URBAN SPATIAL STRUCTURE AND ECONOMIC GROWTH IN US METROPOLITAN AREAS

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ABSTRACT

This paper presents an empirical study of the links between metropolitan spatial structure and economic growth. Consistent with an urban evolution hypothesis, the growth effects of employment dispersion were found to be dependent on metropolitan size. A metropolitan area with a more clustered spatial form grows faster, perhaps enjoying agglomeration economies when it is small; whereas more dispersion leads to higher growth rates as metro areas grow large. Just as a city needs to successfully take on higher-order functions and economic activities to move upward within the national urban system, it also needs to restructure its spatial form in a way to mitigate congestion or other diseconomies of size for continued growth. Therefore, attempts to find one specific efficient urban form – at least with respect to growth – may not be promising, just as the efforts to find an optimal city size have not been fruitful.

1. INTRODUCTION

Does urban spatial structure influence economic performance or growth in metropolitan areas? Is one particular type of urban form more efficient than another? Or is the efficient spatial structure contingent on the size and other attributes pertaining to each metropolitan area? We address these questions by investigating the links between urban spatial structure and economic growth in a cross section of 79 US metropolitan areas. In particular, we probe into the question how these links relate to metropolitan size.

Considerable evidence has accumulated on the existence and extent of agglomeration economies (for surveys of the literature, see Moomaw 1983; Gerking 1994). In general, firms in large cities tend to have higher productivity because they can either lower production costs or facilitate competitive innovation due to agglomeration economies arising from a variety of sources.[1] Not only firms but also people tend to have more chances to learn and acquire skills in urban agglomerations that ensure them higher returns (Glaeser 1999). Moreover, consumers in larger cities enjoy a variety of specialized goods and services, and cultural and entertainment opportunities (Clark, Kahn, and Ofek 1988). High-end restaurants and Broadway shows in Manhattan and professional sports teams in big cities are examples. However, urban growth is not without costs. Firms and households in large cities also suffer from negative externalities such as congestion, pollution, and higher crime rates.

The trade-off between these agglomeration economies and diseconomies has provided a rationale for the attempts to define an optimal city size (Carlino 1987). Optimal city size, in

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[1] Various types and sources of agglomeration economies are discussed in the literature. These include internal scale economies, localization economies – arising from labor market pooling, technological spillovers, intra-industry specialization and scale economies of industry specific infrastructure – and urbanization economies – arising from specialized business services, public infrastructure and 'law of large numbers' (Mills 1994; Richardson 1995; Eberts and McMillen 1999). More recent literature emphasizes the role of innovative process localized within urban clusters (Malmberg 1996; Porter 2000). Whereas manufacturing sectors tend to benefit more from specialization and localization economies (Henderson 1986; Moomaw 1988; Henderson, Kuncoro, and Turner 1995), urban diversity and localized competition

general, derived as the maximal point of agglomeration economies net of associated diseconomies are supposed to be an inverted U-shaped function of city size (Begovic 1991). Some early studies attempted to find the minimal point of U-shaped cost curves of urban public services (Clark 1945; Hirsch 1959).

However, the notion of optimal city size was criticized on the grounds that there coexist cities of various sizes in a national urban hierarchy, through which specialized goods and services are delivered, and innovation and other economic functions are channeled across cities (Richardson 1972). And relative size distributions of cities have been remarkably stable over time in most countries (Eaton and Eckstein 1997; Black and Henderson 1999, 2003; Nitsch 2003). Many have been shown to obey Zipf's law or the rank-size rule (Gabaix 1999). Although economic reasons for the empirical regularity are still murky, it implies parallel urban growth patterns in relation to city size rather than convergence to a particular optimal city size (Barnard and Krautmann 1988; Eaton and Eckstein 1997; Glaeser, Scheinkman, and Shleifer 1995)[2].

Within the hierarchical urban system, cities at different ranks (different size) take on different economic functions with variant 'efficient sizes' (Richardson 1972; Capello and Camagni 2000). Hence, the prospective growth of a city depends on "its ability to move to ever higher urban ranks, developing or attracting new and superior functions (Camagni, Diappi, and Leonardi 1986)". Prud'homme and Lee (1999) made a similar point by suggesting that good city management – transportation and land use policy – can shift marginal benefits of city size upward and costs downward, increasing the efficient city size. Empirically, upward mobility within the US urban hierarchy for the last century was found to be promoted by favorable geographical

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are found to be contributing to more innovation and growth in more knowledge intensive sectors (Glaeser et al. 1992; Harrison, Kelley, and Gant 1996; Feldman and Audretsch 1999; Combes 2000).

[2] Wheeler (2003) found an 'inverted U-shaped' growth pattern in a cross-section of US counties, but not in metropolitan level data in the 1980s. We interpret the county level results as the growth with fixed geographical boundary.

amenities – climate and coastal location – and higher market potential (Black and Henderson 1999, 2003).

The links between urban form and growth can be understood in this context of urban evolution. To the extent that a city can adjust its spatial structure in such a way as to mitigate the negative externalities of city size, it can afford continued growth or achieve better odds of upward mobility in the urban hierarchy. The transition from monocentric to polycentric structure has been thought of as one way of abating diseconomies in urban economics (Sasaki and Mun 1996; Fujita, Thisse, and Zenou 1997). In particular, Fujita and Ogawa's (1982) urban model predicted that the equilibrium number of subcenters increases as population and commuting costs increase and this prediction was empirically supported by McMillen and Smith (2003). Two recently developed urban models show that even greater employment dispersion is possible under the condition of high congestion with little clustering economies (Anas and Kim 1996; Wheaton 2004).

Nevertheless, empirical research directly examining the relationships between urban form and growth (or economic efficiency) is rare with the exception of a study by Cervero (2001). He argued that more compact, centralized and accessible cities have higher productivity and presented empirical support at both inter- and intra metropolitan levels. However, both levels of the analyses using labor productivity were flawed.[3]

Many of the problems in his study were largely due to the limited available economic output data at metropolitan and sub-metropolitan levels. This is one reason why we examine the variation in growth rates instead of productivity across metropolitan areas with different spatial

[3] First, a labor productivity analysis without controlling capital input as done in the study is likely to be misleading. Second, productivity comparisons should be done within a single industrial sector and more disaggregated data would give better estimates (Rigby and Essletzbichler 2002). Otherwise, industry mix should be controlled in a better way. Finally, given his assumption on the same labor productivity of each SIC sector within California, his results – higher labor productivity in sub-metro areas with larger labor market shed and higher accessibility between residence and firms – actually mean that industrial sectors with higher productivity tend to locate those areas.

forms and sizes. Moreover, a productivity study involves only the production sphere although consumer externalities are also important factors in the analysis of urban growth and structure (Glaeser, Kolko, and Saiz 2001; Gabriel and Rosenthal 2004). Thus, we believe the study of urban growth can be the basis of a better market test.

