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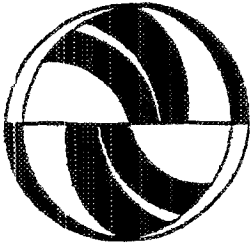
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Authors

Giuliano, Genevieve
Small, Kenneth A.

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The determinants of growth of employment subcenters

Genevieve Giuliano^{a,b,*}, Kenneth A. Small^b

^a *University of Southern California, School of Urban Planning and Development, Los Angeles, CA 90089-0042, USA*

^b *Department of Economics and ITS, University of California, Irvine CA 92717 USA*

Abstract

This paper presents an empirical analysis of subcenter growth. We develop a series of hypotheses based on the theoretical concepts that have been proposed as explanations for the emergence and growth of subcenters. We then conduct tests of these hypotheses using 1970–80 data from the Los Angeles region. We find that subcenters containing fast-growing industries tended to grow rapidly, and so did those close to airports. There is weak evidence that large subcenters and those located near downtown Los Angeles grew more slowly in proportional terms, possibly indicating diseconomies of scale due to congestion. © 1999 Elsevier Science Ltd. All rights reserved.

1. Introduction

It is now well verified that urban employment tends to cluster in subcenters as well as in a large main center, and that these subcenters are an increasingly important part of urban structure. There is also growing empirical information about the sizes, shapes, densities and associated commuting patterns that characterize them.¹

Theoretical understanding of subcenter formation is based mainly on four forces.² First, firms desire accessibility to members of the labor force many of whom seek cheaper residential land far from the main employment center. Second, many firms achieve economies of agglomeration by locating close to each other, either in the main center or in subcenters. Third, if the main center becomes very large, its desirability becomes limited by land scarcity, congestion, or other scale diseconomies. Fourth, subcenters may develop near important inter-regional transportation nodes.

Although these theoretical motivations for subcenter formation are widely accepted, they have been subjected to little if any empirical testing. Indeed, there is little

empirical literature of any sort on how subcenters emerge and grow. Only a few empirical studies have even examined the same area for changes in the polycentric form over time: e.g. McDonald and McMillen (1990) and McMillen (forthcoming) for Chicago; Stern (1994) for Jerusalem and Tel Aviv; Richardson et al. (1990) and Small and Song (1994) for Los Angeles. Other studies such as Palumbo et al. (1990) and Boarnet (1994) have examined the growth of municipalities within a metropolitan area, but without identifying those that are subcenters. No studies explicitly identifying subcenters have examined hypotheses about such questions as which subcenters are most likely to grow, or where within the metropolitan area new ones are likely to emerge.

An important reason for the lack of research on the growth and development of subcenters is that the number of subcenters within any given metropolitan region is small, making systematic analysis difficult. The Los Angeles region is an important exception. Its large size and long history of dispersed development has resulted in many subcenters. This paper formulates and estimates empirical models to explain the emergence and growth of 32 locations of concentrated employment in the Los Angeles region between 1970 and 1980.³ These

* Corresponding author. Tel. +1 213 740 3956, e-mail: giuliano@almaac.usc.edu

¹ For example, Greene (1980), Griffith (1981), Dunphy (1982), Erickson (1986), Cervero (1989), McDonald and McMillen (1990), Gordon et al. (1986), Heikkila et al. (1989), Richardson et al. (1989), Giuliano and Small (1991, 1993), Small and Song (1994), Cervero and Wu (1996).

² See Hartwick and Hartwick (1974), White (1976), Odland (1978), Fujita and Ogawa (1982), Kim (1983), Wieand (1987), Scott (1988), Sasaki (1990), and Helsley and Sullivan (1991).

³ Using 1970 and 1980 data for an analysis conducted in the mid-1990s merits explanation. Our analysis requires very disaggregate data whose geographic units are consistently defined across at least two time periods. Because of the many changes that occurred in the way data were collected and in the definitions of geographic units on which they were based, 1970 and 1980 provided the most consistent match in our judgement.

concentrations are objectively defined using simple criteria based on employment density and total employment, adapted from those developed previously by Giuliano and Small (1991).

The results suggest that subcenters were most likely to grow rapidly if they specialized in industries that were fast-growing regionally, and if they were located close to Los Angeles Airport or one of the three major regional airports. We cannot clearly disentangle the effect of subcenter size on its future growth, therefore we are not able to verify the role of economies or diseconomies of agglomeration, although there is some evidence for diseconomies in large centers and in those close to downtown Los Angeles. Good accessibility to labor force and good highway access were so prevalent across our sample that they did not exert any discernible effects on differential growth rates of subcenters.

