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The Influence of Metropolitan Spatial Structure on Commuting Time*

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INTRODUCTION

The monocentric city ultimately becomes inefficient as urban growth continues because of increasing congestion close to the CBD. Although the exhaustion of CBD agglomeration economies is another major reason for the breakdown of monocentricity, these congestion costs are sufficient grounds alone for the emergence of the policentric metropolitan region. Theoretical models of the policentric city usually imply shorter commuting times because of the assumption that households in choosing residential locations cluster around employment subcenters to minimize commuting trips. However, in a world of multiple economic sectors that are not uniformly dispersed, heterogeneous labor, and residential neighborhood differentiation, workers may commute across metropolitan areas so that average trip times could become longer rather than shorter. Which of these outcomes is more prevalent is an empirical question that has not received much attention.

Apart from the number of major employment centers, commuting times are also influenced by city size and metropolitan density. However, at the level of descriptive analysis the relationship between city size, population density, and travel time is not clear-cut. For example, Table 1 shows these data for the 19 urbanized areas with population densities greater than 3500 persons per square mile and for the 20 largest urbanized areas (7 of the cities are members of both groups). New York is an outlier with the longest average commute (32.3 minutes) combined with a very low value for vehicle miles traveled (VMT) per capita, suggesting severe congestion. The eight

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TABLE 1

Densities, Mean Travel Time, and Daily VMT per Capita in Urbanized Areas with Population Density Greater than 3500 and Top 20 Cities, 1980

Urbanized area	Urbanized area pop. density	Urbanized area pop. ($\times 10^3$)	Mean travel time	VMT per capita
New York	5552.6	15,591.7	32.3	10.9
Los Angeles	5188.6	9,479.6	24.1	14.3
Salinas	4860.8	82.6	15.8	10.3
Miami	4730.0	1,608.2	23.7	15.7
New Orleans	4689.4	1,078.6	25.1	9.9
Chicago	4525.8	6,779.7	28.3	14.0
Laredo	4319.9	95.0	16.9	9.2
Honolulu	4313.9	582.4	21.4	11.8
Philadelphia	4052.5	4,113.3	26.0	12.1
San Francisco	4008.6	3,190.8	25.2	17.0
Champaign–Urbana	3905.0	109.3	14.0	10.0
Kenosha	3899.2	85.8	16.2	10.0
San Jose	3816.1	1,244.0	22.7	14.8
Buffalo	3768.0	1,002.3	19.1	13.7
State College	3662.9	51.3	13.2	n.a.
Detroit	3648.7	3,809.2	22.9	17.0
Erie	3566.8	178.3	16.0	11.1
Boulder	3536.3	81.3	18.3	15.9
New Bedford	3505.0	133.2	16.8	12.1
Washington, D.C.	3424.4	2,763.5	28.1	17.2
Baltimore	3356.2	1,755.3	26.3	11.0
Boston	3126.5	2,679.4	23.1	15.5
St. Louis	3096.1	1,848.4	22.6	n.a.
Seattle	2874.0	1,393.9	22.6	17.3
San Diego	2789.8	1,704.5	19.4	14.9
Cleveland	2786.0	1,752.4	23.3	17.7
Pittsburgh	2538.9	1,810.2	23.2	14.3
Houston	2299.5	2,412.2	26.2	20.6
Phoenix	2198.2	1,409.0	21.7	11.5
Dallas–Fort Worth	1915.1	2,451.3	22.4	21.6
Minneapolis	1824.5	1,788.0	19.6	16.6
Atlanta	1782.9	1,613.6	25.3	14.5

Note. Source: U.S. Department of Transportation, Federal Highways Administration, *Transportation Planning Data for Urbanized Areas Based on the* 1980 *Census*, Washington, DC (January 1985).

small, densely populated urbanized areas with populations less than 200,000 have the lowest mean travel times and relatively low VMTs per capita. With these exceptions, however, the relationship becomes much more blurred. High values for mean travel time are not confined to the large densely populated cities (such as Chicago) but are also found in less dense metropolitan areas such as Houston (the runner-up to Dallas in terms of VMT per capita). Only three of the million-plus cities (Buffalo, San Diego, and Minneapolis) have mean travel times less than 20 minutes. To the extent that generalization is possible, commuting times tend to be longer in large cities than in small, but the impact of density is obscure. Much depends on the specifics of the metropolitan spatial structure, and population density is a very poor proxy for this.

A specific incentive for this study is the availability of a new data source on metropolitan land use from the U.S. Geological Survey's LANDSAT file. This permitted estimates to be made of residential densities (i.e., total population/residential land), industrial densities (i.e., manufacturing workers/ industrial land), and commercial densities (i.e., commercial workers/ commercial land). The land use data were available at the county level for 12 states (eventually, data will be available for the whole country). These data were aggregated into 91 SMSAs for this research, subsequently pruned to 82 SMSAs for which income data were available.

