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All Centers Are Not Equal: An Exploration of the Polycentric Metropolis

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Abstract

There is now widespread recognition among urban researchers that a fundamental shift is underway in the internal structure of American urban areas. Polycentrism is increasingly supplanting monocentrism as the dominant urban form. However, the extent to which this has occurred and the implications of this change in urban form, while widely noted and discussed, have, surprisingly, not been the subject of a large body of carefully conducted and generalizable empirical research. We explore the extent of polycentrism for a sample of fifty U.S. metro areas, using an absolute threshold definition for identifying employment centers. We situate our results within the broader literature on subcenters, and compare our results to previous research on polycentrism. Using cluster analysis, we identify broad types of metros according to the incidence and patterning of centers within our sample. Variables of interest include the number of centers, the relative concentration of jobs within centers, the relative dominance of the core center, and the concentration of employment in major and minor centers. We also explore relationships between types of polycentrism and various metro attributes, such as population size, city age, geographic region, municipal fragmentation, and economic function. Finally, we set out a detailed agenda for future research.

Introduction

Harris and Ullman (1945) first articulated the multiple nuclei theory of urban form, which suggests that urban areas develop several specialized activity centers, such as the central business district (CBD), a manufacturing district, an industrial district, a residential district, then suburbs and satellites outside the city, as well as other smaller nuclei such as parks and universities scattered throughout the region. In the ensuing 60 years, the concept of distinct activity centers has become an accepted descriptor of metropolitan form, spawning additional theories (see, e.g., Lynch, 1961; Baerwald, 1978, 1982; Hartshorn & Muller, 1989; Vance, 1990; Harris, 1997). Today, it is conventional wisdom that many, if not most, large metropolitan areas that were once dominated by a single, dominant CBD have become multi-centered, or *polycentric*, as outlying and edge cities (Garreau, 1991) have grown in scale. [1]

However, neither the extent to which polycentrism actually is supplanting monocentrism as the dominant urban form, nor how it affects the way in which metropolitan areas function, has been the subject of a large body of carefully conducted comparative empirical research and general theory-building. The first step in that process is an exploration of the extent to which polycentrism is, in fact, becoming the dominant urban form, and whether different degrees, dimensions, or types of polycentric development can be discerned and described across many metropolitan areas. If so, development of a robust research agenda to understand its nature, patterns, processes, causes, and consequences can follow. We here attempt that first slippery step.

[1] Polycentrism within a metropolitan area, as studied here, should be distinguished from the polycentric urban regions (PURs) most recently discussed in the European context (Dieleman & Faludi, 1998; Lambooy, 1998; Batty, 2001; Champion, 2001; Kloosterman & Musterd, 2001). The "Northeast Corridor" between Washington-New York-Boston might be thought of as a U.S. example, where each major metropolitan area assumes in important and distinct role in the larger region (e.g., Washington is the head of government, New York is the head of commerce).

The paper proceeds first by examining the prominent literature on polycentrism, by specifying a conceptual definition of polycentrism and identifying its several dimensions, and by specifying a theoretically justified study area and unit of analysis for the study of polycentrism. Comparative empirical analysis follows, in which the patterns of polycentrism are explored across a sample of fifty large U.S. metropolitan areas as of 1990. The sample areas are ranked according to two simple indices of polycentrism, and cluster analysis is used to group areas according to type of polycentrism. The paper ends by discussing the implications of the study and suggesting a detailed agenda for further study.

A Concept Searching for Definition

Although agreeing that the transformation of metropolitan areas from monocentric to polycentric is an important change in urban form, urban scholars have yet to agree on a common definition of polycentrism. A comprehensive review of the literature concluded that:

> . . . past studies have considered a variety of techniques for identifying activity concentrations, but . . . only a few have presented objective criteria for arriving at specific definitions. Even fewer have applied these criteria to more than one urban area . . . . It is noteworthy that hardly any study to date has adopted the technique proposed by an earlier author, preferring instead to develop a new procedure. Also indicative of a lack of consensus is the plethora of labels used so far for activity concentration (in alphabetical order, activity center, business center, central business district, downtown … , edge city, employment [sub]center, major employment center, minicity, suburban center, suburban downtown, suburban nucleation, zone of concentration) (Forstall & Greene, 1997, p.709).

Consequently, we have little consistent evidence about the nature or extent of polycentrism in metropolitan areas, how and why it varies among areas, and its consequences for important social, economic, or environmental outcomes. Does it, for instance, in any of its various forms or dimensions, adversely or positively contribute to housing costs, the journey to work, air quality, or urban poverty? How do centers affect the spatial and social fabric of the metropolitan area, especially in terms of the quality of life and opportunities available to underserved populations?

Following Harris & Ullman, polycentrism in the geographic literature generally denotes the existence of multiple centers of employment in an urban area. For example, Erickson (1986, p.331) notes that the "multicentered [metropolitan] form is characterized by the presence of relatively dense nodes or nucleations of business establishments and employment outside the central city". Like mainstream geographers, economists have been concerned conceptually with centers of concentrated employment and the effects of these centers on the distribution of employment and population throughout the metropolitan region (Anas, Arnott, & Small, 1998).

Others have conceptualized a nucleus or center to consist of some specific *mix* of economic activities concentrated within an area such that the center takes on the characteristics typically associated with a downtown area (Knox, 1992; Godfrey, 1995). Hartshorn & Muller (1989) define suburban centers as including a regional shopping center of a certain size, a

threshold amount of office space that includes one *Fortune-1000* tenant, a threshold amount of hotel rooms, and employment above a threshold level. Similarly, Garreau (1991) defines an edge city as one that includes thresholds of office and retail space, has greater employment than population, and is perceived as a destination.

Several authors (see, e.g., Odland, 1978; Hughes, 1993; Clark & Kuijpers-Linde, 1994) have characterized centers by their position or dominance within networks, such as transportation, communication and production networks. Still others have envisioned centers simply as jurisdictions of a particular population size and growth rate, such as the "fast-growing suburban cities" or boomburbs examined by Lang & Simmons (2003, p.102).

Although there is widespread agreement that polycentrism involves multiple centers of employment, there is no consensus on how significant (either in absolute terms, or relative to the employment of either the metropolitan area or the CBD) a nucleus or node must be to qualify as such. And there has been even less consideration about whether there may be additional *dimensions* of this phenomenon worth study, beyond simply the number of centers.

What Does It Take to Make a Center in a Polycentric Metro?

The lack of consensus on how many jobs have to be concentrated in a nucleus for it to be deemed a center appears to be, in large part, an artifact of the limitations of data on the one hand, and the related fact that much of the research has involved case studies of only one or a small number of metropolitan areas—often of similar size. The issue is important because the metrics used to identify centers, in terms of population and/or employees and area, determine how many centers a metropolitan area may have. The unit of analysis is also important. It matters greatly whether the threshold amount of specified activities must occur within a municipality, census tract, traffic analysis zone, specified acreage, or some other geographic unit or construct.

Absolute Employment Thresholds. Table 1 summarizes prior studies of employment centers that have relied on absolute employment thresholds. The number of employees required for designation of a center varies in these studies from 1000 in a census tract for a specialized financial services center to 20,000 in a continuous set of traffic analysis zones (TAZ) and a *population* of 25,000 in a suburban city.

One difficulty with the geographic unit in each of these studies is that it may vary in area across a single metropolitan area, and the variation is even greater across several metropolitan areas. A municipality can range in area from a few square miles to more than a hundred, and some census tracts or TAZs may involve a few city blocks, while others—especially on the urban fringe—may cover several square miles. Unless there is a uniform area for the spatial unit(s) that the centers contain, as well as a common employment threshold, there can be no assurance that one is actually comparing like centers of concentrated employment.

The most common criticism of absolute employment threshold definitions is that they are often selected subjectively based on knowledge of employment centers in the metropolitan region(s) being studied (Craig & Ng, 2001; Muniz, Galindo, & Garcia, 2003). Anas, Arnott & Small (1998, p.1434) note that the "exact pattern of centers so defined may be quite sensitive to the choice of cutoff values, especially when comparing polycentrism in a large number of

metropolitan areas. A threshold of 5,000 employees may be relevant in identifying centers in large metropolitan areas but inapplicable in areas with populations of 75,000. On the other hand, it seems reasonable that a center of economic activity, even in a relatively small metropolitan area, should contain some respectable absolute number of jobs. Using an employment density threshold may help in ensuring that employment is concentrated in a center rather than spread across the cityscape, but again, a high density threshold that works for New York may be unachievable in Omaha, and one that captures the latter's employment concentrations well may produce an unrealistic number of centers in the former.

Relative Employment Thresholds. An alternative to identifying centers by some absolute number of jobs is to require that each one have a high degree of employment relative to some expected norm or reference center. For instance, Greene (1980, p.36) defined a zone of concentration as "any zone containing more than twice the [MSA] employment it would have had if all zones contained equal levels of employment". Similarly, Erickson (1983, p.115) defined suburban nucleations as "municipalities with 10,000 or more population… and containing 1% or more of SMSA employment". McDonald (1987) operationalized employment centers as all postal zones whose employment density exceeds that of all other contiguous postal zones. Forstall & Greene (1997, p.721) defined a worker concentration as an area that "includes at least one census tract with an employment/residence [E/R] ratio of 1.25 or greater – in other words, net in-commuting of at least 25%…. Most tracts with an E/R between 1 and 1.25 also were included in concentrations if contiguous to one over 1.25". Though the relative approach may be more appropriate for studying a cross-section of metropolitan areas because it allows for wide differences in the total population and/or employment of metropolitan areas, it still faces the criticism of an arbitrary choice of thresholds. Other exploratory spatial statistical methods have recently been employed to sidestep this problem, including the use of Moran's *I* statistic to identify areal units that have statistically higher levels of employment or employment density than their surrounding units, regardless of location in the metropolitan area (e.g., Baumont, Ertur, & Le Gallo, 2004).

The economics literature on polycentrism often uses employment or population density functions to determine the presence of centers. In effect, local peaks on density gradients represent a specific type of relative threshold in that centers are identified as major deviations from what would be expected from the overall density gradient (Odland, 1978; Gordon, Richardson, & Wong, 1986; McDonald, 1987; McDonald & Prather, 1994). One of the strongest criticisms of the use of density gradients is that the functions "identify a concentric circle rather than a point" (Craig & Ng, 2001, p.101), such that the investigator must identify the actual center(s) using local knowledge of the region. In addition, deviations from density gradients do not necessarily identify highly concentrated centers of activity. Employment density gradients typically decline rapidly from the center. As a consequence, major deviations from the expected density at the periphery may, indeed, be considerably higher than expected while still being lower than more heavily concentrated areas nearer to the center that are expected to be higher. McMillen (2003b) and McMillen & Smith (2003) dealt with this problem in part by identifying potential subcenters using significant residuals from an estimated density function, and then identifying actual subcenters as clusters with more than 10,000 employees.

A small subset of the literature has defined employment centers by examining travel patterns. These studies attempt to determine the importance of a center not just in terms of its

employment but also because of its trip generation capacity, which may include work as well as non-work trips (Gordon & Richardson, 1996; Pfister, Freestone, & Murphy, 2000; Jun & Ha, 2002).