We do not seek to find one particular efficient urban form. Rather, we hypothesize that efficient urban forms would vary across different stages or sizes of urban development. To test this research question, we have to define and quantify urban spatial structure first. The next section briefly describes how we measure urban spatial structure in multiple dimensions. In Section 3, an empirical model of metropolitan growth is specified. Section 4 presents the estimation results, followed by discussion and conclusions.

2. QUANTIFYING METROPOLITAN SPATIAL STRUCTURE

At the conceptual level, urban spatial structure can be defined as "an abstract or generalized description of the distribution of phenomena in [urban] geographic space (Horton and Reynolds 1971)." In this study, we define urban spatial structure as the distributions of population and employment in urban space, with an emphasis on the latter, following the tradition in the urban economics and land use literature.

Dimensions of urban spatial structure are highly dependent on geographical scales. A survey of the literature identifies eight dimensions of urban form that are closely tied to geographical levels (Schwanen 2003). For instance, the extent of land use mix, design, and accessibility are of research interest at the neighborhood or community level while urban size, density, and 'mono/polycentricity' are major spatial variables measured at a city or metropolitan level.

We focus on two dimensions of metro level spatial structure, centralization and concentration. As Anas, Arnott, and Small (1998) suggest, spatial structure in a metropolitan area can be *centralized* versus *decentralized* and it can also be *clustered* versus *dispersed*. Centralization is the extent to which employment is concentrated with reference to the CBD, whereas concentration measures how disproportionately jobs are clustered in a few locations (Galster et al. 2001). The two spatial dimensions may be associated, but are distinctive as empirically revealed by a factor analysis in Cutsinger et al. (2005). Polycentric urban structure is a combined outcome of metro-wide decentralization and local level (Anas, Arnott, and Small 1998). If deconcentration concurs with decentralization, the metropolitan area would evolve in a more generally dispersed form without significant subcentering.

At the operational level, we measure each spatial dimension based on relative shares of metropolitan employment by location types: the metro level central business district (CBD), subcenters, and dispersed location. Thus, identifying urban employment centers is a crucial step in constructing the spatial measures. Primary qualities of urban centers are significantly higher employment density than the surrounding areas (Mcdonald, 1987) and their influences on density profiles of nearby locations (Gordon, Richardson, and Wong 1986; Giuliano and Small 1991; McMillen 2001). While urban researchers have often used two types of procedures, a minimum density procedure (Giuliano and Small 1991) and a nonparametric method (McMillen 2001), the latter works better in identifying suburban density peaks (Lee 2007).

We used a modified version of McMillen's geographically weighted regression (GWR) procedure to identify CBDs and subcenters in 79 largest U.S. metropolitan areas with population of a half million and more. Whereas he identified traffic analysis zones (TAZs) that have actual employment density higher than the estimated (smoothed) surface by GWR with a large window (50 percent), we evaluated the differentials between two estimated employment density surfaces – one with a small window size (10 neighboring census tracts) and the other with a large window size (100 census tracts) (for detailed descriptions of the procedure, see Lee 2007). Among the identified density peaks, we qualified only those with more than 10,000 jobs as employment centers.

In the employment center identification procedure, we used census tract level employment data from 2000 Census Transportation Planning Package (CTPP). While the data series of employment by place of work and commuting drawn from the Census journey to work surveys are available since 1980, only 2000 package begins to provide the data by census tracts for all US metropolitan areas. Although TAZ can be considered as a better geographical unit for employment data analysis, each metro's TAZ systems are constructed by individual metropolitan planning organizations (MPOs), lacking consistency across metropolitan areas. Thus, average TAZ size greatly varies among different metropolitan areas and this variation significantly affects the number of identified employment centers as in McMillen (2001). This is why we didn't include the spatial structure analysis for 1990, in which TAZ was used for most metropolitan areas.

Table 1 presents employment shares in identified CBDs and subcenters, and dispersed locations for all of the metros studied. One of the most important features of the modern metropolis described in the Table is that workplace locations are predominantly dispersed. Lang made a case for *edgeless cities* – "a form of sprawling office development that does not have the density or cohesiveness of *edge cities*" – by emphasizing that they account for twice the office space of *edge cities* in thirteen largest metropolitan areas (Lang 2003). The current research presents far stronger evidence of employment dispersion. Average *dispersed* employment share among 79 metropolitan areas is 82 percent.

The metropolis with the largest dispersed employment share in the largest metro group is Philadelphia, followed by Boston. While these metros have bigger CBDs than the average of the group, employment outside the CBD is the least clustered in subcenters. This finding might be counter to popular perceptions, but coincides with that of the Lang's office space study. Los

Angeles and San Francisco (and Detroit to a lesser extent) have a contrasting spatial form. These two western polycentric metropolises have relatively smaller CBDs, but largest subcenter shares.

Contemporary US metropolitan areas are also remarkably decentralized. The CBD's average employment share is no more than 11 percent. The notion of job decentralization is not new, but the magnitude of it reported here is. Las Vegas is the most centralized metropolis, with 28 percent of total employment in the CBD. Los Angeles has the smallest CBD; it accounts for only 2.8 percent of metro employment. In the largest metro group, New York has the largest CBD employment share (9.9 percent) followed by Philadelphia and Seattle.

Finally, Figure 1 presents a way to overview the patterns in employment distribution among metropolitan areas. The X-axis is the job share in all employment centers, indicating the degree of concentration, while the Y-axis is the share in the CBD, representing the extent of centralization. The bubble size of each metropolitan area is proportionate to its population size. Thus, the upper right corner of the chart indicates highly centralized and concentrated spatial structure, which resembles a nineteenth-century monocentric structure. Las Vegas, NV, with a unique location and industrial structure, possesses by far the most centralized spatial structure.

While employment location is decentralized in most metropolitan areas, they also reveal a wide range in the extent of subcentering. Subcentering is the most pronounced in Los Angeles, San Francisco and San Diego in the West and Detroit in the Midwest. Other Midwestern metros such as Chicago and Cleveland, and Boston and Philadelphia in the Northeast are decentralized in relatively more dispersed forms.