The residential density estimate available from this source is much superior to the alternative previously used. Dividing total SMSA population by total SMSA land area gives gross residential density, an easily accessible measure but a misleading one. Density gradient parameters (city center density and the slope of the density gradient) are reliable only if the city is monocentric and displays radial symmetry, conditions that are satisfied in few, if any, U.S. cities.

DENSITIES

The a priori relationship between residential densities and mean travel time is unclear. On the one hand, the impact of residential density on the length of work trips is ambiguous. In a monocentric city high densities imply shorter trips, and low densities mean longer trips. In a policentric city, low densities could mean either shorter or longer trips depending upon whether workers choose homes around employment subcenters (or, alternatively, firms decentralize to locations close to the areas from which their labor forces are drawn) or whether cross-commuting across metropolitan areas is common. In a study of the Los Angeles metropolitan region average intracounty commuting distances in the peripheral counties were found to be only 28–43% of those in the core region of Los Angeles County [4, pp. 170–171]. On the other hand, high densities would tend to be associated with high mean travel times because of the effects of congestion. The net effect of residential density on travel time has to be determined empirically.

The effects of employment densities on commuting patterns also have to be considered. A distinction has to be drawn between commercial and industrial densities because their locational distribution differs [10]. High commercial densities imply a heavy CBD concentration of office workers. The greater this concentration the more likely that traffic congestion will increase mean travel times. Manufacturing tends to be predominantly located in suburban areas, and high industrial densities imply subcenter clustering of manufacturing jobs. But the density levels are much lower absolutely than with office employment, and any congestion impact should be minimal. The effect of industrial densities on work trip length, however, depends upon whether manufacturing job clustering induces travel-to-work minimizing residential location behavior (and a dispersed job pattern means a high degree of accessibility to jobs) or whether high manufacturing densities imply substantial cross-commuting (and job dispersion means longer work trips). The problem is that our knowledge of suburban commuting patterns is so sketchy that there is no a priori expectation of the answer to this question.

URBAN SIZE

Mean travel times may be expected to be longer in larger cities, even in cases where their spatial structure is policentric. The only exception to this generalization would be if there was a critical city size at which cities switched from being monocentric to policentric, at which point travel times would dramatically fall. However, there is little evidence for this critical size; the conditions under which the shift from monocentricity to a policentric pattern occurs vary widely from case to case. The two obvious scale variables are urbanized area population and the urban land area. The latter is preferred because spatial extent has a more direct effect on trip length (and hence on travel time) than population size.

DECENTRALIZATION AND POLICENTRICITY

The influence of the macrospatial structure of urban space on travel time is an interesting question, but one which is difficult to answer because of the absence of cross-sectional data for measuring spatial structure. In this paper we have chosen a simple variable, CITYEMP, to measure the degree of monocentricity of a SMSA. This variable is the proportion of SMSA employment found in its largest city; in cases where there is only one city the variable takes the value of 1.00. Of course, this measures the degree of monocentricity better than it measures policentricity because modest values

> 0.5 could be found in duocentric cities.[1] Once again, there is no a priori expectation of the sign on this variable unless assumptions are made about how decentralization influences the length of work trips (and travel times). However, holding city size constant, for a nonmonocentric, such as a policentric,[2] city to have longer travel times than a monocentric city, workers would have to commute from one side of the city to another. This finding would be inconsistent with the conventional theory that commuting cost savings are one of the benefits of decentralization [8, 11].

ECONOMIC STRUCTURE

The economic structure variables used in this study are the proportion of workers in industrial employment (INDEMP) and in commercial employment (COMMEMP). The hypothesis is that the spatial distributions of industry and commerce are different and that these differences influence mean commuting times. One possible hypothesis is that the higher the share of industrial employment the more suburbanized the distribution of jobs (because manufacturing is more decentralized than commerce), and that

[1]There are some alternative measures, none fully satisfactory. In earlier research [4], we used the Wright coefficient (a modification of the Gini coefficient that solves the problem of detecting upper and lower tail skewness) relating the frequency distribution of employment to that of area, but this is an employment dispersion measure not an index of policentricity. Erickson [3] uses the *number* of suburban nucleations, defined in terms of suburban municipalities with 5000 or more jobs in manufacturing, retail trade, wholesale trade, and selected service industries. This is not convincing because employment subcenters do not conform to municipal boundaries and the small employment threshold of 5000 jobs might easily be dispersed over a spatially large municipality without an employment cluster. A better approach, although it would be a major task to obtain a large sample of SMSAs, would be to identify contiguous clusters of high-employment-density Census tracts from the 1980 Census. But, the degree of policentrism is not merely a matter of the number of subcenters but also of their relative size. It might be measured more satisfactorily by applying a version of the H index, used in interurban analysis by Henderson [7] and Wheaton and Shishido [14] in an intrametropolitan context. The H index is a sum-of-squares relative share measure, and in this case would be

$$H = \sum_{i}^{n} (E_i/E)^2,$$

where E_i = employment at node i (including the CBD) and E = sum of employment at all the nodes. The advantage of the H index is that it reflects both the *number* of nodes and their *relative size*. Even better would be to take account of the relative spacing of the nodes by using a spatial variant of the H index as suggested by Yim [16]. In this case it would imply substituting an employment potential measure for each node, V_{E_i}, for E_i in the H index as defined above.