To summarize, conceptually, virtually all studies agree that polycentrism is the existence of more than one highly concentrated, major employment node in a metropolitan area. It is widely accepted as a common, if not dominant, metropolitan form but there is no agreement on how much employment it takes to qualify as a center. Although most studies use employment alone in defining them, some use population and others use both employment and population. The threshold number of people or jobs needed to constitute a center appears to vary to fit the areas under study. There is even less agreement on the geographic unit within which the threshold should be reached. It is hardly surprising, therefore, that the term has been inconsistently operationalized, inadequately measured, and that existing work has arrived at disparate conclusions.

Polycentrism is Multi-Dimensional

Taken together, the literature on polycentrism does not constitute a coherent body of knowledge so much as a series of unrelated but suggestive efforts. The one constant is that each center, whether the sole CBD of a traditional monocentric metropolis or an edge city of others, contains a dense concentration of employment, and that altogether, the region's centers provide a substantial proportion of the metropolitan area's jobs. Therefore, our conceptual definition of polycentrism is as follows:

> *A metropolitan area is polycentric to the extent that two or more separate and distinct centers of employment contain a significant amount of the area's total employment, and the ratio of employment in the core center to employment in all other centers is low.*

Beyond this basic definition, we conceive of polycentrism as *multidimensional*. Five dimensions are explored here in our initial attempt to determine the extent to which metropolitan areas are monocentric or polycentric:

- *Frequency*: the number of centers in a metropolis that meet threshold requirements. We expect metropolitan areas to be distributed on a continuum from those that have a single center to those with many. The vast majority of studies on polycentrism are concerned with the number of centers within a metropolitan area (Greene, 1980; Dunphy, 1982; Erickson, 1983, 1986; Gordon et al., 1986; McDonald, 1987; Garreau, 1991; Giuliano & Small, 1991; Waddell & Shukla, 1993; McDonald & Prather, 1994; Small & Song, 1994; Fujii & Hartshorn, 1995; Godfrey, 1995; Gordon & Richardson, 1996; Forstall & Greene, 1997; McMillen & McDonald, 1997; Suarez-Villa & Walrod, 1997; Cervero & Wu, 1998; Bogart & Ferry, 1999; Pfister et al., 2000; Anderson & Bogart, 2001; Craig & Ng, 2001; McMillen, 2001; Jun & Ha, 2002; Lang & Simmons, 2003; McMillen, 2003b, 2003a). In many cases, the frequency with which centers occur is the only dimension of polycentrism considered.

- *All Centers Dominance*: the percent of total area employment located in all of the centers. This dimension allows distinguishing strong polycentric or monocentric regions from weak ones by the share of total metropolitan employment its centers capture. Several prior studies considered the share of the total regional employment located in an area's centers to be an important dimension of polycentrism (Greene, 1980; Erickson, 1983, 1986; Gordon & Richardson, 1996; Forstall & Greene, 1997; Suarez-Villa & Walrod, 1997; Bogart & Ferry, 1999; Pfister et al., 2000; Anderson & Bogart, 2001; Jun & Ha, 2002; Lang & LeFurgy, 2003; McMillen, 2003a).

- *Core Center Dominance*: the percent of total employment located in the largest center, usually the Central Business District (CBD). *All centers* and *core center dominance* will coincide in monocentric regions, but the extent to which the core center captures the region's employment determines whether the region's monocentrism can be characterized as a strong or weak. The strength of polycentrism should also vary with the extent to which the largest center remains the dominant place of employment even though one or more other places meet threshold requirements for centers. A few studies consider the share of the total regional employment located in the core center (Waddell & Shukla, 1993; Godfrey, 1995; Forstall & Greene, 1997; Anderson & Bogart, 2001; Lang & LeFurgy, 2003).

- *Relative Core Center Dominance*: the percent of employment in all centers that is located in the core center. When the largest, or core center, contains a smaller percentage of all center employment it suggests that a metropolis is more polycentric. The strength of the core relative to other centers, measured over time, also permits an assessment of the evolution of polycentrism.

- *Concentration*: the percent of all metropolitan employment in centers that is contained in the largest X centers. This dimension is also useful in measuring the extent and change in polycentric and monocentric regions over time. If one finds, for example, that the proportion of employment captured by the region's five largest centers is declining, it can suggest that it is becoming more polycentric, if other centers are gaining in employment share, but if centers cumulatively are losing employment share, the region may be taking on a more diffused or uncentered form (see Waddell & Shukla, 1993).

Three additional dimensions are suggested in previous studies:

- *Dispersion*: the distance between centers. This dimension is important in understanding the role centers play in such matters as housing price gradients, commuting time, and the design and operation of a region's infrastructure systems. Centers that are essentially adjacent or have little distance between them may function little differently than specialized districts of the core or a monocentric region. Thus, the greater the distances among centers, the more a region is polycentric (see Erickson, 1986).

- *Balance*: the employment/housing ratio in centers. Assuming a center meets the absolute or relative employment threshold, the extent to which it also contains a high ratio of housing units to jobs can have important implications for a wide range of public policies

(see Giuliano & Small, 1991; Cervero & Wu, 1997; Forstall & Greene, 1997; Jun & Ha, 2002).

- *Function*: the specialization of economic functions performed in the center. Some centers may be highly diversified in terms of the economic sectors they contain; others may be highly specialized—especially retail, office, and manufacturing centers. The role of a region in the economy may play a large part in whether it takes on a polycentric form (see Giuliano & Small, 1991; Bogart & Ferry, 1999; Anderson & Bogart, 2001; Jun & Ha, 2002). Also, the extent to which a region's centers are functionally specialized can impact its housing distribution, transportation system, and local fiscal capacities.

While we believe these three additional dimensions are important, the first five dimensions appear sufficient for an initial characterization of patterns of polycentrism given available data, and we leave description of these three dimensions to another time.

Identifying a Metropolitan Area's Centers

Centers of What? Although all studies of polycentrism conceptually focus on the metropolitan area, they vary considerably in the actual area for study, ranging from the *Metropolitan Statistical Area* (Greene, 1980; Erickson, 1983, 1986; Hughes, 1993; McDonald & Prather, 1994; Bogart & Ferry, 1999; Anderson & Bogart, 2001; McMillen, 2001; Lang & LeFurgy, 2003; McMillen, 2003b, 2003a) or the *Consolidated Metropolitan Statistical Area* (CMSA) (Godfrey, 1995; Forstall & Greene, 1997) to a unspecified metropolitan area or region (Dunphy, 1982; McDonald, 1987; Waddell & Shukla, 1993; Clark & Kuijpers-Linde, 1994; Fujii & Hartshorn, 1995; Cervero & Wu, 1997; McMillen & McDonald, 1997; Lang & Simmons, 2003). Several studies of the Los Angeles metropolitan region use the urbanized portion of a five-county study region delimited by the Southern California Association of Governments, which was described as larger than the Los Angeles-Long Beach MSA but part of the larger Los Angeles CMSA (Gordon et al., 1986; Giuliano & Small, 1991; Small & Song, 1994; Song, 1994; Gordon & Richardson, 1996).

These variations in the study area suggest the need for a theoretically justifiable specification of the appropriate area for the study of polycentrism and other dimensions of urban development. One of the problems with using metropolitan statistical areas (MSAs) or other definitions based on counties is that they often contain urbanized areas or centers in the outer reaches of large counties that have weak ties to the urban and urbanizing metropolis. Particularly, from the point of view of understanding polycentrism, some older cities in outlying counties may be more closely aligned with a different urban core than with the one with which the MSA designation has associated them--although this may change over time.[2] To ensure that

[2] Two examples in the Washington region are Hagerstown, Maryland and Fredericksburg, Virginia. Both are old and independent cities, roughly 60 miles from the District of Columbia. Hagerstown was long more within the economic influence of Baltimore than Washington, to which it is equidistant, but increasingly came under the sway of the latter. In 2000 it became part of the Washington-Hagerstown PMSA. Fredericksburg, the seat of Spotsylvania County was long more closely associated with, but beyond, the Richmond MSA. It, like Hagerstown, has increased its connections to Washington's Northern Virginia suburbs.

the centers we identify are strongly associated with the geographic area under consideration we have defined an *Extended Urbanized Area* (EUA) for each metropolitan region, as follows:

> *The Extended Urban Area (EUA) consists of the Census Bureau-defined urbanized area, modified to follow census tract boundaries, as well as additional ''outlying'' one mile square grid cells that contain 60 or more dwelling units (identified using data at the census block level), and are located in census tract from which at least 30 percent of the workers commute to the urbanized area.* (Wolman et al., 2005, p.96)

This definition avoids both the over-bounding of study areas common in use of regions based on county boundaries, and under-bounding that occurs in studies that focus on the urbanized area alone. Moreover, it provides assurance that any centers identified in the EUA have a strong economic linkage to the metropolis. Finally, it provides a consistent way of circumscribing areas for purpose of comparative and cross-sectional studies and of establishing relationships between polycentrism and other dimensions of urban development patterns, such as density, continuity, centrality, concentration, mixed-use, and proximity of land uses (see Galster et al., 2001).

Choosing the Unit of Analysis. Once the area within which the search for centers has been determined, a specified geographic unit must be selected from which centers can be constructed based on the amount of employment each unit contains. Because most previous studies have dealt with only one or a few similar areas, thresholds appear to have been selected to meet some subjective judgment of the amount of employment needed to qualify as a center in those places. Previous studies have used municipalities, zip codes, census tracts and Transportation Analysis Zones as units of analysis, with centers consisting of individual or clusters of such units.[3] Together with different criteria for defining centers, the result is a substantial divergence in the number of centers identified by different studies of the same metropolitan areas using data for the same time period.

As Table 1 demonstrates, the number of centers found by different studies of the same metropolitan areas using 1990 data can vary substantially. Depending on assumptions, Atlanta had four or eight centers; Baltimore five or eight, and Dallas nine, 12, or 28. Studies of Houston's centers found as few as seven and as many as 25, between one and eleven in Indianapolis, and as few as 12 and as many as 120 in Los Angeles. One study of Seattle found

[3] The following units have been used: political jurisdictions, including *municipalities* (Erickson, 1983, 1986), *incorporated cities* (Hughes, 1993), and *counties* (Gordon et al., 1986; Gottdiener & Kephart, 1991; Clark & Kuijpers-Linde, 1994; Godfrey, 1995); locally generated units of analysis from journey to work surveys (McDonald, 1987), or other sources (Greene, 1980:31, used "small-area geographic units comparable to census tracts in size," and Waddell & Shukla, 1993:39, utilized "employment-related land use polygons" that are contained within postal zones); *census tracts* (Haynes, 1971; Odland, 1978; Gordon et al., 1986; Fujii & Hartshorn, 1995; Gordon & Richardson, 1996; Cervero & Wu, 1997; Forstall & Greene, 1997; Craig & Ng, 2001; Coffey & Shearmur, 2002; Muniz et al., 2003) or *census blocks* (Dunphy, 1982; Moudon & Hess, 2000); *transportation analysis zones* (TAZs) (McDonald, 1987; Giuliano & Small, 1991; Small & Song, 1994; Song, 1994; Cervero & Wu, 1997; McMillen, 2001, 2003b; McMillen & Smith, 2003); and *sections* (McDonald & Prather, 1994; McMillen & McDonald, 1997; McMillen, 2003a).

five centers, another found 13. St. Louis studies reported five and ten and one study said Washington had ten centers while another discovered 24.