2. Data

Our study area is the Los Angeles region comprising most of the jurisdiction of the Southern California Association of Governments (SCAG). It covers most of the populated areas of five counties: Los Angeles, Orange, Riverside, San Bernardino, and Ventura. The region is divided into a system of transportation analysis zones (AZs), as defined by SCAG for its 1970 traffic and land-use analyses. After eliminating 139 very low-density outlying zones, we are left with 1146 zones covering an area of 3536 square miles. These zones contained 4.0 million jobs and 9.4 million residents in 1970, by 1980 they contained 5.3 million jobs and 10.6 million residents. This 32.5% employment increase marks the region as one of the most rapidly growing large metropolitan areas in the nation during that decade.

Our data include population and employment by 13 industry groups for the 1146 zones within the region. The employment data used here to define subcenters, and the population data to define labor-force accessibility, were derived from the California Economic Development Department (EDD),⁴ rather than from the US Census journey-to-work questions as in our earlier papers (Giuliano and Small, 1991, 1993). The procedures used to locate the work-place addresses reported by Census respondents were somewhat different in 1970 than in 1980, so we feared that centers based on census data might not be comparable.

We did use the Census data, however, to attribute to each zone the proportions of employment in each of 13 industry groups, since this information was not available by zone in the EDD data. This introduces some inac-

curacy due to discrepancies between the amounts of employment by zone in the two data sets. We believe this is not too serious for using industry mix in our independent variables – indeed, less serious perhaps than the limitations of having only the 13 aggregate industry groups defined in the data.

We define a center or subcenter as a contiguous set of zones with average 1970 employment density greater than 10 employees per acre, and total 1970 employment greater than 3000. This definition is simple, objective, and easily replicated in other areas where comparable data are available. Furthermore, it gives a reasonable approximation to what would be recognized locally as an employment cluster, and identifies the amount of employment in that cluster.

In earlier papers (Giuliano and Small, 1991, 1993) we have found that similar criteria, when applied to 1980 Census journey-to-work data, yield a set of centers that is useful for analysis and that shows plausible patterns of size, density, commuting, and industry mix. Our earlier work considered only those centers with 10,000 or more employees, here we include smaller centers (3000 or more employees) in order to increase our number of observations for the statistical analysis, and to account for potentially emerging subcenters – both those that did and those that did not in fact become significant subcenters by 1980.

The criteria just described define 33 centers in 1970. They are listed by 1970 size rank in Table 1, and their locations are shown in Fig. 1, along with the 1980 freeway system. Employment growth is measured in constant boundaries.

Table 1 shows that all but three centers increased employment between 1970 and 1980.⁵ The center we name “Downtown Los Angeles” (which is considerably larger than the central business district) remained by far the largest center in 1980, despite a slight loss of employment over the decade. The next four largest centers all grew very substantially. Three of them (#2, 3, and 5 in rank), together with Downtown Los Angeles, formed a nearly contiguous arc of high employment density extending some fifteen miles from downtown Los Angeles to the Pacific Ocean.

Downtown Los Angeles is the region's main center. The Riverside and San Bernardino centers, located in cities of those names, were remote and served less as subcenters to the region than as centers of their respective counties which, even by 1980, were not closely integrated into the Los Angeles economy. Our analysis

⁴ The data were put in the desired geographical basis by the California Department of Transportation for its forecasting analyses.

⁵ This robust growth of subcenters might appear at first glance to contradict the finding of Gordon and Richardson (1996) that Los Angeles subcenters became less important over the same decade. But they use a quite different subcenter definition (based on total trip generation), and even so their subcenters declined only in relative, not absolute, employment (see their Table 1).

Table 1
Centers, subcenters, and their characteristics

Rank	Location ^a	Employment 1970 (1000 s)	Employment Change 1970–80 (%)	Employment Density 1970 (empl/acre)	Distance to CBD (miles)
1	Downtown Los Angeles	615.0	-1.6	37.3	1.1
2	Los Angeles west	100.3	41.0	17.3	8.9
3	UCLA/Santa Monica	95.5	19.1	18.7	15.8
4	Los Angeles Airport/ Inglewood	85.9	27.8	16.2	18.8
5	Hollywood west	45.0	31.5	23.6	8.3
6	Commerce/East Los Angeles	44.6	5.7	14.5	9.2
7	Long Beach	43.9	-0.9	20.8	25.3
8	Pasadena	33.6	10.0	16.0	12.1
9	Burbank/Glendale northwest	33.0	29.4	13.4	12.3
10	Burbank Airport	30.8	25.5	33.4	16.5
11	Long Beach Airport	25.3	-16.3	11.9	23.3
12	Hawthorne	17.1	37.8	11.8	13.5
13	Glendale southeast	16.8	33.1	13.6	9.3
14	Riverside (RIV)	16.8	41.7	15.4	56.9
15	Downey	16.1	62.9	19.1	14.8
16	Canoga Park southwest	15.7	14.5	10.2	27.4
17	Pomona	14.9	-8.2	13.7	34.0
18	Santa Ana (OR)	14.6	47.9	15.4	32.9
19	Harbor Gateway	13.6	56.6	11.3	16.9
20	Hollywood east	13.4	33.9	32.0	6.1
21	Los Angeles east	12.9	22.9	29.4	6.8
22	Sherman Oaks	12.4	54.2	11.0	18.6
23	Pasadena east	12.3	13.4	12.5	16.2
24	San Bernardino (SB)	11.3	11.8	15.2	64.4
25	San Pedro	11.0	62.0	10.6	23.3
26	South Gate	10.9	5.3	10.8	7.8
27	Marina del Rey/Hughes Airport	10.0	17.5	16.2	12.8
28	Culver City east	8.4	34.5	13.3	9.5
29	Vernon East	7.0	5.4	11.4	4.9
30	Culver City west	5.3	36.6	12.6	12.0
31	Ontario	5.3	45.4	17.2	41.2
32	San Fernando	4.8	11.5	10.9	22.6
33	Venice	4.5	23.2	10.2	17.7