3. MODEL SPECIFICATION

There are two types of empirical models of urban growth in the literature, a supply side urban economic growth model developed by Glaeser and his collegues (Glaeser 2000; Glaeser, Scheinkman, and Shleifer 1995; Glaeser and Shapiro 2003) and population and employment adjustment models (Steinnes and Fisher 1974; Carlino and Mills 1987; Clark and Murphy 1996; Mulligan, Vias, and Glavac 1999). A key difference is that the former assumes a spatial equilibrium while population and employment partially adjust to the spatial equilibrium in each period in the latter models. Whereas both models can serve to identify the growth effects of spatial structure controlling other variables, it is easier to interact spatial structure variables with metropolitan size in the former type model.

Thus, we adopt the empirical framework of Glaeser (2003), in which certain attributes of cities contribute to economic growth in three ways: 1) becoming more important in the production process; 2) attracting more consumers either by reducing the cost of living or enhancing amenity levels; or 3) increasing technological growth rate. His empirical analysis found that higher levels of human capital, warmer and drier climate and automobile oriented transportation system are three key factors explaining the variation in growth rates among US cities in the 1990s.

We add spatial structure variables, as measured in the previous section, to the growth model and also include interaction terms between the spatial measures and population (employment) size. Both spatial structure and metropolitan size variables are centered by subtracting mean values for ease of interpretation. Coefficients of centered size and spatial measure variables are the main effects of corresponding variables when the other variable is at the average level. Thus, β_2 in equation (1) is the spatial structure impact on metropolitan growth at the sample average of log population/employment size – 1.25 millions and 0.6 million, respectively. But, the spatial structure effect depends on metropolitan size and the sign of β_3 determines whether the spatial effect increases or decreases with metropolitan size as in equation (2).

$$Log\left(\frac{N_t}{N_{t-1}}\right) = \alpha X_{t-1} + \beta_1 \log(N_{t-1}) + \beta_2 F + \beta_3 \log(N_{t-1})F \qquad (1)$$

$$= \alpha X_{t-1} + \beta_1 \log(N_{t-1}) + [\beta_2 + \beta_3 \log(N_{t-1})]F \quad (2)$$

where N_t and N_{t-1} denote population (employment) size in 2000 and 1990, respectively; X a vector of metropolitan attributes listed in Table 2 including constant; F a spatial structure variable.

Two spatial structure variables, each indicating urban dispersion and polycentricity, are used in the model estimations.[4] The coefficient of dispersion, measured as the share of metropolitan employment dispersed outside centers, is expected to show whether clustered or dispersed urban form is more amenable to urban growth. After controlling the extent of employment dispersion, the polycentricity term will test whether monocentric or polycentric structure is associated with faster growth. The two spatial indicators are measured as of 2000 due to data limitations, assuming that there has been not much change in urban spatial structure during the ten year period. The exogeneity of the spatial variables can also be justified by the assumption that spatial restructuring is a long-term process.

All other explanatory variables are measured as of 1990. These include log population density, industrial mix, local amenities, and human capital and other demographic variables (Table 2). While density is suggested to have productivity effects by lowering transportation costs, positive externalities and specialization (Ciccone and Hall 1996), it trades off against higher congestion costs (Carlino and Chatterjee 2002). Human capital accumulation is increasingly emphasized in the urban economic growth literature (Simon and Nardinelli 2002; Glaeser and Shapiro 2003; Shapiro 2006).

Our main data sources are the decennial Population Census, the Regional Economic Information System (REIS 1969-2000) published by the Bureau of Economic Analysis, and the 1994 County and City Data Book. All of the descriptive statistics are shown in Table 3.

[4] Is spatial structure endogenous? We have argued that it is, but it is also true that it changes slowly. In our case, the spatial structure variables used were not available for 1990 nor for previous years for a large enough number of metro areas to be included in our tests.

4. ESTIMATION RESULTS

Table 4 shows ordinary least squares (OLS) regression results without the spatial structure variables. All significant variables had the expected signs. Metros with more industrial base in manufacturing experienced slower growth. Metros with larger nonwhite and aged segments of population also grew slowly. Lower density metros grew faster. Mean January temperature was highly significant, confirming the economic shift from the frostbelt to sunbelt regions; whereas other amenities were not significant. It should be noted that the dependent variable is not metro size but the change in size. The (dis)amenities of these insignificant variables might have already been reflected in the population/employment distributions in the beginning period, to the extent that the distributions approximate the equilibrium status.

Some other variables were significant in either population or employment growth model, but not in the other. Metros with larger proportions of foreign born population attracted more people but not more jobs. This perhaps presents the role of gateway metros. To the contrary, the coefficient of percent college graduates was significantly positive only in employment growth models. Metropolitan size was not significant in both sets of models, implying parallel growth patterns. It is interesting to see that regional effects after controlling all these variables are somewhat different from the regional growth patterns that we observe. The most consistently fast growing region was the Mountain Division.

Full specifications of Models 3 and 6 explained about 70 and 80 percent of cross-sectional variation in metropolitan population and employment growth, respectively.

In Tables 5 and 6, we show a series of regression results that examine the effects of spatial structure variables generated by the GWR procedure after dropping some insignificant control variables from Table 4.

Model 6 in each table is our final model which we refer to in the following discussion. Both population and employment models show moderate increases in explanatory power compared with estimations without the spatial structure variables in Table 4. The inclusion of spatial structure variables did not change the sign and significance of most control variables except that log population size became significant with positive sign and percentage manufacturing's share turned out insignificant in population models.

Turning to the key variables of main interest, the main coefficient of neither dispersion (dispersed employment share) nor polycentricity (subcenters' share of all center employment) was significant (Model 6 in each table). However, the interaction term of employment dispersion was significant with expected positive sign while the interaction term of polycentricity was not significant.

These findings are useful. First, whether employment location is more clustered or dispersed matters more with respect to metropolitan growth than whether the clustering occurs in the CBD or in subcenters. Second, consistent with the hypothesis put forward in the introduction, the growth effects of spatial form (dispersion) do depend on metropolitan size. A metropolitan area with more clustered spatial form grows faster when it is small; whereas more dispersion leads to a higher growth rate as it grows large.