Each approach may be rationalized for a specific area or a small number of areas but for a major comparative analyses, square mile cells (McDonald & Prather, 1994; McMillen & McDonald, 1997) seem the most appropriate. Other units vary so much in size that it makes comparative analysis problematic; particularly so if any attempt is made to normalize for area size. In a square mile cell, any threshold number also serves as a standard for minimum employment density. Moreover, using one square-mile areas as the unit of analysis provides an area that is small enough to capture employment centers of smaller metropolitan areas, and a unit that can be combined with others to identify large and extensive centers in the nation's largest urban regions.

Thus, following Galster et al. (2001) and Wolman et al. (2005) we laid a grid of one-square-mile cells over each metropolitan area in a sample of 50 metropolitan areas drawn from a pool of the 100 largest metropolitan areas in the United States, based on 1990 population. This sample was regionally stratified and then a proportionate random sample was drawn from each of the four Census Regions. The final sample includes 11 metropolitan areas from the Northeast Region, 11 from the North-Central Region, 12 from the Western Region, and 16 from the Southern Region. The Extended Urbanized Area of each metropolis was defined, and using ESRI ArcMap®, jobs were allocated to one-mile square grid cells.[4] Table 2 lists the metropolitan areas in our sample by Census Region. It also includes the total 1990 population and employment for the Extended Urban Area of each metropolis.

How Much Employment Must a Unit Have to Be Counted as Part of a Center? Most prior studies used an absolute employment threshold to identify centers. We discussed earlier the shortcomings of this approach, but we have employed it here for three reasons. First, this is an exploratory effort to demonstrate the feasibility of using common metrics to describe the extent of polycentrism across a large number of metropolitan areas. Second, it is easy to understand. And third, it permits us to compare our results directly with most other studies on similar terms. We leave to a later time development of a relative measure that can be applied across a large number of areas, because that is a substantial task in itself that would be a distraction from our goals in this paper.[5]

In a comparative study that encompasses large and small metropolitan areas the number of employees per unit of analysis cannot be so small it would be considered insignificant in Los Angeles or Philadelphia, nor so great that even the central business districts of Fresno or Fort Wayne could not reach it. To solve this problem we adopted a two-tiered approach that

[4] Transportation Analysis Zones (TAZ) geographic boundaries were joined with the Place of Work data file in the Census Transportation Planning Package (CTPP) prepared by the U.S. Census Bureau for the U.S. Department of Transportation. The resulting values were used to represent the number of jobs in a TAZ. The number of jobs was then allocated to each one-mile square grid cell based on the proportion of each TAZ that fell wholly or partially within a grid cell, assuming a homogenous distribution of employment within each TAZ.

[5] We think a good place to start that inquiry is to test Greene's (1980) approach of establishing as a threshold some multiple of the average employment per unit area.

distinguished major and minor centers, and that guaranteed at least one major center could be identified for each metropolitan area in our sample.

A *major center* consists of any single square-mile cell that contains 8000 or more employees and any cells contiguous to it containing 4000 or more employees. The largest of these major centers is the *core center*. This is usually, but not necessarily, the CBD of the central city of the metropolitan area.

A *minor center* consists of any single cell or two adjacent cells containing 4000-7999 employees, including cells that may be connected only at the corners, and are separated from another major or minor center by at least one cell containing fewer than 4000 employees.

In cases where clusters of cells containing more than 8000 employees and surrounded by cells with 4000 or more employees were connected by a single cell with 4000 we followed a rule that the cluster would count as two or more centers. Examples of such situations are the CBD-to-Santa Monica corridor in LA, that involves downtown, Century City-Westwood, and Santa Monica; or the Dallas central area that includes the CBD and the Stemmons I-35 corridor, which are separated by the interstate and perform different economic functions.

This two-level approach captured most centers of a size that are included in other studies of polycentrism without dropping the threshold so low that it is trivial in the larger EUAs. It also compensates for the arbitrary placement of our grid, which could divide a substantial employment center. By using this approach, our major centers have at least 8000 employees and a density greater than 4000 employees per square mile, which is slightly less than suggested by Giuliano & Small (1991) but well within the range that has been used in case studies of U.S. metropolitan areas.

Figures 1 and 2 show the major and minor centers in the 1990 Baltimore-Washington CMSA and the Salt Lake City MSA. The black-shaded cells contain 8000 or more employees, and with the adjacent cells comprise the core and other major centers. The grey-shaded cells contain 4000-7999 employees. Where two or more of them are separated by an unshaded cell from a cluster containing an 8000-employee cell, they comprise a minor center.

And the Centers Are . . .

Table 3 lists the areas in our sample by the number of centers each contains (*frequency*), the amount and share of the EUA's employment in all centers (*all centers dominance*), the core (*core center dominance*) and other major centers (*concentration*), and the percentage of employment in all major centers that is located in the core (*relative core center dominance*). Data are also provided on minor centers and the employment that was located outside of centers. Several things are apparent from this table:

- Nineteen (38%) of the metropolitan areas in our sample of 50 had only one major center in 1990—the core center. Another sixteen (32%) had only two major centers. Only eight (16%) had more than three significant centers. This suggests that although polycentrism may well be the emerging urban form, it was not yet pervasive in 1990, even among the nation's largest metropolitan areas.

- Total metropolitan employment does not, in itself, appear to determine the extent to which an area is polycentric or monocentric. Of the five largest areas in our sample, Los Angeles had 12 major centers and 21 minor centers. Philadelphia, second in employment, had only two major centers, and 10 minor centers. The next three largest areas—Washington, Boston, and Houston—had, respectively, eight, five, and three major centers. Washington and Boston each had seven minor centers, and Detroit had five. Among the metropolises with a single major center, EUA employment ranged from 716, 233 jobs in Pittsburgh to 141,546 in Stockton, CA.

- Monocentric and polycentric areas, respectively, vary widely in the strength of their core centers—in both their share of total metropolitan employment and, in the case of the polycentric areas, in relationship to other centers. The three weakest core centers were Detroit, Mobile, and Youngstown. Detroit was one of the most polycentric areas in our sample, with only eight percent of its total employment located in its core center. The other two areas had a single center, but each contained fewer than 10 percent of its region's jobs.

- Of considerable interest in understanding urban form is the percentage of jobs that are not located in any center, at least as we have defined them here. In only four of the EUAs in our sample—Las Vegas, Miami, San Jose, and Washington—were more than half of all jobs located in centers. More than two of every three jobs in 28 of the areas are located outside of centers, and in eleven of the areas, three-fourths of the jobs were located outside centers. San Antonio was the most extreme case, with fewer than one job in five located in its two major and one minor centers. For students of urban form, this suggests that particular attention should be given to those areas where a high percentage of all jobs are concentrated in major centers, to determine if there are any common factors that may explain their relative strength. This finding also challenges us to consider at what point we should characterize these areas as *dispersed*, *beyond polycentric*, or *post-polycentric* (Waddell & Shukla, 1993; Gordon & Richardson, 1996; Lang & LeFurgy, 2003).

Table 4 compares the total number of major (including the core center) and minor centers we found to the centers identified in earlier studies using 1990 data for the metropolitan areas in our sample. First of all, Table 4 demonstrates the importance in the search for centers of differences in employment thresholds, units of analysis, and the territorial extent. Using Los Angeles as an example, Forstall and Greene (1997) found 120 centers in their case study; McMillen (2001), using a 50-mile radius from the CBD, found 20; McMillen and Smith (2003), using a different threshold and unit of analysis found 47; and Gordon and Richardson (1996) found only 12. An inspection of Table 4 reveals other examples of substantial differences among the studies. This suggests that if any sense is to be made of measuring the extent of urban polycentrism it is first essential to establish some common metrics so that the same thing is being measured in the same way in different places. This will also be important for tracing the extent to which metropolitan areas are becoming more or less polycentric over time, to trace whether minor centers eventually grow to become major centers, or if most of them remain about the same size, suggesting a specialized or localized function, rather than playing a fundamental role in determining urban form. Because of their problematic status, we ignore minor centers and deal only with the core and other major centers in the remainder of this paper.

How Should Areas Be Ranked or Classified with Respect to Their Polycentrism?

It is one thing to count centers; it is another to distinguish among classes of areas with regard to the extent to which they are polycentric in any but the simplest meaning of the term, i.e., they have more than one major employment center. Table 3 suggests that monocentrism and polycentrism, respectively, do not operate the same way—even in metropolitan areas with the same number of centers. Among monocentric metropolises, Las Vegas (where nearly three of every five jobs is in the single core center) must function in a very different way than Baton Rouge, Youngstown, or Mobile (where no more than one job in ten is centrally located). Similarly, it is hard to imagine that Washington functions the same way as Detroit region, even though both are clearly polycentric. Washington had eight major centers containing over half of the region's total employment and its core center captured a third of all EUA jobs and two-thirds of all major center jobs. Detroit's seven major centers contained only 27.7 percent of all jobs and its core center employed only eight percent of workers in its EUA and captured just over a third of all major center jobs. Thus, while the number of centers is an important characteristic of polycentrism, simply specifying the number of centers fails to adequately describe urban form, much less provide a useful hierarchy or classification scheme for differentiating between types of polycentrism.

Our initial step in classification involved measuring the degree to which an area's employment was single-centered as opposed to multi-centered or dispersed, in terms of its employment structure. We constructed two simple indices, the results of which are reported in Table 5. The first index was derived from Lang (2003), in which thirteen major urban areas were classified according to the percentage of their commercial office space located in primary or secondary downtown settings and in edge cities versus the percentage outside of all centers. Our index is the difference between the percentage of total area employment located in the core center and the percentage total employment located outside all centers, as of 1990. When sorted from largest to smallest, this index ranks areas by their *core centeredness*. Las Vegas, Miami and San Jose were the most strongly core centered, in that each had a larger percentage total area employment in their core center than was located outside all centers. At the opposite end of the spectrum, Tulsa, Mobile, and Youngstown had nearly all of their employment outside centers, with a very small percentage of its total area employment in the core center.

The second index of polycentrism measures the degree to which an area was centered at all as opposed to dispersed (also see Table 5). This index is computed as the difference between the percentage total employment located in all centers and the percentage total employment located outside all centers. This permits a rough ranking of areas by their *overall centeredness*. While this index parallels the first, there are some subtle changes in the rankings. For instance, we found the same three areas—Las Vegas, Miami and San Jose—plus Washington were strongly centered in terms of total area employment in centers. At the opposite end of the spectrum, we again find Youngstown and Tulsa, and other highly dispersed areas with more than 70% total area employment outside centers. Los Angeles offers an interesting case, in that it falls roughly in the middle of the list on the first index, but moves up the rankings by a considerable amount on the second index, suggesting that it is strongly centered, although not single centered.