^a County in parentheses if not Los Angeles County. OR = Orange, RIV = Riverside, SB = San Bernardino. (There are no centers in Ventura County.)

is limited to growth of subcenters, not main centers, we therefore exclude the Downtown Los Angeles center and introduce a dummy variable for the two outlying centers to control for a possible difference in their growth potential. (Results do not change much if the outlying centers are instead deleted.)

If we had more confidence in our industry data, we would consider using them to create an enlarged set of observations consisting of subcenter-industry pairs. We would then explain the growth of a given industry in a given subcenter, just as Glaeser et al. (1992) explain the growth of a given industry in a metropolitan area. This

technique would take advantage of industry-specific growth information and thereby offer greater explanatory power. But given the data we have, we feel safer explaining aggregate employment only.

Our earlier work showed that there was considerable variety in the types of subcenters within any particular geographical subregion. Furthermore, most subcenters are separated from each other by at least several miles. Therefore, the problems of spatial autocorrelation seem likely to be less severe than in many geographical data sets. Given the very limited degrees of freedom available to test our hypotheses, we felt it unwise to complicate

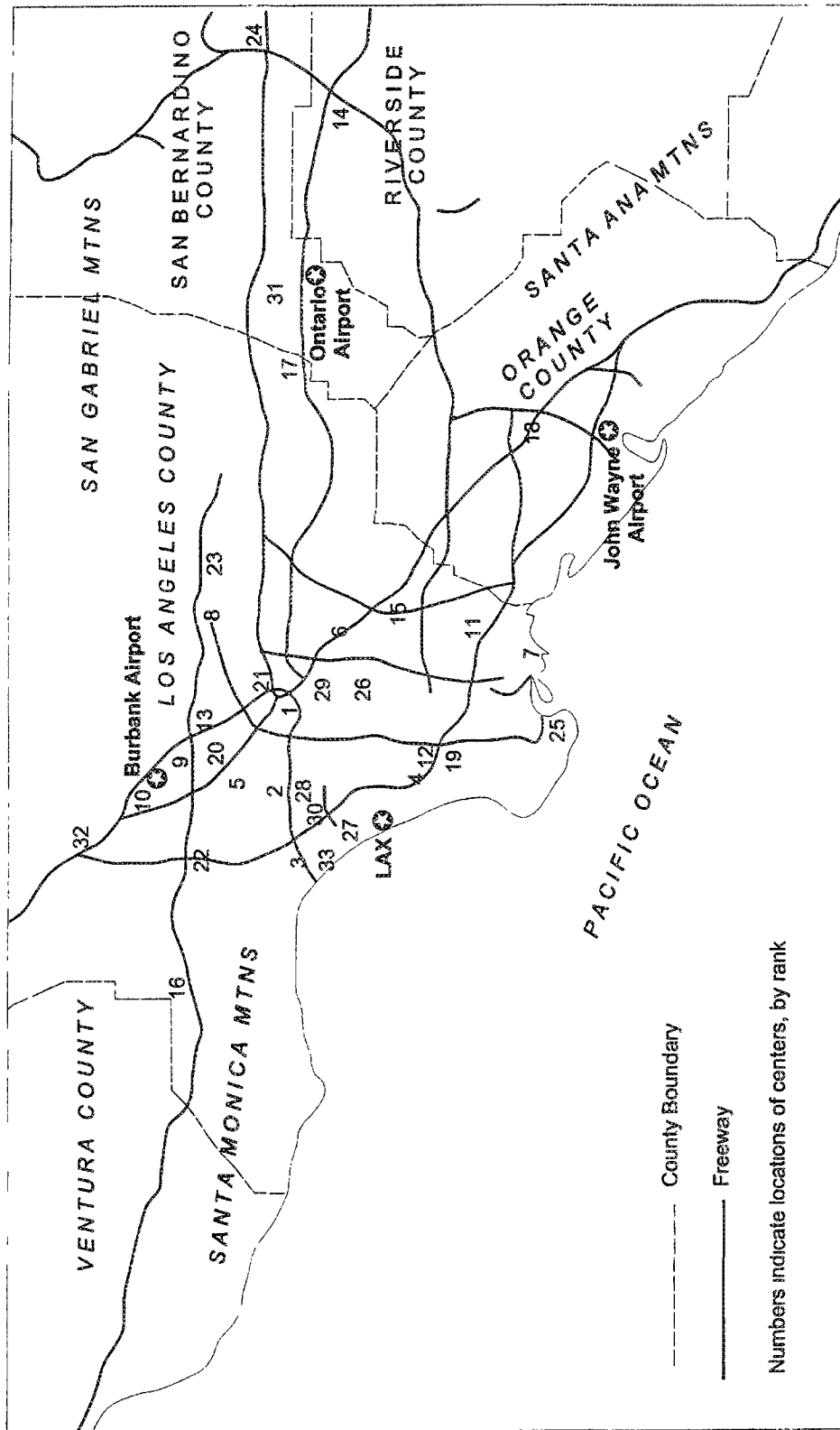


Fig. 1 1970 employment centers

the model by accounting for such spatial effects, and have therefore limited our statistical techniques to ordinary least squares. We do, however, test one hypothesis specifically postulating a relationship among centers close to each other, as noted in Section 3.2

3. Hypotheses

What factors are associated with subcenter growth? Theories of city growth are based on such forces as access to labor, economies of agglomeration, diseconomies of scale due to congestion and limited land, and access to transport facilities. These factors are likely important for subcenter growth as well. In addition, subcenters compete with the main center and with one another.

In this section we specify concrete hypotheses organized around these overall forces, grouping them into three sets. One set consists of hypotheses related to economic productivity of subcenters, including factors affecting economies of agglomeration, congestion, land scarcity, and the growth prospects of existing firms. The second set is related to labor-force accessibility, and the third to transportation facilities. Variables constructed to test each hypothesis are given in Appendix A.

Our purpose is to explain growth of subcenters over a period of a decade, based on subcenter characteristics that are for the most part exogenous with respect to the growth process. Hence, we do not formulate hypotheses about the effects of land prices or taxes, which can quickly change as a result of growth itself or the prospects of growth. Similarly, we avoid using construction employment to explain growth; it is better viewed as a reflection of developers' forecasts of that growth, presumably based on many of the factors we hypothesize as causal. On the other hand, we are not attempting to explain the more fundamental historical factors that may have led a subcenter to develop to the point at which we observe it in 1970, therefore we include its 1970 characteristics, such as subcenter size and density, as explanatory variables for its subsequent growth.