In Table 7, to help fathom the second finding, we present varying growth effects of spatial form evaluated at different metropolitan sizes using estimated coefficients in Tables 5 and 6. As explained above, the coefficient of dispersion variable (-0.0009 in population Model 6 and -0.0005 in employment Model 6), although not significantly different from zero, is its growth impact when log metropolitan size is about sample mean (1.25 million population and 0.6 million employment).

When population is about half the average size, the coefficient changes to -0.0069 (-0.0009 - 0.0060), meaning that the dispersion of additional one percent of metro employment leads to approximately 0.7 percent slower growth rate for the ten year period. A one standard deviation increase of dispersed employment share (about 6 percentage points) implies about 4.2 percent slower growth rate. To the contrary, increased employment dispersion by the same extent lead to about 3 percent and 6.6 percent higher growth rate, respectively when population size is about 3.4 million and 9.3 million. Given that average population growth rate (log point growth) was about 14 percent in the 1990s, these growth effects of employment dispersion are substantial. A similar pattern is also found in employment growth, but in a little smaller magnitude.

We also calibrated the growth effects of polycentricity at different employment sizes although none of the coefficients were significant. Overall, the metropolitan growth effects were very small. Monocentric structure (after controlling dispersion) was more amenable to population growth to a considerable extent only in small metropolitan areas with about a half-million residents.

5. CONCLUSIONS

For perspective, we cite Bogart's (2006) succinct summary:[5]

> A fundamental misunderstanding of how metropolitan areas work has hampered the current debate on the causes and consequences of urban sprawl. This misunderstanding is analogous to the pre-Copernican fallacy that the earth is the center of the universe, and everything revolves around the earth. In the discussion of urban sprawl, the downtown or central city takes the place of the earth in the Ptolemaic cosmology, and the rest of the metropolitan area is defined only in relation to the downtown.
>
> It is possible for the basic urban structure of a metropolitan area to change over time. Such a change has been occurring in U.S. metropolitan areas for the last 100 years, and the change is coming to fruition at the beginning of the new century. To plan for future urban growth, it is vital to recast our understanding of how urban areas operate.

In this paper, we examined how the links between metropolitan spatial structure and economic growth depend on metropolitan size. Consistent with the urban evolution hypothesis discussed in the introduction, growth effects of employment dispersion were found to be dependent on metropolitan size. A metropolitan area with more clustered spatial form grows faster, perhaps enjoying agglomeration economies when it is small; whereas more dispersion leads to higher growth rate as it grows large. Just as a city needs to successfully take on higher order functions and economic activities to move upward within the national urban system, it also needs to restructure its spatial form in such a way to mitigate congestion or other diseconomies of size for continued growth.

Therefore, attempts to find one particular efficient urban form – at least with respect to growth – may not be promising, just as the efforts to find the optimal city size have not been fruitful. Efficient spatial structure may depend not only on the city size but also on other urban attributes such as industrial structure and the shape of transportation networks, which are products of the historical path of urban development. Insignificant growth effects of polycentric versus monocentric structure imply that there may exist many plausibly competitive urban forms and different paths of spatial evolution.

[5] More elaborate historical context is described in Bruegmann (2005)

TABLES AND FIGURES

Table 1. Employment shares by location type in US metropolitan areas, 2000

Metro name	Pop	Emp	No. of Sub-centers	Share of emp (%) CBD A	Sub-centers B	Dis-persed	Sub/All Centers B/(A+B)	Rank Dis-persed	Decen-tralized	Poly-Centric B/(A+B)
3 million and plus			17	7.1	15.0	77.9	64.8			
Philadelphia	6,188	2,781	6	8.6	4.5	86.9	34.3	13	35	49
Boston	5,829	2,974	12	8.0	8.0	84.0	50.1	33	26	31
Atlanta	4,112	2,088	6	8.0	10.7	81.3	57.2	43	25	19
Chicago	9,158	4,248	17	7.0	11.9	81.1	62.9	45	17	13
Washington	7,608	3,815	16	7.4	11.8	80.8	61.3	46	20	16
Phoenix	3,252	1,464	9	7.1	12.9	79.9	64.4	51	18	12
Dallas	5,222	2,566	10	4.9	15.8	79.3	76.2	54	4	5
New York	21,200	9,418	33	9.9	11.2	78.8	53.0	57	46	25
Seattle	3,555	1,745	7	9.3	11.9	78.8	56.0	58	43	21
Miami	3,876	1,624	6	7.5	15.0	77.5	66.8	63	21	10
Detroit	5,456	2,509	22	5.2	22.2	72.6	81.1	72	5	2
Houston	4,670	2,076	14	8.0	20.8	71.2	72.3	75	24	8
San Francisco	7,039	3,513	22	5.9	24.2	70.0	80.5	76	10	3
Los Angeles	16,370	6,717	53	2.8	28.8	68.4	91.0	78	1	1
1 to 3 million			2.6	10.8	7.0	82.2	38.3			
Orlando	1,645	834	1	6.5	1.4	92.1	18.1	2	13	57
Cleveland	2,946	1,417	4	5.9	7.1	87.0	54.7	11	11	23
Buffalo	1,170	527	1	8.9	4.2	86.9	31.8	12	39	52
Portland	2,265	1,106	2	8.8	4.4	86.8	33.4	14	37	50
Milwaukee	1,690	837	3	8.3	4.9	86.8	37.0	15	29	46
Oklahoma City	1,083	510	3	6.8	7.1	86.2	51.1	17	14	28
Hartford	1,184	595	0	13.9	0.0	86.1	0.0	18	60	67
Sacramento	1,797	800	2	9.0	5.4	85.6	37.5	22	40	44
Grand Rapids	1,089	562	2	7.3	7.3	85.5	50.0	24	19	32
Minneapolis	2,969	1,627	3	8.5	6.1	85.4	41.5	25	34	41
Providence	1,189	507	1	12.6	2.3	85.1	15.1	26	58	60
Rochester	1,098	527	1	12.2	2.8	84.9	18.9	27	54	56
Charlotte	1,499	793	2	11.5	4.0	84.6	25.7	28	50	53
Cincinnati	1,979	951	3	8.3	7.7	84.0	48.0	31	28	35
Greensboro	1,252	618	2	5.2	10.8	84.0	67.4	32	6	9
Pittsburgh	2,359	1,075	1	14.5	1.6	83.9	9.8	34	64	64
Tampa	2,396	1,058	6	4.2	12.0	83.8	74.1	35	2	6
Nashville	1,231	659	0	16.3	0.0	83.7	0.0	36	68	66
Salt Lake City	1,334	661	2	8.4	8.7	82.9	50.9	39	30	30
Indianapolis	1,607	821	2	14.6	3.5	81.9	19.3	40	65	55
Raleigh	1,188	652	4	6.9	11.5	81.6	62.6	41	15	14
Jacksonville	1,100	506	1	15.8	2.7	81.5	14.5	42	67	61
New Orleans	1,338	582	1	16.7	2.0	81.3	10.6	44	72	63
Kansas City	1,776	904	4	8.1	11.4	80.5	58.3	48	27	18
Denver	2,582	1,363	5	9.5	10.0	80.4	51.2	49	44	27
St. Louis	2,626	1,250	6	7.7	12.4	80.0	61.6	50	22	15
Norfolk	1,570	659	4	5.6	14.8	79.6	72.8	52	8	7
Columbus	1,540	818	3	12.0	9.2	78.8	43.2	56	53	39
Memphis	1,136	525	2	10.6	11.0	78.3	51.0	59	47	29
Louisville	1,026	523	3	16.3	7.8	76.0	32.4	67	69	51
Austin	1,250	657	1	21.5	4.0	74.6	15.6	68	76	59
San Antonio	1,592	681	2	11.8	15.6	72.7	57.0	71	52	20
San Diego	2,814	1,210	10	5.8	22.7	71.6	79.8	73	9	4
Las Vegas	1,563	686	1	28.2	2.3	69.6	7.4	77	79	65