Metropolitan areas are arrayed across both indices relatively continuously, without obvious demarcations to suggest different types. A more refined classification scheme appears necessary to better understand patterns of employment across urban areas, and to distinguish patterns of core centeredness from overall centeredness.

Using four dimensions of polycentrism defined above (center frequency, center dominance, core dominance, and relative core dominance), we used cluster analysis to mathematically group together areas according to their employment patterns. Cluster analysis is a mathematical technique that contains subjective elements. The technique can generate many different cluster solutions, depending on the choice of method, all of which are valid. The cluster solution chosen reflects the judgment of the researchers concerning what is appropriate in light of the research objectives. We sought to identify groups of areas that showed strong similarity among its members (i.e., formed tight clusters), but also to identify a manageable number of groups that appeared qualitatively distinct. Different clustering methods would generate different results; we only aim to demonstrate the feasibility of classifying areas according to polycentrism in a way that appears to accord with reasonable notions about how they might be grouped.

After trying a large variety of clustering methods, we selected a solution generated by weighted average linkage clustering.[6] This method is hierarchical in nature, meaning that it combines areas sequentially such that a set of nested clusters is generated. The method defines groups according to the average similarity among observations using Euclidean distance, and assigns each group equal weight (as opposed to equally weighting each observation). The preferred solution identified eleven clusters, although four are single area clusters that are grouped together separately from all the other areas. We collapse these four single area clusters into one cluster. We also collapse another single area cluster into the next closest cluster, because it appears to have qualitatively similar values on all four dimensions as the next closest group. These alterations left us with seven classes of areas reported in Table 6. Three clusters exhibit decreasing intensities of polycentrism, three are increasingly monocentric, and the remaining cluster contains three areas with such weak centers we have called them dispersed.

We also sought to understand how our groups might differ according to several important characteristics not used in the clustering, but typically used to explain urban form (geographic scale, age of the metropolitan area, population size, population growth rate, median household income, government fragmentation, and economic structure). One-way analysis of variance (ANOVA) tests were performed to determine whether statistically significant differences could be found across group means, as compared to the whole sample mean, on each of these variables. Further statistical review, using the Scheffe test, was performed to determine which group means were significantly different from the others. In several cases (population growth, income, some location quotients), the ANOVA tests returned significant but Scheffe tests failed to reveal significantly different means when correcting for multiple testing bias and different group sizes. The results are reported in Table 7. Small sample sizes in some of the groups may preclude a finding of significance at conventional levels.

[6] Details available from the corresponding author upon request.

Cluster Profiles

Dispersed Areas. Three areas in our sample—Tulsa, Baton Rouge, and Mobile—have very small percentages of their total employment located in either their core center or any other centers. Employment is so widely dispersed throughout the area that they cannot fairly be considered to be either monocentric or polycentric. The cluster analysis confirmed grouping them together. Consistent with their ranking on the simple indices, above, we have labeled them *dispersed*, indicating an almost random distribution of employment across the metropolitan area. These three metropolises are among the least populous and smallest in land area of the 50 in our sample, but statistical tests did not reveal any notable characteristics about this cluster.

Strong Polycentric Areas. Each Census Region contained one of the four strong polycentric metropolises in 1990. Statistical tests confirmed that these areas, on average, were more populous and had more jobs than all the other clusters. Each metropolis in this cluster had more than a million jobs and five or more major centers (*frequency*). Except for Los Angeles, however, each of the other three strong polycentric areas contained fewer jobs than at least one area in another cluster. All in this class but Detroit had a relatively high percentage of employment located in their centers (*all centers dominance)*, with much of that in major centers (*concentration*).

Los Angeles had the largest number of major (12) and minor (21) centers of any area in the sample and a high proportion (44.3%) of all its jobs were located in those centers, with 38.5 percent of them concentrated in the 12 major centers. Its relatively weak core center, however, captured only 15.1 percent of all EUA employment and just over a third of all center jobs. Except for Washington, with 34.2 percent of all EUA jobs and 61.1 percent of all center employment in its core center, the strong polycentric areas had relatively low levels of *absolute* and *relative core center dominance*. Dallas's core center, with 23.1 percent of all EUA jobs and over half of all center jobs, also was relatively strong. Detroit had the weakest core center, with just over eight percent of EUA employment and only 29 percent of major center jobs located there. Detroit is the most problematic member of the group, in that it does not appear very polycentric, aside from having a larger number of major centers.

Polycentric Areas. The six metropolises in this cluster are unevenly distributed among the Census Regions. Three are located in the Northeast (Albany, Boston, and Wilmington), three in the Southern Region (Baltimore and New Orleans), and one in the West (Seattle). None were in the North Central Region. Total employment and land area varied widely among the metropolitan areas this cluster, and the number of major centers ranged from five in Boston to two in New Orleans and Wilmington. Only Boston had a substantial number of minor centers (seven). All the areas have higher levels of core dominance than the strong polycentric areas, except Washington, and higher levels of relative core dominance than any of the strong polycentric areas. What distinguished them from the strong polycentric areas were their lower concentrations of EUA employment in major centers other than the core and the relatively high percentage of all center employment located in the core. Statistical tests did not reveal any notable characteristics about this cluster.

Weak Polycentric Areas. The weak polycentric cluster of six areas included two in the Southern Census Region (Atlanta and Raleigh), three in the North Central Region (Omaha,

Minneapolis, and Youngstown) and one (Allentown) in the Northeastern Region. Only Atlanta, the largest area in the cluster, had more than three major centers and more than a single minor center (five). Its employment in non-core major centers was, however, the weakest in the cluster, as was its measure of relative core dominance. All areas in this cluster had weaker core centers (measured in terms of either absolute or relative dominance) than the polycentric cluster. Population, employment, and land area also varied widely among areas in this cluster, and statistical tests did not reveal any notable characteristics.

Weak Monocentric Areas. Nineteen weak monocentric areas comprise the largest cluster. Seven were in the North Central Census Region, six in the Western Region, four in the Northeast, and only two in the Southern Region. Only three areas (Houston, Milwaukee, and Phoenix) had as many as three major centers in 1990. All but two (San Antonio and Fresno) of the weak monocentric areas had more than one of every five jobs located in their core centers, which were very strong in relationship to other centers. Even those areas with more than three minor centers had cores with high measures of relative core center dominance, suggesting that these minor centers were, indeed, less important economically or in shaping urban form. The grouping of these areas, especially Philadelphia (10 minor centers), San Diego and Houston (5 each), Phoenix and St. Louis (4 each), and Denver (3), suggest that understanding the tendency toward or against polycentrism requires a deeper analysis than reciting a region's age, economic role, or Census Region. Clearly, polycentrism, in any meaningful sense of the term, is not inevitable, even for the largest metropolises. The diversity of areas in this cluster, ranging in size from Philadelphia to Grand Rapids, and containing areas such as Houston and Portland, with land use policy frameworks that are virtual opposites, argues for better explanatory theory as well as more rigorous empirical analysis than we have been able to provide in this initial exploration of the condition. Statistical tests did not reveal any notable characteristics about this cluster.

Monocentric Areas. Six of the nine areas in this cluster are in the Northeast Region, and one is located in each of the other three Census Regions. All of the northeastern areas are old manufacturing centers, and among them only Pittsburgh and Rochester had developed by 1990 even a single minor center, and the core centers of those two areas still contained over 90 percent of all center employment. Statistical tests did not reveal any notable characteristics about this cluster.

Strong Monocentric Areas. The three strong monocentric areas in our sample have more than 45 percent of all their employment in the core, and although both San Jose and Miami have major and minor non-core centers, the core remains the overwhelmingly dominant location for jobs. Las Vegas, which has been one of the nation's fastest growing metropolises, was by far the most monocentric of the 50 areas in 1990. Statistical tests revealed that this cluster has a larger location quotient for the service industry than the weak monocentric, dispersed and weak polycentric clusters, on average.

A final note about our classification. Our classification scheme, with three levels of monocentrism and three levels of polycentrism, plus a dispersed category, may appear more parsimonious than the analysis warrants. To illustrate, the hierarchy of clusters (or dendrogram) produced by the cluster analysis is depicted in Figure 3. Dendrograms visually represent how similar the members of each cluster are to members in other clusters; the Y-axis scale in this

dendrogram shows the level of dissimilarity as measured by the simple Euclidean distance. We see that the cluster analysis placed the strong polycentric areas separate from all the other areas, suggesting their unique status in relation to all the other areas in our sample. We also see that the polycentric and weak monocentric clusters are the two most similar groups. Other cluster analysis methods we tried often grouped the polycentric and weak monocentric areas together into one large cluster, while keeping the rest of the classification roughly the same, suggesting that the two clusters may be more similar than we have portrayed them. However, we saw qualitative differences among areas in the larger cluster, and chose a cluster solution that broke that grouping up into two clusters. Finally, we see that the dispersed cluster is most similar to the weak polycentric cluster. While selecting this cluster solution as appearing most appropriate out of several trials, and conforming to our expectations, we acknowledge that the classification likely requires more conceptual and operational attention.

Conclusions and Agenda

Our exploration of urban polycentrism suggests that, although the concept has been widely discussed in economics, geography, planning, and urban affairs literature, it has not been consistently defined or subjected to close examination across a large number of metropolitan areas. Our effort here has involved modest, but we believe, useful first steps toward a workable definition of polycentrism as one of several dimensions of urban development. This has entailed specifying: (1) the area within which polycentrism is to be measured; (2) the appropriate and uniform geographic unit of analysis to be used to identify employment centers; and (3) the employment threshold that must be met within the unit of analysis to qualify as a center. Each of these tasks proved feasible and theoretically defensible, as well as practicable. We also identified and operationally defined five dimensions of polycentrism, which in combination with cluster analysis techniques, helped us to produce a basic typology of areas, ranging from dispersed and strong polycentric to strong monocentric.

Based on this initial exploratory analysis, there is some reason to challenge the conventional wisdom that polycentrism has displaced monocentrism as the dominant urban form. At least in 1990, in our sample of half the 100 largest U.S. metropolitan areas, many more areas showed varying degrees of monocentrism, as we have classified them, than degrees of polycentrism. It is conceivable but unlikely that a comparable examination of the other 50 would produce an opposite result. Area, age, population, income, number of general purpose governments, or economic functions do not appear to provide much help in explaining a given area's location in the typology. The speculation that Southern and Western metropolises, or areas that came to maturity after the advent of the automobile age are more inclined toward polycentrism than older cities from the industrial belt is not supported by the evidence. Eight of the areas we classified as polycentric were from the Southern and Western Census Regions, but Washington and Baltimore share few of the characteristics and almost none of the development or economic history of places like Dallas, Raleigh, Atlanta, or Los Angeles. In all, seven of the 16 polycentric areas were from the Northeast and Northcentral Regions. Among the monocentric areas, 16 were in the Southern and Western Regions, and 15 were from the Northeast or Northcentral Regions.

This exploratory analysis, in operationally defining and measuring four dimensions of polycentrism for 50 metropolitan areas, and employing cluster analysis to develop a rough

typology of seven differing types of monocentrism and polycentrism, prepares the ground for further empirical description and theory building. Several empirical issues warrant further examination.