3.1 Hypotheses related to economic productivity

Size of subcenter Large subcenters (as measured by 1970 total employment) might grow faster because of the benefits of economies of agglomeration, or slower because of the disbenefits of congestion, land scarcity, crowding of public services, and other negative scale effects. The relationship might also be nonlinear, with small subcenters suffering from inadequate economies of agglomeration but large subcenters suffering from congestion.

The effect of subcenter size on growth is also implicit in the choice of dependent variable. It is not clear a priori

whether the factors reviewed in this list of hypotheses most directly affect absolute growth, percentage growth, or something in between. That is, if $x'\beta$ is a combination of effects of factors x on growth ΔE of a subcenter, we could specify $\Delta E = x'\beta + \varepsilon$ (absolute growth), $(\Delta E/E) = x'\beta + \varepsilon$ (percentage growth) or, more generally,

$$\frac{\Delta E}{E'} = x'\beta + \varepsilon, \quad (1)$$

where $0 \leq \lambda \leq 1$. In each case, ε is assumed to be a normally distributed error term. The more general dependent variable in (1) has absolute growth and percentage growth as the special cases $\lambda = 0$ and $\lambda = 1$, respectively.

Density of subcenter Subcenters with low employment density have more room to expand, which may be reflected in lower land costs (at least relative to other centers at comparable distances from downtown Los Angeles) or more vacant land.

Industry composition If the economic functions carried out within a subcenter are slow to change, the subcenter's growth will be strongly affected by the regional growth experienced in its industries. Thus, with other factors held constant, subcenters specializing in sectors that grew rapidly in the Los Angeles region as a whole, such as services, would grow faster than those specializing in slow-growth sectors such as manufacturing.

This can be tested with a measure equal to the amount of growth that would have occurred if each industry sector within the subcenter had grown at its average rate for the entire Los Angeles region, which we could call "predicted" employment change

$$\Delta E^p = \sum_i E_i \bar{g}_i, \quad (2)$$

where E_i is beginning-of-period employment in industry sector i , and \bar{g}_i is the sector's regional growth rate. This variable is a combination of the regional-growth and industry-mix effects in shift-share analysis (Merrifield, 1983). A strong version of the hypothesis would be that ΔE^p influences absolute subcenter growth ΔE one for one, so that $\Delta E/E' = \Delta E^p/E' +$ (effects of all other variables).