Table 1. Continued

Metro name	Pop	Emp	No. of Sub-centers	Share of emp (%) CBD A	Sub-centers B	Dis-persed	Sub/All Centers B/(A+B)	Rank Dis-persed	Decen-tralized	Poly-Centric
half to 1 million			0.9	12.2	5.2	82.6	25.7			
Allentown	638	270	0	4.4	0.0	95.6	0.0	1	3	72
Fort Wayne	502	262	0	8.7	0.0	91.3	0.0	3	36	79
Springfield	602	271	0	8.8	0.0	91.2	0.0	4	38	74
Tucson	844	363	0	9.0	0.0	91.0	0.0	5	41	68
Harrisburg	629	332	0	11.6	0.0	88.4	0.0	6	51	73
Greenville	962	471	2	5.9	5.8	88.3	49.4	7	12	33
El Paso	680	238	1	5.5	6.5	88.0	53.9	8	7	24
Albuquerque	713	325	0	12.4	0.0	87.6	0.0	9	55	70
McAllen	569	171	0	12.5	0.0	87.5	0.0	10	56	75
Youngstown	595	241	1	6.9	6.5	86.6	48.5	16	16	34
Knoxville	687	337	1	11.2	3.0	85.8	21.2	19	49	54
Toledo	618	309	1	8.4	5.8	85.8	40.6	20	31	42
Wichita	545	269	0	14.2	0.0	85.8	0.0	21	63	77
Baton Rouge	603	280	1	9.0	5.4	85.6	37.5	23	42	43
Fresno	923	336	1	8.5	7.0	84.5	45.0	29	33	38
Colorado Springs	517	243	1	9.9	5.6	84.5	36.3	30	45	47
Columbia	537	276	0	16.3	0.0	83.7	0.0	37	70	78
Charleston	549	246	0	16.8	0.0	83.2	0.0	38	73	76
Syracuse	732	335	0	19.3	0.0	80.7	0.0	47	74	69
Scranton	625	258	1	8.5	12.0	79.6	58.6	53	32	17
Albany	876	410	2	13.1	7.8	79.1	37.1	55	59	45
Richmond	997	497	2	14.1	7.6	78.3	35.0	60	62	48
Bakersfield	662	226	0	21.7	0.0	78.3	0.0	61	77	71
Little Rock	584	295	2	12.6	9.4	78.0	42.7	62	57	40
Stockton	564	196	2	11.0	11.8	77.2	51.7	64	48	26
Mobile	540	221	1	8.0	14.9	77.1	65.2	65	23	11
Dayton	951	461	1	20.1	3.8	76.1	15.9	66	75	58
Birmingham	921	420	1	22.8	2.9	74.3	11.5	69	78	62
Tulsa	803	388	1	14.0	11.8	74.2	45.7	70	61	37
Sarasota	590	243	2	15.4	13.3	71.3	46.3	74	66	36
Omaha	717	379	3	16.4	20.8	62.9	55.9	79	71	22

1) Dispersion ranking is ranked by dispersed employment share; decentralization ranking is by employment share outside the CBD; and polycentricity ranking is by the ratio of subcenters' share to all center employment.
2) Metropolitan areas sorted by dispersed employment share within each size population group.

Table 2. Definitions of variables

Variables	Descriptions
Dependent variables	
Log population growth	Log(pop2000/pop1990)
Log employment growth	Log(emp2000/emp1990)
Metropolitan size and spatial structure	
Log population	Log(population 1990)
Log employment	Log(employment 1990)
Log population density	Log(population 1990/acre), measured for 95% population area and excluding extremely low density census tracts under 100 persons per square miles
Dispersion	Percent dispersed location share of total employment
Polycentricity	Subcenters' share of center employment: subcenter' emp. / (subcenters' emp. + CBD emp.) * 100
Industrial mix	
Percent manufacturing	Percent manufacturing's share of total earnings
Human capital and demographic variables	
Percent college	Percent of 25+ years persons with bachelor's degree or higher
Percent poverty	Percent persons with income below poverty level
Percent nonwhite	Percent nonwhite population
Percent immigrants	Percent foreign-born population
Percent pop over 64	Percent population over 64 years
Amenities	
Mean Jan. temperature	January mean of average daily temperature (F°) for 1961-1990
Annual precipitation	Average annual precipitation for 1961-1990
Violent crime rate	Violent crimes known to police per 100,000 population
Coastal location	Dummy variable indicating coastal location
Regions	
Eight dummies of Census Division	New England, Middle Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain (Reference= Pacific)

1) All explanatory variables are measured as of 1990 except dispersion and polycentricity.
2) Population data are from Population Census; employment data are from Regional Economic Information System (REIS 1969-2000) published by the Bureau of Economic Analysis, US Department of Commerce; all other demographic and amenity variables are from 1994 County and City Data Book.