First, extending the present analysis to all U.S. metropolitan areas—or at least the remaining 50 largest ones—would settle any issues of selection bias, however inadvertent, in this study. Our sample deliberately excluded New York City and Chicago, because of the cost of conducting the GIS work required to provide the necessary grid and data allocation. While we included Los Angeles, it is conceivable that large global command and control centers function quite differently and take on a different or more pronounced form that less important areas.

Second, there is evidence based on limited case studies and comparisons of smaller numbers of areas that urban form may evolve from monocentric to polycentric or dispersed forms. For example, Greene's (1980) study of five metropolitan areas found that, while universally decentralizing from the CBD, the number of suburban employment zones and the percent of regional employment in them increased during the 1960s for Atlanta, Baltimore, Denver and Fort Worth, but declined in Buffalo. Erickson (1986) found the number of centers and the relative metropolitan employment in the centers increased from 1967 to 1977 in ten of the largest MSAs. Over a thirty-year period (1947-1977) he found an "emerging randomness in the patterning of suburban nucleations [that] may reflect a much larger set of suburbs that could reasonably become future nucleations" (Erickson, 1986, p.343). Gordon & Richardson (1986) found that Los Angeles had experienced a declining number of subcenters with a smaller percentage total employment from 1970-1990, which they characterize as a pattern of "generalized dispersion." However, recent comparative analysis for large metropolitan areas over time is lacking. Thus, comparing a larger sample of areas over several census periods could address whether some areas foster new major centers as old core centers weaken, or if employment growth is diffused almost randomly across the metropolis rather than concentrated in nodes (Gordon et al., 1986; Waddell & Shukla, 1993).

Third, we think there is considerable potential in examining the significance of three dimensions of polycentrism that we were unable to include in this paper: dispersion (distance between centers); balance (whether centers contain substantial percentages of residences as well as jobs); and the specialization of economic functions performed in centers. Both distance and function have implications for both the extent to which major and minor centers are in fact components of a truly different urban form, or whether they are mere satellites or dependents of the core center and thus variations on the monocentric model. Balance has important implications for how the metropolis functions and whether and how centers with certain properties are associated with indices of urban well-being or other dimensions of development patterns, such as density, proximity, etc. The extent to which certain economic functions *within* a polycentric metropolitan area (as distinguished from the major economic function of the whole area in the national economy) tend to co-locate in specialized major centers while others seek more diversified environments or simply spread themselves fairly evenly across the landscape may help us understand why some places evolve as they do. This effort may also help us identify agglomeration economies and how important they are in our sample areas.

Fourth, we limited this paper to using absolute employment thresholds, arriving at a threshold that worked for our 50 areas through trial and error. While it has common sense appeal

and was relatively easy to select, we find it intellectually unsatisfying. In earlier work (Galster et al., 2001), we suggested that additional centers (termed *nuclearity* in that study) might be identified by a relative measure, such as *x* standard deviation from the mean of the employment in the cells comprising the core. We believe some such relative threshold measure would better address the problem that a Los Angeles, Philadelphia, or Washington center is not the same, in terms of the way these places function, as a Tulsa, Fresno, or Grand Rapids center.

Fifth, our analysis of the significance of the major economic functions performed by an area on mono-or-polycentrism was limited to one-digit industrial sector codes. Moving to the second or third digit in economic analysis appears to be a fruitful line of inquiry as we seek explanations of why specific areas take on or hold onto particular urban forms. Earlier studies found that an area's industrial structure affected its polycentrism, since some industries are more prone to take advantage of agglomeration economies within the context of decentralization (Erickson, 1986; Coffey & Shearmur, 2002). The entertainment industry in Las Vegas, the automobile industry in Detroit, the financial sectors of some cities, and the government functions of Washington and state capitals may encourage aggregations of firms and employment that explain more fully why certain urban forms exist or persist in particular areas.

Sixth, given the differences we have seen among urban areas that were placed in the same clusters, further analysis is warranted that includes policy or other variables to determine if or the extent to which an urban area can consciously manage development forces to control its form. The ability for businesses to decentralize is, in large part, contingent upon the expansion and flexibility of transportation networks. The existence of suburban transportation networks has been examined both theoretically and empirically as an important determinant of metropolitan form (von Boventer, 1976; Baerwald, 1982; Erickson, 1983, 1986; Harris, 1997). Transportation was deemed an important enough influence on urban form that early conceptions of polycentrism distinguished clustered centers that formed around highway intersections with the linear development patterns that are now typically found along major transportation corridors (Baerwald, 1982). Others specifically examined the proximity of subcenters to the transportation network, such as nearness to a highway interchange (Erickson, 1983; McMillen & McDonald, 1997), finding a strong and significant relationship between subcenter location and highway proximity. On the other hand, some areas may use land use or tax policy to discourage decentralization from the core, or alternatively, to encourage the formation of discrete subcenters in the "urban village" tradition. Factors related to policy that are also worth considering in a historical context include an area's social and economic history, landscape and physiographic province, and philosophical differences in land use planning or land preservation.

Seventh, the *consequences* for urban well-being of a change in urban form need to be examined. The consequences that have received the most attention are effects on travel patterns, in particular on commuting flows, and effects on land values or housing prices. Case studies of commuting patterns in the Los Angeles & San Francisco regions indicate that commuting times tend to be shorter in the outer areas and longer for commutes to centers, such as the traditional CBDs (Gordon et al., 1986; Giuliano & Small, 1991; Clark & Kuijpers-Linde, 1994; Cervero & Wu, 1997). Fujii & Hartshorn (1995, p.698) obtained similar results for the Atlanta metropolitan region, but also found that the importance of the Atlanta CBD in dominating commuting flows shifted, "reflect[ing] the major employment concentrations in the more mature suburban counties and the growth of more distant bedroom communities on the urban fringe".

The literature on polycentrism with respect to housing prices has found fairly consistently that proximity to centers has a positive effect on local housing price gradients as predicted by economic theory (Hoch & Waddell, 1993; Waddell, Berry, & Hoch, 1993). McDonald (1987, p.255) earlier had argued, based on previous studies of the effect of changing urban form on land values for the Chicago metropolitan region that "the impact of employment subcenters on residential land values is generally not evident in the raw data." The ability to move from case studies of specific areas to cross-sectional analysis of at least 50 areas should help settle this issue. Related questions of the effect of polycentrism on outcomes such as the spatial distribution of incomes, access to employment opportunities for low-income workers, racial segregation, and environmental conditions such as air and water quality, and factors such as carbon sequestration (Nowak & Crane, 2002; Pouyat, Groffman, Yesilonis, & Hernandez, 2002), are also ripe for investigation.

From a theoretical perspective, it is one thing to notice that metropolitan areas are organizing themselves in different formations to perform their urban chores. Much has been asserted about the transformation of cities and regions as a result of economic restructuring, the pervasiveness of information technology, and the emergence of the informational or transactional city (Castells, 1989). The economics literature has reached virtual consensus that the typical monocentric model does not adequately represent the complexity of today's urban areas (Odland, 1978). Empirical research has verified the shift towards polycentrism in Los Angeles (Gordon et al., 1986; Small & Song, 1994), although some authors found that Los Angeles can be better characterized as dispersed than polycentric (Song, 1994; Gordon & Richardson, 1996). Indeed, our finding that many areas have relatively uncentered employment makes us challenge the scholarly community to consider, both conceptually and operationally, at which point we might differentiate polycentrism from a dispersed or beyond polycentric pattern.

If polycentrism is indeed a new urban form, the places that are so organized should be expected to function, both internally and externally, in ways that differ from the classic central place model. We should use the empirical information we develop to modify the traditional model or build new urban theory that can suggest why and under what conditions this new form should be expected to occur, and how the evolution of centers affects property value gradients, influences both physical and virtual hinterlands, and changes the patterns of economic transactions and social life within and among urban areas.

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Table 1. Number of Centers Reported by Studies of Selected Metropolitan Areas Using 1990 Data		
Metro Area	**Number of Centers**	**Study**
Albany	2 subcenters	McMillen & Smith, 2003
Atlanta	4 downtowns, including CBD	Fujii & Hartshorn, 1995
	1 old CBD 4 edge cities 3 emerging edge cities	Garreau, 1991
	4 subcenters	McMillen & Smith, 2003
Baltimore	1 old CBD 3 edge cities 4 emerging edge cities	Garreau, 1991
	5 subcenters	McMillen & Smith, 2003
Buffalo	0 subcenters	McMillen & Smith, 2003
Charlotte	1 old CBD 1 edge city	Garreau, 1991
	1 subcenters	McMillen & Smith, 2003
Cincinnati	3 subcenters	McMillen & Smith, 2003
Columbus	1 subcenters	McMillen & Smith, 2003
	2 old CBDs 4 edge cities 3 emerging edge cities	Garreau, 1991
	12 subcenters	McMillen & Smith, 2003
Denver	1 old CBD 1 edge city 1 emerging edge city	Garreau, 1991
	5 subcenters	McMillen & Smith, 2003
Detroit	2 old CBDs 5 edge cities 3 emerging edge cities	Garreau, 1991
	8 subcenters	McMillen & Smith, 2003
El Paso	0 subcenters	McMillen & Smith, 2003
Fresno	0 subcenters	McMillen & Smith, 2003
Houston	1 old CBD 9 edge cities 2 emerging edge cities	Garreau, 1991
	8 subcenters	McMillen & Smith, 2003
	3 subcenter rings, 7 employment centers	Craig & Ng, 2001
	25 employment subcenters (within 50mi CBD)	McMillen, 2001
Indianapolis	11 employment centers	Anderson & Bogart, 2001
	1 subcenters	McMillen & Smith, 2003
Jacksonville	3 subcenters	McMillen & Smith, 2003
Las Vegas	1 old CBD 1 edge city	Garreau, 1991
	1 subcenters	McMillen & Smith, 2003
Los Angeles	2 old CBDs 16 edge cities 8 emerging edge cities	Garreau, 1991
	12 centers	Gordon & Richardson, 1996
	46 subcenters	McMillen & Smith, 2003
	120 employment concentrations (28 > 50K jobs, 72 > 10K jobs)	Forstall & Greene, 1997
	19 employment subcenters (within 50mi CBD)	McMillen, 2001
Miami	1 old CBD 1 edge city 1 emerging edge city	Garreau, 1991
	1 subcenters	McMillen & Smith, 2003
Milwaukee	1 old CBD 2 edge cities	Garreau, 1991
	3 subcenters	McMillen & Smith, 2003
Minneapolis-St. Paul	2 old CBDs 1 edge city 1 emerging edge city	Garreau, 1991
	7 subcenters	McMillen & Smith, 2003
New Orleans	2 employment subcenters (within 50mi CBD)	McMillen, 2001
Omaha	1 subcenters	McMillen & Smith, 2003