It may also be that agglomeration economies are more important for some industrial sectors than for others, and therefore that the presence of particular industries encourages growth in a subcenter. This is tested using variables measuring specific industry shares.

Diversity of economic base Economies of agglomeration are often divided into *economies of localization*, in which efficiencies are reaped due to proximity to other firms in the same industry, and *economies of urbanization*, in which the efficiencies result from inter-industry linkages (Henderson, 1988, p. 32). The agglomeration economies captured by the size variable could be of ei-

ther type. We can be more specific by testing whether centers where employment is concentrated in a few industries grow faster than centers that are diversified, if so, we have possible evidence of economies of localization.

We use the entropy-like measure of diversity suggested by Cervero (1989, pp. 77-78)

$$DIV = [-\sum_i S_i \log S_i] / [-\log \bar{S}],$$

where S_i is the share of the subcenter's employment (excluding agriculture, mining, and construction) in industry sector i , and \bar{S} is the inverse of the number of sectors. The sum is over ten sectors, after deleting agriculture, mining, and construction, and with remaining shares normalized to add to one. This measure lies between zero and one, it is zero for a subcenter completely specialized in one industry sector,⁶ and one for a subcenter with equal amounts of employment in each sector.

Location in the overall region. If economies of urbanization are important, a subcenter's growth prospects may depend on the centrality of its location within the overall region, or its accessibility with respect to total regional employment. A convenient measure of this is distance to the Los Angeles central business district (CBD), or its inverse. To the extent that functions provided by downtown Los Angeles are unique and valuable to firms locating in subcenters, proximity would encourage growth. On the other hand, such proximity means higher land costs and congestion in the surrounding area, through which people must travel to do business there, this could cause proximity to retard growth.

3.2 Hypotheses related to labor-force accessibility

Labor-force accessibility. Some subcenters are located in areas where the resident labor force (which consists of workers residing in the surrounding area) outnumbers the supply of jobs. These subcenters should be able to attract labor more cheaply, and thus become magnets for employment growth, indeed, this is the primary mechanism for subcenter formation in theories rooted in the standard paradigm of urban economics. There is indirect empirical evidence for this hypothesis in two types of studies. First, studies of firm location decisions usually find accessibility to a labor pool to be one of the most important factors (Blair and Premus, 1987). Second, studies of suburbanization find residential suburbanization to be an independent causal factor in explaining the simultaneous process of employment suburbanization (Bradbury et al., 1982, p. 94).

Following standard formulations of spatial interaction theory, labor-force accessibility can be measured by a gravity-type function. We adopt the exponential form proposed by Hansen (1959) and widely used in regional science and urban planning (e.g. Shukla and Waddell, 1991). According to this version of the hypothesis, the influence of each resident worker declines exponentially with his or her distance from the employment subcenter. More precisely, if L_j is the labor force living in zone j , and r_{jm} is the road-network distance from zone j to the highest-density zone of subcenter m , we define the subcenter's *absolute labor-force accessibility* as

$$A_m = \sum_j L_j e^{-\beta r_{jm}} \quad (3)$$

and its *relative labor-force accessibility* as

$$B_m = \sum_j L_j \left(E_m e^{-\beta r_{jm}} / \sum_k E_k e^{-\beta r_{km}} \right), \quad (4)$$

where β is a parameter and where both sums extend over all zones, including those in the subcenter in question. Both measures have units of number of employees, so we divide them by E_m^2 to make them commensurate with the dependent variable.

The parameter $(1/\beta)$ measures the commuting distance over which attractiveness declines to a fraction e^{-1} of its peak value. When a spatial-interaction model is constructed with such an exponentially declining interaction term, it is found that $(1/\beta)$ is equal to \bar{r} , the regional average commuting distance (Thomas and Huggett, 1980, pp. 161-162). In our data \bar{r} is 10.81 miles, so we set $\beta = 1/10.81$. (We also tried $\beta = 1/3$, which did not improve the results.)

The relative-accessibility measure, B , may be viewed as attaching to each member of the labor force a probability, based solely on commuting distance, of choosing to work in the subcenter in question. Hence it reflects the competitive locational advantage of the subcenter's firms. We take this as embodying our primary hypothesis about labor-force accessibility.

In addition, we consider two subsidiary hypotheses. First, in addition to a subcenter's relative competitive position at attracting labor force, there may be an advantage to a large labor force within easy commuting range regardless of competition for it from other jobs, because a large labor pool increases the probability of finding people with the right skills. We test this by including the absolute labor-force accessibility measure A_m (again divided by E_m^2) as an additional variable.

