatFalls-Missoula-Billings,MT	Denver-GrandJuction,CO-Cheyenne,WY-Scottsbluf	0	3	0.539
Sacramento-Redding,CA	SanFrancisco-Oakland-Eureka,CA	0	3	0.948
Stockton-Modesto,CA	SanFrancisco-Oakland-Eureka,CA	0	3	0.552
Rochester,NY	Syracuse-Utica,NY	0	4	0.569
Jackson,MS	Memphis,TN	0	4	0.614
Cincinnati,OH	Columbus,OH	0	4	0.828
Dayton-Springfield-Lima,OH	Columbus,OH	0	4	0.781
GrandRapids-Saginaw,MI	Detroit,MI	0	4	0.722
Lansing-Kalamazoo,MI	Detroit,MI	0	4	0.715
FortWayne-SouthBend,IN	Indianapolis-Kokamo,IN-Champaign,IL	0	4	0.684
Appleton-GreenBay-Wausau,WI	Milwaukee-Madison,WI-Dubuque,IA	0	4	0.621
RapidCity-SiouxFalls-Aberdeen,SD	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	4	0.483
Minot-Fargo-GrandForks-Bismark,ND	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	4	0.466
Duluth,MN	Minneapolis-St.Paul-Rochester,MN-LaCrosse,WI	0	4	0.311
Portland-Eugene,OR	Seattle,WA	0	4	0.882
BoiseCity,ID-Spokane-Yakima,WA	Seattle,WA	0	4	0.774
Anchorage,AK	Seattle,WA	0	4	0.624
Lexington,KY-Huntington,WV	Louisville,KY-Evansville,IN	0	5	0.708
Springfield,MO-Fayetteville,AR	KansasCity,MO-Topeka,KS	0	5	0.740
Wichita-Salina,KS	KansasCity,MO-Topeka,KS	0	5	0.609

Notes: Lower order center in the first column; its single most important higher order center in the second column. The *centrality* score from Equation (2). *Reached by* gives the number of nodes that can reach the region in the first column by any path in the directed, unvalued graph given by **Δ**. *Reaches to* gives the number of nodes that the region in the first column can reach by any path in the directed, unvalued graph given by **Δ**.