Table 1. Number of Centers Reported by Studies of Selected Metropolitan Areas Using 1990 Data		
Metro Area	**Number of Centers**	**Study**
Philadelphia	1 old CBD 3 edge cities	Garreau, 1991
	4 subcenters	McMillen & Smith, 2003
Phoenix	1 old CBD 3 edge cities 4 emerging edge cities 5 expected edge cities	Garreau, 1991
	5 subcenters	McMillen & Smith, 2003
Pittsburgh	1 old CBD 1 edge city 1 emerging edge city	Garreau, 1991
	1 subcenters	McMillen & Smith, 2003
Portland, OR	1 old CBD 1 edge city 1 emerging edge city	Garreau, 1991
	3 subcenters	McMillen & Smith, 2003
	11 employment centers	Anderson & Bogart, 2001
Providence	3 subcenters	McMillen & Smith, 2003
Rochester, NY	1 subcenters	McMillen & Smith, 2003
Salt Lake City	0 subcenters	McMillen & Smith, 2003
San Antonio	1 old CBD 2 edge cities 1 emerging edge city	Garreau, 1991
	5 subcenters	McMillen & Smith, 2003
San Diego	1 old CBD 3 edge cities 2 emerging edge cities	Garreau, 1991
	6 subcenters	McMillen & Smith, 2003
Seattle	2 old CBDs 1 edge city 3 emerging edge cities	Garreau, 1991
	13 subcenters	McMillen & Smith, 2003
St. Louis	10 employment centers	Anderson & Bogart, 2001
	1 old CBD 2 edge cities 1 emerging edge city	Garreau, 1991
	5 subcenters	McMillen & Smith, 2003
Washington, DC	1 old CBD 16 edge cities 7 emerging edge cities	Garreau, 1991
	10 subcenters	McMillen & Smith, 2003

Table 2. Sample Metro Areas, by Census Region					
METRO AREA	**1990 POPULATION**	**1990 EUA EMPLOYMENT**	**METRO AREA**	**1990 POPULATION**	**1990 EUA EMPLOYMENT**
West			***Northeast***		
Denver	1,622,980	796209	Albany	742,177	321495
Fresno	755,580	227083	Allentown	595,081	206321
Las Vegas	852,737	336863	Boston	3,227,707	1893664
Los Angeles	8,863,164	5081069	Buffalo	1,189,288	500252
Phoenix	2,238,480	947662	New Haven	861,424	261595
Portland	1,515,452	487391	Philadelphia	4,922,175	2021861
Salt Lake City	1,072,227	438201	Pittsburgh	2,394,811	716233
San Diego	2,498,016	1147348	Providence	1,134,350	356250
San Jose	1,497,577	820008	Rochester	530,180	389385
Seattle	2,033,156	903006	Syracuse	587,884	235542
Stockton	480,628	141546	Worcester	478,384	197357
Tacoma	586,203	172376	***Southern***		
North-Central			Atlanta	2,959,950	1348523
Cincinnati	1,526,092	630142	Baltimore	2,382,172	1019489
Columbus	1,345,450	581373	Baton Rouge	528,264	186767
Detroit	4,266,654	1738000	Charlotte	1,162,140	424838
Fort Wayne	456,281	157346	Dallas	2,676,248	1271931
Grand Rapids	937,891	291693	El Paso	591,610	207877
Indianapolis	1,380,491	555854	Houston	3,322,025	1616614
Milwaukee	1,432,149	659581	Jacksonville	906,727	384392
Minneapolis	2,538,834	1153189	Miami	1,937,094	935328
Omaha	639,580	295716	Mobile	476,923	150713
St. Louis	2,492,525	1018123	New Orleans	1,285,270	439382
Youngstown	600,895	181254	Raleigh/Durham	855,545	276232
			San Antonio	1,324,749	485804
			Tulsa	708,954	186406
			Washington	4,223,485	2020616
			Wilmington	513,293	244872

Table 3. Number of Centers, Employment and Employment Shares in Centers in 50 U.S. Metropolitan Areas, 1990

Extended Urban Area (EUA)	Number of Centers			Jobs														
					In All Centers		In Major Centers (Including Core)		In Core Center				In Other Major Centers		In Minor Centers		Outside of Centers	
										Percent of:								
	Total	Major (incl. Core)[1]	Minor	EUA Total	Number	Percent[2]	Number	Percent[3]	Number	All EUA Jobs[4]	All Major Center Jobs[5]	Jobs in All Centers	Number	Percent	Number	Percent	Number	Percent
Las Vegas	1	1	0	336863	194037	57.6	194037	57.6	194037	57.6	100.0	100.0	0	0.0	0	0.0	142826	42.4
El Paso	2	1	1	207877	86465	41.6	77897	37.5	77897	37.5	100.0	90.1	0	0.0	8568	4.1	121412	58.4
Syracuse	1	1	0	235542	79465	33.7	79465	33.7	79465	33.7	100.0	100.0	0	0.0	0	0.0	156077	66.3
Rochester	2	1	1	389385	137339	35.3	127196	32.7	127196	32.7	100.0	92.6	0	0.0	10143	2.6	252046	64.7
Tacoma	1	1	0	172376	54456	31.6	54456	31.6	54456	31.6	100.0	100.0	0	0.0	0	0.0	117920	68.4
Columbus	3	1	2	581373	195295	33.6	164382	28.3	164382	28.3	100.0	84.2	0	0.0	30913	5.3	386078	66.4
Worcester	1	1	0	197357	55130	27.9	55130	27.9	55130	27.9	100.0	100.0	0	0.0	0	0.0	142227	72.1
Portland	3	1	2	487391	158744	32.6	129386	26.6	129386	26.6	100.0	81.5	0	0.0	29358	6.0	328647	67.4
Buffalo	1	1	0	500252	123362	24.7	123362	24.7	123362	24.7	100.0	100.0	0	0.0	0	0.0	376890	75.3
Pittsburgh	2	1	1	716233	179753	25.1	170047	23.7	170047	23.7	100.0	94.6	0	0.0	9706	1.4	536480	74.9
Fort Wayne	2	1	1	157346	51769	32.9	36603	23.3	36603	23.3	100.0	70.7	0	0.0	15166	9.6	105577	67.1
Stockton	2	1	1	141546	42921	30.3	32281	22.8	32281	22.8	100.0	75.2	0	0.0	10640	7.5	98625	69.7
New Haven	2	1	0	261595	58788	22.5	58788	22.5	58788	22.5	100.0	100.0	0	0.0	0	0.0	202807	77.5
Indianapolis	2	1	1	555854	129918	23.4	121085	21.8	121085	21.8	100.0	93.2	0	0.0	8833	1.6	425936	76.6
Grand Rapids	2	1	1	291693	72724	24.9	61864	21.2	61864	21.2	100.0	85.1	0	0.0	10860	3.7	218969	75.1
Fresno	2	1	1	227083	48078	21.2	37295	16.4	37295	16.4	100.0	77.6	0	0.0	10783	4.8	179005	78.8
Tulsa	2	1	1	186406	39825	21.4	21816	11.7	21816	11.7	100.0	54.8	0	0.0	18009	9.7	146581	78.6
Baton Rouge	2	1	2	186767	47861	25.6	19471	10.4	19471	10.4	100.0	40.7	0	0.0	28390	15.2	138906	74.4
Mobile	3	1	2	150713	36688	24.3	12980	8.6	12980	8.6	100.0	35.4	0	0.0	23708	15.7	114025	75.7
Miami	8	2	6	935328	565112	60.4	493757	52.8	480495	51.4	97.3	85.0	13262	1.4	71355	7.6	370216	39.6
New Orleans	3	2	1	439382	193086	43.9	183689	41.8	154299	35.1	84.0	79.9	29390	6.7	9397	2.1	246296	56.1
Cincinnati	4	2	2	630142	228403	36.3	199147	31.6	184230	29.2	92.5	80.7	14917	2.4	29256	4.6	401739	63.8
Wilmington	2	2	0	244872	89631	36.6	89631	36.6	70270	28.7	78.4	78.4	19361	7.9	0	0.0	155241	63.4
Charlotte	3	2	1	424838	138174	32.5	128145	30.2	117070	27.6	91.4	84.7	11075	2.6	10029	2.4	286664	67.5
Salt Lake City	3	2	1	438201	134149	30.6	120573	27.5	111949	25.6	92.9	83.5	8624	2.0	13576	3.1	304052	69.4
Denver	5	2	3	796209	272043	34.2	233279	29.3	195109	24.5	83.6	71.7	38170	4.8	38764	4.9	524166	65.8
Jacksonville	3	2	1	384392	125291	32.6	104976	27.3	92410	24.0	88.0	73.8	12566	3.3	20315	5.3	259101	67.4
Providence	2	2	0	356250	98786	27.7	98786	27.7	80540	22.6	81.5	81.5	18246	5.1	0	0.0	257464	72.3
St. Louis	6	2	4	1018123	357802	35.1	285250	28.0	230003	22.6	80.6	64.3	55247	5.4	72552	7.1	660321	64.9
Philadelphia	12	2	10	2021861	611670	30.3	472965	23.4	454846	22.5	96.2	74.4	18119	0.9	138705	6.9	1410191	69.8
San Diego	7	2	5	1147348	445127	38.8	316275	27.6	256026	22.3	81.0	57.5	60249	5.3	128852	11.2	702221	61.2
Omaha	2	2	0	295716	108096	36.6	108096	36.6	65774	22.2	60.9	60.8	42322	14.3	0	0.0	187620	63.5
Raleigh	3	2	1	276232	116953	42.3	102433	37.1	59037	21.4	57.6	50.5	43396	15.7	14520	5.3	159279	57.7
San Antonio	3	2	1	485804	110137	22.7	96230	19.8	81560	16.8	84.8	74.1	14670	3.0	13907	2.9	375667	77.3

Table 3. Number of Centers, Employment and Employment Shares in Centers in 50 U.S. Metropolitan Areas, 1990																		
	Number of Centers			Jobs														
					In All Centers		In Major Centers (Including Core)		In Core Center				In Other Major Centers		In Minor Centers		Outside of Centers	
										Percent of:								
Youngstown	2	2	0	181254	33097	18.3	33097	18.3	16921	9.3	51.1	51.1	16176	8.9	0	0.0	148157	81.7
San Jose	4	3	1	820008	453235	55.3	433434	52.9	374943	45.7	86.5	82.7	58491	7.1	19801	2.4	366773	44.7
Albany	3	3	0	321495	127834	39.8	127834	39.8	88660	27.6	69.4	69.4	39174	12.2	0	0.0	193661	60.2
Houston	8	3	5	1616614	578596	35.8	479208	29.6	445107	27.5	92.9	76.9	34101	2.1	99388	6.2	1038018	64.2
Phoenix	7	3	4	947662	341532	36.0	281030	29.7	242581	25.6	86.3	71.0	38449	4.1	60502	6.4	606130	64.0
Milwaukee	5	3	2	659581	200843	30.5	178286	27.0	150483	22.8	84.4	74.9	27803	4.2	22557	3.4	458738	69.6
Minneapolis	4	3	1	1153189	319694	27.7	300235	26.0	202663	17.6	67.5	63.4	97572	8.5	19459	1.7	833495	72.3
Allentown	3	3	0	206321	59926	29.1	59926	29.1	33181	16.1	55.4	55.4	26745	13.0	0	0.0	146395	71.0
Seattle	6	4	2	903006	394750	43.7	363391	40.2	265063	29.4	72.9	67.1	98328	10.9	31359	3.5	508256	56.3
Baltimore	6	4	2	1019489	363133	35.6	320752	31.5	235726	23.1	73.5	64.9	85026	8.3	42381	4.2	656356	64.4
Atlanta	9	4	5	1348523	444938	33.0	317684	23.6	217903	16.2	68.6	49.0	99781	7.4	127254	9.4	903585	67.0
Boston	12	5	7	1893664	726245	38.4	634054	33.5	499774	26.4	78.8	68.8	134280	7.1	92191	4.9	1167419	61.7
Dallas	7	5	2	1271931	560933	44.1	531501	41.8	293801	23.1	55.3	52.4	237700	18.7	29432	2.3	710998	55.9
Detroit	12	7	5	1738000	481381	27.7	400755	23.1	139571	8.0	34.8	29.0	261184	15.0	80626	4.6	1256619	72.3
Washington	15	8	7	2020616	1130552	56.0	1045142	51.7	690315	34.2	66.1	61.1	354827	17.6	85410	4.2	890064	44.1
Los Angeles	33	12	21	5081069	2250626	44.3	1956091	38.5	765953	15.1	39.2	34.0	1190138	23.4	294535	5.8	2830443	55.7