Second, there may be a disadvantage of competing with nearby centers beyond that reflected in the denominator in Eq. (4), which covers all zones regardless of whether they are in centers. This could occur if some workers have idiosyncratic preferences for jobs in the general region in which the subcenter is located, and so are more likely to take a job in that subcenter if there are

⁶ Since $-\log(1) = 0$, and $S_i \log S_i \rightarrow 0$ as $S_i \rightarrow 0$.

no similar jobs nearby. This is analogous to the “competing destinations” hypothesis of Fotheringham (1983) for spatial-interaction models, which suggests an independent effect of the following measure

$$H_m = \sum_{n \neq m} E_n e^{-\gamma r_{nm}}, \quad (5)$$

where the sum is over all centers, including the main center but excluding the subcenter in question. However, there is an offsetting effect due to possible economies of agglomeration across several subcenters in proximity to each other. Thus the net effect of this variable could be in either direction. We tried several values of $(1/\gamma)$ covering a range of inter-center distances, from 2 to 20 miles, the results reported are for $(1/\gamma) = 5$ miles, which gave a slightly better fit than other values tried.

3.3 Hypotheses related to transportation facilities

In addition to providing access to the labor force, transportation facilities provide access to markets within and outside the region. We expect that access to the air transport network and access to the regional highway system may be important factors in explaining subcenter growth. We do not consider access to the rail transport system because of its very limited role in passenger transport and most goods movements in this region.

Proximity to airports. Accessibility to airports may be advantageous to many firms, especially those that participate in frequent national or international transactions. Proximity to airports should therefore facilitate subcenter growth. The most important airport is Los Angeles International (LAX). Because this airport is located on the Pacific Ocean, however, proximity to LAX may also capture environmental amenities associated with the ocean, such as milder climate and better air quality, to the extent that these are not already captured indirectly by the labor-force accessibility measures.

Each of the three next largest airports in the region is a hub for a large amount of business travel from major subregions. In order of size they are Ontario (in San Bernardino County, serving the eastern part of the region), John Wayne (in Orange County, serving the southern part), and Burbank, serving the north and northwest (see Fig. 1). We therefore expect proximity to these airports to affect subcenter growth.

Accessibility to the expressway system. Our measures of accessibility to labor force and other employment, described above, depend solely on distance. Accessibility is further enhanced if the center in question has easy access to the region's extensive system of limited-access highways, locally called “freeways.” We test the role of freeway accessibility with a variable constructed manu-

ally from road maps and a list of freeway segments in existence in 1970. For each zone in the subcenter in question, we measure the distance from the zone center to the nearest freeway entrance. For subcenters containing more than one zone, we then average these distances, weighting by the zone's area. The result is an approximation to the average distance from each unit of land in the subcenter to a freeway entrance.

4. Results

Table 2 lists variable names and definitions, and presents selected means and standard deviations. Standard deviations for several variables are quite small, especially for our measure of relative labor force accessibility and the two industry composition variables. Among the transportation access measures we note that mean distance from an airport is quite long (nearly 25 miles for Los Angeles International, and over 17 miles for the nearest secondary airport), while mean distance to the nearest 1970 freeway entrance is quite short, at 1.2 miles, with most centers within 2 miles of a freeway entrance.

Based on the hypotheses outlined in the previous section we have estimated regression models explaining the ten-year growth rate of total employment across our sample of 32 subcenters. As a starting point, Table 3 shows the results for two models: the first explaining absolute growth ($\lambda = 0$) and the second explaining fractional growth rate ($\lambda = 1$). Although initial subcenter employment E is not statistically significant, its signs in these regressions suggest that large subcenters experience more growth in absolute terms, but less in proportional terms, than small subcenters.

Models with these same variables were estimated for each value of λ in the interval from 0 to 1, in increments of 0.1. In each case, a likelihood function was calculated as the probability of the observed values of ΔE given each estimated model. This was done by using the definition of the dependent variable,

$$y_m = \frac{\Delta E_m}{E_m^\lambda}, \quad (6)$$

where m represents a subcenter, to transform the probability density $f(y_m)$ of the dependent variable into a probability density $g(\Delta E_m)$ of the absolute employment growth. The relationship⁷ is simply

⁷ This relationship is determined by the requirement that a small change in ΔE_m , written $d(\Delta E_m)$ and the corresponding change in y_m written $dy_m = d(\Delta E_m)/E_m^\lambda$, encompasses the same probability mass: i.e. that $f(y_m)dy_m = g(\Delta E_m)d(\Delta E_m)$.