Table 3. Descriptive statistics of variables

	No. obs.	Mean	Std. dev.	Min.	Max.	No. Metros
Log population growth	79	0.1423	0.1099	-0.0217	0.6061	
Log employment growth	79	0.2366	0.1239	-0.0015	0.6157	
Population 1990 (thousands)	79	2,015	2,938	384	19,550	
Employment 1990 (thousands)	79	1,003	1,465	102	9,407	
Population density 1990 (per acre)	79	1.80	1.02	0.69	6.50	
GWR results						
Dispersion (%, dispersed emp. share)	79	81.59	6.05	62.86	95.59	
Polycentricity (%, subcenters / center)	79	38.07	25.49	0.00	91.04	
MD results						
Dispersion (%, dispersed emp. share)	79	72.78	7.79	53.29	89.06	
Polycentricity (%, subcenters / center)	79	32.85	19.98	0.00	80.47	
Percent manufacturing' share	79	18.69	7.75	3.29	36.21	
Percent nonwhite	79	19.16	9.04	1.65	41.95	
Percent immigrants	79	6.21	5.89	1.12	27.17	
Percent pop over 64	79	12.05	3.35	7.38	30.37	
Percent college	79	21.04	4.41	11.50	31.71	
Percent poverty	79	12.55	4.89	7.05	41.88	
Mean Jan. temperature	79	36.79	12.27	11.80	67.20	
Annual precipitation	79	36.23	14.33	4.13	63.96	
Violent crime rate	79	814	338	172	2190	
Coastal location	79	0.34	0.48	0	1	27
New England	79	0.05	0.22	0	1	4
Middle Atlantic	79	0.13	0.33	0	1	10
East North Central	79	0.15	0.36	0	1	12
West North Central	79	0.06	0.25	0	1	5
South Atlantic	79	0.19	0.39	0	1	15
East South Central	79	0.08	0.27	0	1	6
West South Central	79	0.14	0.35	0	1	11
Mountain	79	0.09	0.29	0	1	7
Pacific	79	0.11	0.32	0	1	9

Table 4. Metropolitan growth models without urban spatial structure variables

	Dependent variable: Log population growth 1990-2000									Dependent variable: Log employment growth 1990-2000								
	Model 1			Model 2			Model 3 (stepwise)			Model 4			Model 5			Model 6 (stepwise)		
	Beta	T		Beta	t		Beta	t		Beta	t		Beta	t		Beta	t	
log pop (emp)	0.0192	1.33		0.0269	1.65		0.0160	1.54		0.0059	0.45		0.0086	0.59				
log pop density	-0.0504	-1.65		-0.0841	-2.32	**				-0.0485	-1.63		-0.0510	-1.48		-0.0547	-3.06	***
% manufacturing	-0.0028	-1.63		-0.0033	-2.09	**				-0.0046	-2.71	***	-0.0050	-3.28	***	-0.0043	-3.29	***
% nonwhite				-0.0029	-1.70	*	-0.0037	-2.78	***				-0.0057	-3.47	***	-0.0063	-4.88	***
% immigrants				0.0062	1.90	*							-0.0005	-0.17				
% pop over 64				-0.0095	-2.48	**	-0.0131	-4.19	***				-0.0089	-2.41	**	-0.0070	-2.15	**
% pop college				-0.0006	-0.24								0.0054	2.04	**	0.0059	2.61	**
% pop poverty				-0.0034	-1.00								0.0016	0.47		0.0033	1.52	
Mean Jan. temperature				0.0052	3.29	***	0.0058	6.83	***				0.0065	4.31	***	0.0046	4.69	***
annual precipitation				0.0000	0.01								-0.0010	-0.74				
violent crime rate				-0.0001	-1.39								0.0000	-1.14				
coastal location				-0.0342	-1.53		-0.0582	-2.98	***				-0.0109	-0.51				
New England	-0.1305	-2.70	***	-0.0249	-0.40					-0.1463	-3.00	***	-0.0539	-0.90		-0.1677	-4.61	***
Middle Atlantic	-0.1531	-3.87	***	-0.0286	-0.51					-0.1306	-3.27	***	-0.0171	-0.32		-0.1211	-4.64	***
East North Central	-0.0827	-2.04	**	0.0729	1.37					-0.0110	-0.27		0.1261	2.46	**			
West North Central	-0.0544	-1.21		0.0785	1.43					-0.0085	-0.19		0.0847	1.60				
South Atlantic	0.0057	0.16		0.0732	1.67		0.0527	2.45	**	0.0366	1.03		0.0844	2.00	*			
East South Central	-0.0543	-1.19		0.0663	1.16					0.0218	0.47		0.1251	2.26	**			
West South Central	0.0146	0.40		0.0545	1.20					0.0706	1.92	*	0.0832	1.89	*			
Mountain	0.1463	3.62	***	0.1944	4.11	***	0.1294	4.51	***	0.1973	4.89	***	0.1721	3.80	***	0.1279	4.29	***
constant	-0.0229	-0.12		-0.1388	-0.62		-0.0665	-0.44		0.2578	1.60		0.0863	0.44		0.2286	2.31	**
R sq.	0.570			0.724			0.659			0.655			0.800			0.762		
Adj. R sq.	0.499			0.629			0.625			0.598			0.731			0.727		

1) The number of observations of all models is 79. * Significant at 10%; ** significant at 5%; *** significant at 1%.
2) Reference region for the census division dummies is Pacific.

Table 5. Metropolitan population growth models with urban spatial structure variables