1 Frequency
2 All Centers Dominance
3 Concentration
4 Core Center Dominance
5 Relative Core Center Dominance

Table 4. Comparison of Centers Identified in Studies of Metropolitan Areas, 1990											
	Sarzynski et al.			Earlier Studies of Polycentrism							
Metro Area	Total Centers	Other Major Centers	Minor centers	Forstall & Greene, 1997	McMillen, 2001	Fujii & Hartshorn, 1995	Craig & Ng, 2001	Anderson & Bogart, 2001	McMillen & Smith, 2003	Garreau, 1991	Gordon & Richardson, 1996
Los Angeles	33	11	21	120	19				47		12
Washington	15	7	7						11	24	
Boston	12	4	7						12	11	
Philadelphia	12	1	10						5	4	
Detroit	12	6	5						9	10	
Atlanta	9	3	5			4			5	8	
Houston	8	2	5		25		11		9	12	
Miami	7	1	5						2	3	
Phoenix	7	2	4						6	13	
Dallas	7	4	2		28				13	9	
San Diego	7	1	5						7	6	
Seattle	6	3	2						14	6	
Baltimore	6	3	2						6	8	
St. Louis	6	1	4					10	6	4	
Denver	5	1	3						6	3	
Milwaukee	5	2	2						4	3	
San Jose	4	2	1								
Cincinnati	4	1	2						4		
Minneapolis	4	2	1						8	4	
New Orleans	3	1	1		2						
Columbus	3	0	2						2		
Albany	3	2	0						3		
Charlotte	3	1	1						2	2	
Portland	3	0	2					11	4	3	
Salt Lake City	3	1	1						1		
Jacksonville	3	1	1						4		
Raleigh	3	1	1								
San Antonio	3	1	1						6	4	
Allentown	3	2	0								
Baton Rouge	3	0	2								
Mobile	3	0	2								
El Paso	2	0	1						1		
Rochester	2	0	1						2		
Wilmington	2	1	0								
Pittsburgh	2	0	1						2	3	
Fort Wayne	2	0	1								
Stockton	2	0	1								
Providence	2	1	0						4		
Omaha	2	1	0						2		
Indianapolis	2	0	1					11	2		
Grand Rapids	2	0	1								
Fresno	2	0	1						1		
Tulsa	2	0	1								
Youngstown	2	0	1								
Las Vegas	1	0	0						1	2	
Syracuse	1	0	0								
Tacoma	1	0	0								
Worcester	1	0	0								
Buffalo	1	0	0						1		
New Haven	1	0	0								

Table 5. Fifty U.S. Metropolitan Areas Classified by Two Simple Polycentrism Indices							
MSA Name	**% EUA Jobs in Core**	**% EUA Jobs in Major**	**% EUA Jobs in Minor**	**% EUA Jobs in All Centers**	**% EUA Jobs Outside Centers**	**Index 1: *Core Centered-ness***	**Index 2: *Overall Centered-ness***
Las Vegas	57.60	0.00	0.00	57.60	42.40	15.20	15.20
Miami	51.37	1.42	7.63	60.42	39.58	11.79	20.84
San Jose	45.72	7.13	2.41	55.27	44.73	1.00	10.54
Washington	34.16	17.56	4.23	55.95	44.05	-9.89	11.90
El Paso	37.47	0.00	4.12	41.59	58.41	-20.93	-16.81
New Orleans	35.12	6.69	2.14	43.94	56.06	-20.94	-12.11
Seattle	29.35	10.89	3.47	43.72	56.28	-26.93	-12.57
Rochester	32.67	0.00	2.60	35.27	64.73	-32.06	-29.46
Syracuse	33.74	0.00	0.00	33.74	66.26	-32.53	-32.53
Albany	27.58	12.18	0.00	39.76	60.24	-32.66	-20.48
Dallas	23.10	18.69	2.31	44.10	55.90	-32.80	-11.80
Cincinnati	29.24	2.37	4.64	36.25	63.75	-34.52	-27.51
Wilmington	28.70	7.91	0.00	36.60	63.40	-34.70	-26.79
Boston	26.39	7.09	4.87	38.35	61.65	-35.26	-23.30
Raleigh	21.37	15.71	5.26	42.34	57.66	-36.29	-15.32
Houston	27.53	2.11	6.15	35.79	64.21	-36.68	-28.42
Tacoma	31.59	0.00	0.00	31.59	68.41	-36.82	-36.82
Columbus	28.27	0.00	5.32	33.59	66.41	-38.13	-32.82
Phoenix	25.60	4.06	6.38	36.04	63.96	-38.36	-27.92
San Diego	22.31	5.25	11.23	38.80	61.20	-38.89	-22.41
Charlotte	27.56	2.61	2.36	32.52	67.48	-39.92	-34.95
Los Angeles	15.07	23.42	5.80	44.29	55.71	-40.63	-11.41
Portland	26.55	0.00	6.02	32.57	67.43	-40.88	-34.86
Omaha	22.24	14.31	0.00	36.55	63.45	-41.20	-26.89
Baltimore	23.12	8.34	4.16	35.62	64.38	-41.26	-28.76
Denver	24.50	4.79	4.87	34.17	65.83	-41.33	-31.67
St. Louis	22.59	5.43	7.13	35.14	64.86	-42.27	-29.71
Jacksonville	24.04	3.27	5.28	32.59	67.41	-43.36	-34.81
Fort Wayne	23.26	0.00	9.64	32.90	67.10	-43.84	-34.20
Salt Lake City	25.55	1.97	3.10	30.61	69.39	-43.84	-38.77
Worcester	27.93	0.00	0.00	27.93	72.07	-44.13	-44.13
Milwaukee	22.81	4.22	3.42	30.45	69.55	-46.73	-39.10
Stockton	22.81	0.00	7.52	30.32	69.68	-46.87	-39.35
Philadelphia	22.50	0.90	6.86	30.25	69.75	-47.25	-39.49
Providence	22.61	5.12	0.00	27.73	72.27	-49.66	-44.54
Buffalo	24.66	0.00	0.00	24.66	75.34	-50.68	-50.68
Atlanta	16.16	7.40	9.44	32.99	67.01	-50.85	-34.01
Pittsburgh	23.74	0.00	1.36	25.10	74.90	-51.16	-49.81
Grand Rapids	21.21	0.00	3.72	24.93	75.07	-53.86	-50.14
Minneapolis	17.57	8.46	1.69	27.72	72.28	-54.70	-44.55
Indianapolis	21.78	0.00	1.59	23.37	76.63	-54.84	-53.25
Allentown	16.08	12.96	0.00	29.05	70.95	-54.87	-41.91
New Haven	22.47	0.00	0.00	22.47	77.53	-55.05	-55.05
San Antonio	16.79	3.02	2.86	22.67	77.33	-60.54	-54.66
Fresno	16.42	0.00	4.75	21.17	78.83	-62.40	-57.66
Baton Rouge	10.43	0.00	15.20	25.63	74.37	-63.95	-48.75
Detroit	8.03	15.03	4.64	27.70	72.30	-64.27	-44.61
Tulsa	11.70	0.00	9.66	21.36	78.64	-66.93	-57.27
Mobile	8.61	0.00	15.73	24.34	75.66	-67.04	-51.31
Youngstown	9.34	8.92	0.00	18.26	81.74	-72.40	-63.48

Table 6. Fifty U.S. Metropolitan Areas by Type of Polycentrism, 1990							
Extended Urban Area (EUA)	**Census Region**	**Number of Centers *(Frequency)***		**% EUA Jobs in Centers *(All Centers Dominance)***	**% EUA Jobs in Major Centers *(Concen-tration)***	**%EUA Jobs in Core *(Core Center Dominance)***	**% Center Jobs in Core Center *(Relative Core Dominance)***
		Major*	**Minor**				
Dispersed							
Baton Rouge	S	1	2	25.6	10.4	10.4	40.7
Mobile	S	1	2	24.3	8.6	8.6	35.4
Tulsa	S	1	1	21.4	11.7	11.7	54.8
Strong Polycentric							
Dallas	S	5	2	44.1	41.8	23.1	52.4
Detroit	NC	7	5	27.7	23.1	8.0	29
Los Angeles	W	12	21	44.3	38.5	15.1	34
Washington	S	8	7	56	51.7	34.2	61.1
Polycentric							
Albany	NE	3	0	39.8	39.8	27.6	69.4
Baltimore	S	4	2	35.6	31.5	23.1	64.9
Boston	NE	5	7	38.4	33.5	26.4	68.8
New Orleans	S	2	1	43.9	41.8	35.1	79.9
Seattle	W	4	2	43.7	40.2	29.4	67.1
Wilmington	NE	2	0	36.6	35.6	28.7	78.4
Weak Polycentric							
Allentown	NE	3	0	29.1	29.1	16.1	55.4
Atlanta	S	4	5	33	23.6	16.2	49
Minneapolis	NC	3	1	27.7	26	17.6	63.4
Omaha	NC	2	0	36.6	36.6	22.2	60.8
Raleigh	S	2	1	42.3	37.1	21.4	50.5
Youngstown	NC	2	0	18.3	18.3	9.3	51.1
Weak Monocentric							
Charlotte	S	2	1	32.5	30.2	27. 6	84.7
Cincinnati	NC	2	2	36.3	31.6	29.2	80.7
Columbus	NC	1	2	33.6	28.3	28.3	84.2
Denver	W	2	3	34.2	29.3	24.5	71.7
Fort Wayne	NC	1	1	32.9	23.3	23.3	70.7
Fresno	W	1	1	21.2	16.4	16.4	77.6
Grand Rapids	NC	1	1	24.9	21.2	21.2	85.1
Houston	S	3	5	35.8	29.6	27.5	76.9
Jacksonville	S	2	1	32.6	27.3	24.0	73.8
Milwaukee	NC	3	2	30.5	27	22.8	74.9
Philadelphia	NE	2	10	30.3	23.4	22.5	74.4
Phoenix	W	3	4	36	29.7	25.6	71
Portland	W	1	2	32.6	26.6	26.6	81.5
Providence	NE	2	0	27.7	27.7	22.6	81.5
Salt Lake City	W	2	1	30.6	27.5	25.6	83.5
San Antonio	S	2	1	22.7	19.8	16.8	74.1
San Diego	W	2	5	38.8	27.6	22.3	57.5
St. Louis	NC	2	4	35.1	28	22.6	64.3
Stockton	W	1	1	30.3	22.8	22.8	75.2
Monocentric							
Buffalo	NE	1	0	24.7	24.7	24.7	100
El Paso	S	1	1	41.6	37.5	37.5	90.1
Indianapolis	NC	1	1	23.4	21.8	21.8	93.2
New Haven	NE	1	0	22.5	22.5	22.5	100
Pittsburgh	NE	1	1	25.1	23.7	23.7	94.6
Rochester	NE	1	1	35.3	32.7	32. 7	92.6
Syracuse	NE	1	0	33.7	33.7	33.7	100
Tacoma	W	1	0	31.6	31.6	31.6	100
Worcester	NE	1	0	27.9	27.9	27.9	100

Table 6. Fifty U.S. Metropolitan Areas by Type of Polycentrism, 1990							
		Number of Centers *(Frequency)*					
Strong Monocentric							
Las Vegas	S	1	0	57.6	57.6	57.6	100
Miami	W	2	6	60.4	52.8	51.4	85
San Jose	W	3	1	55.3	52.9	45.7	82.7

Notes: * Includes core center.