Table 2
Variable definitions with selected means and standard deviations

Name	Definition	Mean ^a	Standard Deviation ^a
$\Delta E/E'$	Measure of 1970–80 subcenter employment change (dependent variable)	0.261	0.199
DUMRIVSB	Dummy variable = 1 for Riverside and San Bernardino centers	0.063	0.246
E	1970 employment	24769.00	25391.00
DENS	1970 employment density within subcenter boundaries (emp/acre)	15.93	6.07
PEAKDENS	1970 employment density within the highest density zone	18.43	8.57
INDMIX	$\Delta E^p/E'$ predicted growth, based on sectoral regional averages	0.260	0.092
DIV	$[-\sum_i S_i \log S_i] / [-\log S_1]$ measure of employment diversity	0.693	0.216
DISTCBD	Distance to Los Angeles CBD (miles)	19.38	13.86
PROXCBD	1/DISTCBD		
B/E'	Measure of relative labor force accessibility	0.956	0.158
H/E'	Competing destinations labor force accessibility	21.23	22.58
DISTLAX	Distance to Los Angeles International airport (miles)	24.72	17.85
PROXLAX	1/DISTLAX		
DISTAIR	Distance to nearest secondary airport (miles)	17.48	8.22
PROXAIR	1/DISTAIR		
DISTFREE	Average street distance from zones comprising subcenter to nearest 1970 freeway entrance (miles)	1.226	0.684
PROXFREE	1/DISTFREE		

^a Values shown are for $\lambda = 1$ (i.e., dependent variable is 10-year growth rate)

$$g(\Delta E_m) = \frac{f'(y_m)}{E'_m} \quad (7)$$

Taking the logarithm and adding over observations m yields the adjustment factor

$$-\lambda \sum_m \log E_m = -\lambda \cdot 315.347, \quad (8)$$

which must be added to the log-likelihood value computed by the regression program for the dependent variable in Eq. (6). We find the best fit, as measured by this adjusted log-likelihood value,⁸ at $\lambda = 0.5$. Therefore we proceed to investigate models using the dependent variable in Eq. (1) with $\lambda = 0.5$.

Our base model, shown in the first column of Table 4, contains what we consider the most successful version of each of the hypotheses. Success here is judged by best overall fit and by robustness to variations in specification of other variables. All other models reported in Table 4 are variations on this specification. Because of considerable searching over alternative specifications, the assumption of a known model and specification, which underlies classical tests of statistical significance, does not hold precisely true; standard errors are therefore somewhat higher than those shown. This caveat applies, of course, to virtually all statistical analysis in the social sciences.

We discuss the results for each hypothesis in turn.

⁸ Vuong (1989) provides a justification for using likelihood value to compare non-nested models, including models with different dependent variables. He also provides a formal hypothesis test for superiority of one such model over another, which we have not computed here.

Size of center: Employment size E has a small and statistically insignificant effect on growth in these equations. When its square is also entered, as in regression Eq. (4) in Table 4, considerably higher t-statistics are obtained but neither coefficient is significant. Furthermore, other coefficients (notably those of variables indicating location within the region and labor-force accessibility) change and become rather unstable with respect to minor changes in specification. We conclude that no effect of initial size on employment growth is discernable in these data other than that inherent in the dependent variable itself, and we adopt the simpler specification of regression Eq. (3) for our base model.

The effect implied by this form for the dependent variable, namely $\Delta E/(E^{0.5})$, is plausible in direction. Other variables held constant, absolute employment growth increases with initial employment, but less than proportionally – consistent with Table 3. This could occur if there are some economies of agglomeration tending to focus the growth of the metropolitan area into existing centers, but they are offset by increasingly severe diseconomies as centers become larger. During the decade, total employment in our sample of subcenters grew by 25%. This is slightly less than the 32% growth in the entire region, but it is larger than would be expected if new development were being added only at the periphery. Therefore it seems likely that local agglomeration economies have persisted, but that subcenter growth is eventually limited by congestion, other scale diseconomies, or land scarcity.

Density of center: Our hypothesis that low employment density permits more growth receives no support.

Table 3
Preliminary regression analysis of subcenter growth rates

Dependent variable	(1)	(2)
	ΔE	$\Delta E/E$
A coefficient	0	1
Constant	12774 0*** (3732 0)	0 368 (0 371)
DUMRIVSB	10747 0** (4595 0)	0 498* (0 258)
<i>Size and density of centers</i>		
E	0 282 (0 212)	-1 51 $\times 10^{-6}$ (1 62 $\times 10^{-6}$)
DENS	-172 7 (134 5)	-0 0040 (0 0078)
<i>Types and diversity of industries</i>		
INDMIX [$\Delta E^p / (E^A)$]	2 088*** (0 368)	1 240** (0 442)
DIV	-7454 0 (3867 0)	-0 118 (0 217)
<i>Location within region</i>		
PROXCBD	-20540 0 (20384 0)	-2 376* (1 317)
<i>Labor-force accessibility</i>		
B/E^A	-0 622** (0 267)	0 085 (0 371)
<i>Accessibility to transportation facilities</i>		
DISTLAX	-165 4** (77 5)	-0 00970** (0 00431)
PROXAIR	37126 0*** (11051 0)	1 336** (0 642)
PROXFREE	-2622 0 (1663 0)	-0 053 (0 095)
R -squared	0 8995	0 4114
S E of regression	3288 0	0 1852
S D of dep variable	8535 0	0 1987
Log Likelihood ^a	-297 801	-296 583

(Standard errors in parentheses)

^a Computed from Eq (8)

* Coefficient is significant at 10% level

** Coefficient is significant at 5% level

*** Coefficient is significant at 1% level

given the very low statistical significance of the employment density variable DENS. Using the alternative variable PEAKDENS, related to the highest-density zone within the subcenter, did not alter this result. The lack of significance of the density variable suggests that by and large, these subcenters are not disadvantaged by inadequate opportunities for expansion.