	Model 1			Model 2			Model 3			Model 4			Model 5			Model 6		
	Beta	t		Beta	t		Beta	t		Beta	t		Beta	t		Beta	t	
Dispersion	-0.0006	-0.36					-0.0014	-0.82		-0.0003	-0.19					-0.0009	-0.53	
Polycentric				-0.0005	-1.04		-0.0006	-1.27					-0.0007	-1.53		-0.0006	-1.08	
Dispersion * log pop.										0.0049	2.75	***				0.0060	2.14	**
Polycentric * log pop.													-0.0008	-1.62		0.0003	0.41	
log pop. centered	0.0294	1.78	*	0.0379	2.14	**	0.0379	2.14	**	0.0315	2.01	**	0.0469	2.56	**	0.0380	2.07	**
log pop. density	-0.0926	-2.77	***	-0.0881	-2.64	**	-0.0882	-2.63	**	-0.0977	-3.07	***	-0.0892	-2.71	***	-0.0934	-2.93	***
% manufacturing	-0.0034	-2.15	**	-0.0031	-1.99	*	-0.0028	-1.68	*	-0.0015	-0.88		-0.0025	-1.56		-0.0006	-0.37	
% nonwhite	-0.0037	-2.26	**	-0.0037	-2.29	**	-0.0039	-2.38	**	-0.0035	-2.22	**	-0.0035	-2.18	**	-0.0037	-2.36	**
% immigrants	0.0044	1.52		0.0043	1.49		0.0045	1.57		0.0076	2.53	**	0.0055	1.88	*	0.0078	2.62	**
% pop over 64	-0.0099	-2.48	**	-0.0089	-2.23	**	-0.0092	-2.30	**	-0.0118	-3.08	***	-0.0093	-2.37	**	-0.0112	-2.89	***
% pop college	0.0001	0.03		0.0001	0.02		-0.0001	-0.05		0.0007	0.27		0.0005	0.21		0.0004	0.17	
mean Jan. temperature	0.0050	3.10	***	0.0047	2.88	***	0.0045	2.76	***	0.0058	3.71	***	0.0051	3.16	***	0.0053	3.32	***
annual precipitation	-0.0003	-0.24		-0.0005	-0.38		-0.0005	-0.32		0.0002	0.13		-0.0006	-0.43		0.0002	0.12	
violent crime rate	-0.0001	-1.48		-0.0001	-1.35		0.0000	-1.24		-0.0001	-1.52		0.0000	-1.30		0.0000	-1.27	
New England	-0.0312	-0.49		-0.0544	-0.83		-0.0547	-0.83		-0.0419	-0.69		-0.0548	-0.84		-0.0703	-1.11	
Middle Atlantic	-0.0462	-0.82		-0.0653	-1.13		-0.0659	-1.14		-0.0390	-0.73		-0.0607	-1.06		-0.0615	-1.11	
East North Central	0.0507	0.98		0.0381	0.73		0.0350	0.66		0.0526	1.08		0.0471	0.91		0.0323	0.64	
West North Central	0.0701	1.33		0.0629	1.19		0.0572	1.07		0.0699	1.39		0.0751	1.42		0.0514	0.99	
South Atlantic	0.0706	1.57		0.0713	1.60		0.0759	1.69	*	0.0598	1.40		0.0749	1.70	*	0.0615	1.40	
East South Central	0.0512	0.92		0.0507	0.92		0.0457	0.82		0.0425	0.80		0.0533	0.98		0.0343	0.64	
West South Central	0.0380	0.95		0.0433	1.08		0.0436	1.09		0.0252	0.66		0.0416	1.05		0.0295	0.77	
Mountain	0.1873	4.13	***	0.1772	3.93	***	0.1809	3.98	***	0.2081	4.76	***	0.1828	4.10	***	0.2024	4.62	***
constant	0.2397	2.14	**	0.2415	2.17	**	0.2447	2.19	**	0.1528	1.38		0.2026	1.81	*	0.1552	1.40	
R sq.	0.708			0.713			0.716			0.742			0.725			0.752		
Adj. R sq.	0.614			0.620			0.618			0.653			0.630			0.655		

1) The number of observations of all models is 79. * Significant at 10%; ** significant at 5%; *** significant at 1%.
2) Log population size and two spatial structure variables (dispersion and polycentricity) that are used in interaction terms are centered by subtracting the mean value for the purpose of ease in interpretation.

Table 6. Metropolitan employment growth models with urban spatial structure variables

	Model 1			Model 2			Model 3			Model 4			Model 5			Model 6		
	Beta	t		Beta	t		Beta	t		Beta	t		Beta	t		Beta	t	
Dispersion	-0.0009	-0.61					-0.0007	-0.45		-0.0007	-0.47					-0.0005	-0.30	
Polycentricity				0.0002	0.51		0.0001	0.31					0.0000	-0.02		0.0001	0.25	
Dispersion * log emp.										0.0044	2.69	***				0.0047	1.96	*
Polycentric * log emp.													-0.0007	-1.62		0.0001	0.17	
log emp. centered	0.0052	0.36		0.0040	0.27		0.0037	0.24		0.0071	0.53		0.0121	0.77		0.0052	0.33	
log pop. density	-0.0612	-1.97	*	-0.0628	-2.00	**	-0.0626	-1.98	*	-0.0678	-2.29	**	-0.0668	-2.15	**	-0.0684	-2.25	**
% manufacturing	-0.0051	-3.43	***	-0.0055	-3.65	***	-0.0053	-3.34	***	-0.0035	-2.26	**	-0.0050	-3.33	***	-0.0036	-2.16	**
% nonwhite	-0.0056	-3.64	***	-0.0054	-3.57	***	-0.0055	-3.57	***	-0.0053	-3.63	***	-0.0051	-3.37	***	-0.0053	-3.54	***
% immigrants	0.0003	0.11		0.0001	0.04		0.0003	0.09		0.0036	1.26		0.0015	0.54		0.0035	1.22	
% pop over 64	-0.0095	-2.54	**	-0.0095	-2.53	**	-0.0096	-2.54	**	-0.0111	-3.10	***	-0.0097	-2.64	**	-0.0113	-3.05	***
% pop college	0.0048	1.95	*	0.0049	2.00	*	0.0048	1.95	*	0.0052	2.23	**	0.0051	2.13	**	0.0052	2.19	**
mean Jan. temperature	0.0066	4.38	***	0.0068	4.42	***	0.0067	4.31	***	0.0072	4.98	***	0.0072	4.69	***	0.0072	4.80	***
annual precipitation	-0.0010	-0.75		-0.0010	-0.77		-0.0010	-0.73		-0.0005	-0.36		-0.0010	-0.77		-0.0004	-0.32	
violent crime rate	0.0000	-1.27		0.0000	-1.37		0.0000	-1.29		0.0000	-1.37		0.0000	-1.43		0.0000	-1.36	
New England	-0.0473	-0.79		-0.0419	-0.68		-0.0419	-0.67		-0.0571	-1.01		-0.0425	-0.70		-0.0546	-0.91	
Middle Atlantic	-0.0135	-0.26		-0.0092	-0.17		-0.0092	-0.17		-0.0073	-0.15		-0.0063	-0.12		-0.0049	-0.09	
East North Central	0.1326	2.76	***	0.1374	2.79	***	0.1360	2.74	***	0.1357	2.96	***	0.1458	2.98	***	0.1367	2.84	***
West North Central	0.0936	1.90	*	0.0996	2.00	*	0.0966	1.91	*	0.0974	2.07	**	0.1118	2.24	**	0.0978	1.98	*
South Atlantic	0.0876	2.08	**	0.0840	2.00	**	0.0864	2.03	**	0.0783	1.95	*	0.0855	2.06	**	0.0767	1.85	*
East South Central	0.1319	2.53	**	0.1356	2.60	**	0.1331	2.52	**	0.1252	2.52	**	0.1353	2.63	**	0.1258	2.48	**
West South Central	0.0947	2.53	**	0.0934	2.48	**	0.0935	2.47	**	0.0860	2.41	**	0.0922	2.48	**	0.0849	2.32	**
Mountain	0.1856	4.39	***	0.1854	4.36	***	0.1872	4.36	***	0.2104	5.09	***	0.1933	4.58	***	0.2115	5.00	***
constant	0.2316	2.20	**	0.2303	2.19	**	0.2310	2.18	**	0.1553	1.50		0.1972	1.87	*	0.1552	1.47	
R sq.	0.800			0.799			0.800			0.822			0.808			0.822		
Adj. R sq.	0.735			0.735			0.731			0.760			0.742			0.752		