Table 7. Statistical Tests of Cluster Mean Variance for External Variables		
	F	**Prob**
Geographic Scale (land area), 1990	4.33	0.0017
Metropolitan Age (decades since 50,000 population, as of 1990)	4.18	0.0022
Population, 1990	5.54	0.0003
Employment, 1990	6.38	0.0001
Population Growth Rate, 1980-1990	2.09	0.0742
Median Household Income, 1990	2.59	0.0313
General Purpose Governments, 1992	0.96	0.4657
Location Quotient: Extractive, 1990	1.18	0.3372
Location Quotient: Construction, 1990	1.93	0.0983
Location Quotient: Manufacturing, 1990	0.53	0.7800
Location Quotient: Transportation, 1990	0.59	0.7362
Location Quotient: Trade, 1990	1.24	0.3029
Location Quotient: FIRE, 1990	2.17	0.0646
Location Quotient: Services, 1990	4.44	0.0014
Location Quotient: Government, 1990	0.69	0.6550
	Chi2	**Prob**
Census Region	31.7902	0.0230

Notes: F = one-way ANOVA F test; Chi2 = Pearson chi-squared test; prob = statistical probability that F or chi2 value is not due to chance. All variables computed for the metropolitan statistical area (MSA). Sources: Land area, population, employment, and median household income from the 1990 Decennial Census; population growth rate computed from the 1980 and 1990 Decennial Censuses; metropolitan age computed from historic census data; general purpose governments from the 1992 Census of Governments; and location quotients computed from the Bureau of Economic Analysis, 1990 employment by industry data (1 digit SIC codes).

Figure 1. Employment Centers in the Baltimore-Washington EUA, 1990

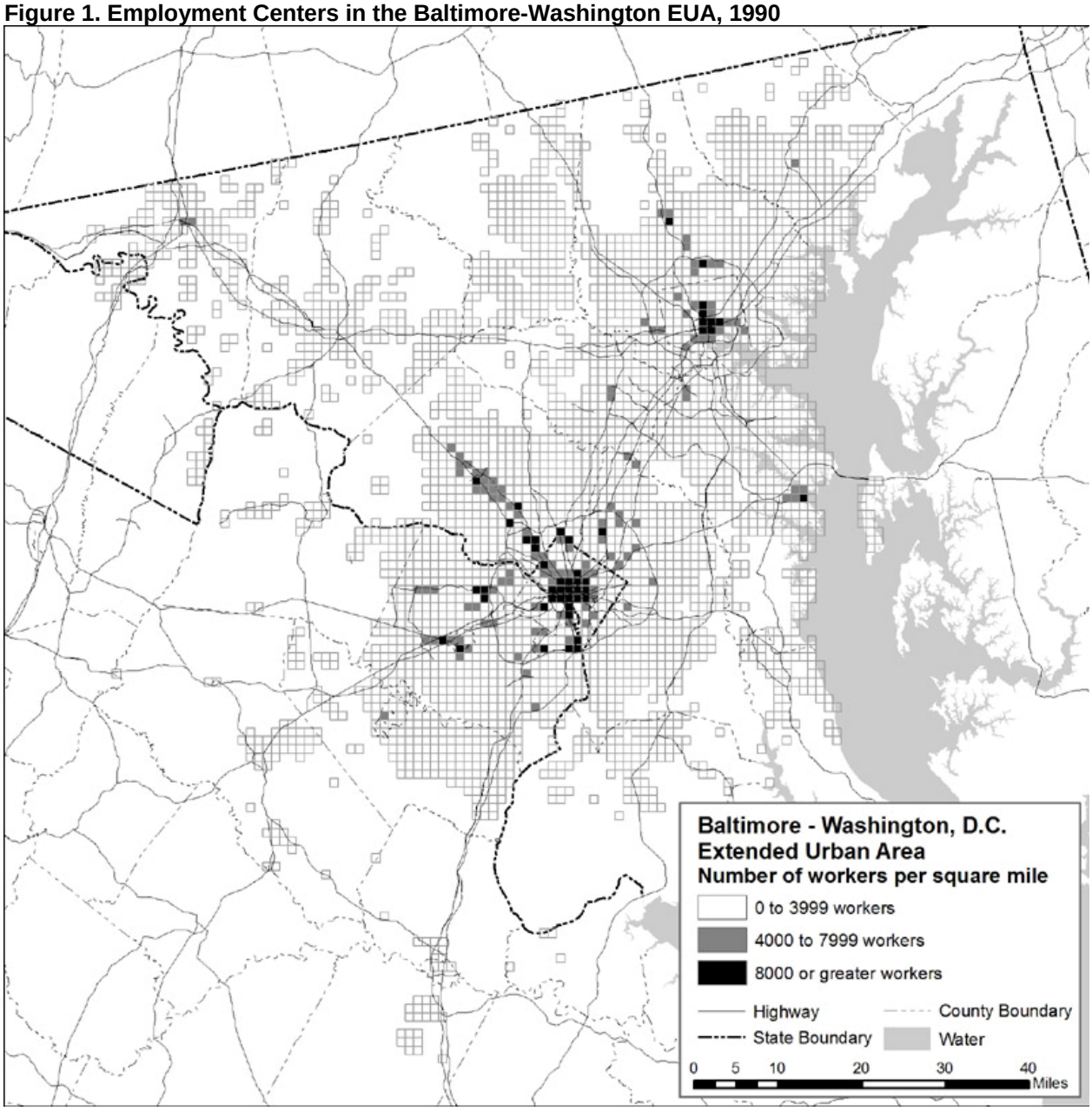

Figure 2. Employment Centers in the Salt Lake City EUA, 1990

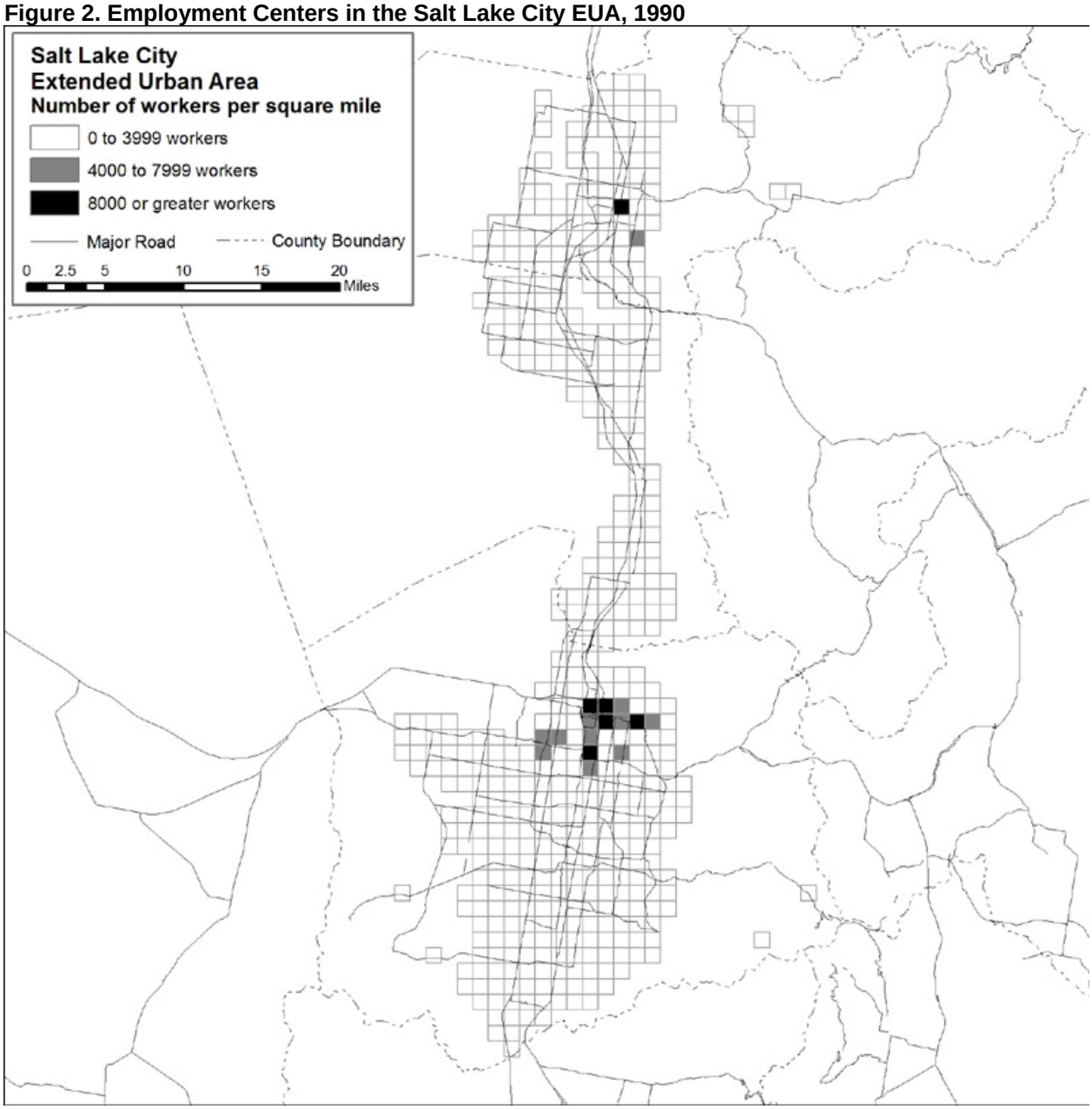

Figure 3. Cluster Analysis Dendrogram