Industry composition The industry-mix prediction for growth, formed from ΔE^p of Eq (2), is the most statistically significant of our variables in explaining growth. A subcenter's growth is closely associated with the regional growth rates of its industries. The coefficient on this variable is somewhat greater than one (1.59, with standard deviation 0.43), possibly indicating that any local employment changes caused by regional trends are

somewhat magnified by the dynamics of subcenter development. Furthermore, this variable has the largest standardized coefficient of all variables in the base model, indicating that differences in industry mix play a substantial role in explaining variation in growth rates across the sample.

This result is not as predictable as it might seem because there are a number of results in the literature showing that industry-mix effects are almost always swamped by other factors in explaining differential growth rates of metropolitan areas, cities, and even parts of cities.⁹ In fact, the only other statistical study we know in which industry mix is found to be important is that by Doeringer et al (1987, pp 21-27) of employment growth across states and across labor market areas with Massachusetts.

We tried a number of variables representing concentrations in specific industries, but none were statistically significant in explaining subcenter growth. That is, once the industry mix component of shift-share analysis is accounted for, we were unable to detect any industry groups that have especially favorable or unfavorable effects on subcenter growth.

Diversity of economic base This variable is negative but not significant at even a 20% significance level. Its negative sign is consistent with the hypothesis of economies of localization: centers specialized in only a few of our ten sectors tend to grow slightly faster than more diversified centers. It is possible that our industry sector data is not detailed enough to reflect industry specialization.

Location in the overall Region There is weak evidence that proximity to the central business district, as measured by the inverse of the distance to the CBD, may diminish subcenter growth. The proximity variable is negative and significant at the 10 percent level in regressions (2), (4) and (6). This conclusion is tentative because such proximity is closely correlated with relative labor-force accessibility, as further discussed in the next subsection.

Relative labor-force accessibility Our base model uses relative labor-force accessibility B , scaled to be in the same units as the dependent variable. This variable, $B/E^{0.5}$, is statistically insignificant in every regression except Eq (1), where it has an unexpected sign. We tried other versions of the variable, including using a smaller interaction distance and not dividing it by E' , with no better success. We also tried the variable A , the measure of absolute labor-force accessibility, without success. Neither did our test of the competing-destinations hy-

⁹ See for example, Danson et al (1980), Bradbury et al (1982, pp 126-139), Merrifield (1983), and Lever and Mather (1986).

glomeration economies, it just means that their nature is different in this metropolitan context. And again, while Los Angeles is probably more prone to producing dispersed region-wide agglomeration economies than are most metropolitan areas, this is a pattern that is likely to become more common in the future.

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Appendix A

A.1 Variable list

Size of center

1a E 1970 employment within subcenter boundaries

1b $\log(E)$ natural logarithm of 1970 employment

1c E^2 square of 1970 employment

Density of Center

2a DENS 1970 employment density within subcenter boundaries (employees per acre)

2b PEAKDENS 1970 employment density within the highest-density zone

Industry composition

3a INDMIX $\Delta E^P/E'$, where λ is the same quantity as in Eq (1), and ΔE^P is the "predicted" employment change, based on the regional-growth and industry mix effects of shift-share analysis, as in Eq (2)

Diversity of economic base

4a DIV $[-\sum S_i \log S_i]/[-\log \bar{S}]$, where S_i is the share of the subcenter's employment (excluding agriculture, mining, and construction) in industry sector i , and \bar{S} is the inverse of the number of sectors

Location in the overall region

5a DISTCBD distance to Los Angeles CBD (miles)

5b PROXCBD $1/\text{DISTCBD}$

Labor force accessibility

6a Relative labor force accessibility B/E' , where B is as defined in Eq (4), and $\beta = 1/10$ 81

6b Absolute labor force accessibility A/E' , where A is defined as in Eq (3)

6c Competing centers labor force accessibility H/E' , where H is as defined in Eq (5)

Proximity to airports

7a DISTLAX distance to Los Angeles International Airport (miles)

7b PROXLAX $1/\text{DISTLAX}$

7c DISTAIR distance to the nearest of the three main secondary airports (in miles)

7d PROXAIR $1/\text{DISTAIR}$

Accessibility to expressway system

8a DISTFREE average street distance from the subcenter's zones to the nearest freeway entrance existing in 1970 (miles)

8b PROXFREE $1/\text{DISTFREE}$

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