1) The number of observations of all models is 79. * Significant at 10%; ** significant at 5%; *** significant at 1%.
2) Log employment size and two spatial structure variables (dispersion and polycentricity) that are used in interaction terms are centered by subtracting the mean value for the purpose of ease in interpretation.

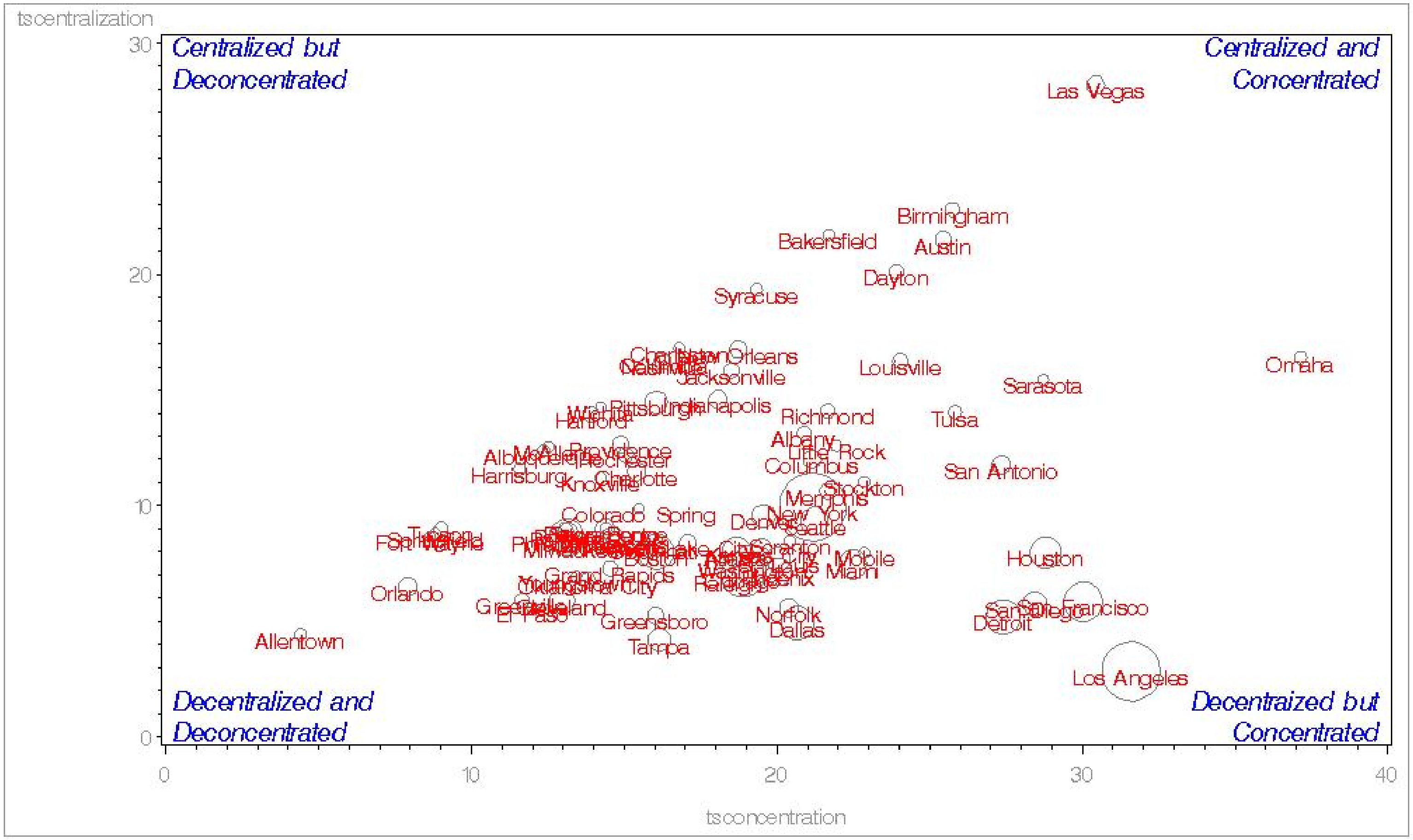
Table 7. Varying growth effects of spatial structure depending on metropolitan size

Population growth					
		Growth effects of 1% increase		Growth effects of 1 std. dev. increase	
log population	population size	dispersion	polycentricity	dispersion	polycentricity
13.04	460,632	-0.69%	-0.09%	-4.2%	-2.2%
14.04	1,252,129	-0.09%	-0.06%	-0.6%	-1.4%
15.04	3,403,639	0.50%	-0.03%	3.0%	-0.7%
16.04	9,252,049	1.10%	0.00%	6.6%	0.1%

Employment growth					
		Growth effects of 1% increase		Growth effects of 1 std. dev. increase	
log employment	employment size	dispersion	polycentricity	dispersion	polycentricity
12.30	220,261	-0.52%	0.00%	-3.1%	0.0%
13.30	598,731	-0.05%	0.01%	-0.3%	0.3%
14.30	1,627,519	0.42%	0.02%	2.5%	0.6%
15.30	4,424,054	0.89%	0.03%	5.4%	0.8%

1) This table is calibrated based on the coefficients of spatial structure variables generated by the GWR procedure in Tables 5 and 6.
2) Sample mean and standard deviation of percent dispersed employment share (dispersion) are 81.6% and 6.05%, respectively; and these values for subcenters’ share of center employment (polycentricity) are 38.1% and 25.5%, respectively.

Figure 1. Employment decentralization and dispersion in US metropolitan areas



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