[2]However, "the rise of dispersed nonmonocentric forms with weak subcenters may be more characteristic of spread than of polycentrism" [5, p. 662].

this offers more opportunities for economizing on commuting times. However, this hypothesis could be tested more directly by adding a variable measuring the suburban share of SMSA employment in manufacturing. When such a variable was added, the equations changed little and the coefficient on the variable itself was positive, contradicting the hypothesis, and was statistically insignificant. The positive sign is consistent, however, with the old job mismatch theory that manufacturing jobs tend to be located in the suburbs and the workers located in the central city. However, our alternative hypothesis for a negative association between industrial-oriented cities and commuting times conflicts with the job mismatch hypothesis. In cities with a proportionately larger industrial base, often older cities, the industries are more likely to be located in areas with major detractions such as pollution, toxic wastes, and visual blight with the result that residential rent gradients around these areas are quadratic with negative externalities outweighing the desire for accessibility close by. Thus, these areas are low-rent residential areas inhabited by blue collar workers who as a result have short commutes. "Clean" industries without a repelling effect are more likely to be found in cities with more modest industrial employment shares.

The more service-oriented, and especially the more office-oriented a city is, the stronger the tendency to economize on commuting times. The explanation is that office buildings, some of which can be very attractive, do not repel residents because of negative externalities to the same extent as factories, if at all. Probably, the only major negative externality around an office zone is traffic congestion. The expectation, therefore, is that the sign on the COMMEMP variable will be negative. The tendency for residential clustering around office zones will be stronger in the newer office subcenters and the higher the income of the labor force (the so-called "urban village phenomenon" [9]).

INCOME

The influence of income on commuting times has been extensively explored, although usually in the context of the standard monocentric model. When income differentials are introduced into a model where housing space and composite consumption are the sole arguments of the utility function and commuting costs per mile are the same for all income groups, the rich must live further out than the poor. The explanation is that income net of commuting cost is larger for the rich, and that housing expenditures increase with income. The rich would consequently consume more housing space at any location, and since the marginal change in commuting costs is invariant with income, rents have to decline with distance for the locational equilibrium condition to hold. The rich therefore consume more housing space at lower land rents and live further out than the poor. Thus, commuting times increase with income.

However, the result may be different in other versions of the model. For example, in the Alonso model [1] distance enters the utility function negatively, and people prefer to live closer to the work place. The location of the wealthy in this case is not as clear-cut. However, Pines [12] showed that in most cases an income elasticity of demand for space greater than unity is a sufficient condition for the rich to live peripherally and to endure longer commuting times. But if the demand for space is income inelastic, the result is ambiguous [2]. Much depends upon the assumptions about the value of travel time. If the marginal disutility of commuting increases with distance, and/or if the rich value travel time at a higher proportion of the wage rate than the poor, the wealthy may live centrally. More specifically, if the income elasticity of commuting cost rises faster than the income elasticity of demand for housing space, commuting times will be lower for high-income groups.

In his well-known paper on this topic, Wheaton [13] presented results suggesting that the income elasticity of land consumption is approximately equal to the income elasticity of travel cost (including commuting time). This implies that "spatial bidding for land by different income groups looks almost identical" [13, p. 630]. His analysis successfully casts doubt on the standard result in the monocentric model that the rich live more distant from work than the poor but does not establish the opposite, that the rich live closer to work. However, Wheaton's results are far from conclusive. His data are not recent, and his analysis assumes a monocentric model and evaluates results at one point (4 miles from the CBD where he assumes the bid-rent functions intersect). Moreover, in a general equilibrium simulation he shows that location patterns are sensitive to changes in parameter values, such as changes in the characteristics of urban travel.

In a nonmonocentric (dispersed or policentric) city, the income effects may even be stronger because higher income households do not necessarily have to trade off commuting costs against housing space as is inevitable for locational equilibrium in the monocentric model. Higher income households have the buying power to choose the sites they prefer and the housing space they desire in the nonmonocentric city. Of course, locational considerations in addition to economizing on commuting time may influence the site choice such as neighborhood quality and clean air, but nevertheless we expect income and commuting time to be negatively and strongly correlated.

The argument that rising incomes strengthen the incentive for commuters to economize on commuting time, and that the opportunities for such economies are greater in nonmonocentric cities, is a much more general argument than the commonly assumed link between higher time commuting costs and gentrification. Gentrification is a limited phenomenon found in only a few, mostly large, cities with significant proportions of high-income professionals and potentially attractive old neighborhoods. It is unclear how important commuting economies are in explaining gentrification compared with other factors such as the quality of the housing stock, the age distribution of the population, or the educational level of the labor force. The number of households involved is probably small. Our argument is much more pervasive and could apply in any or all of our sample of 82 cities. We have examined data from the 1983–1984 Nationwide Personal Transportation Study that show tendencies for higher income groups to economize on commuting (whether measured by average trip distances, average trip times, or median trip times). These tendencies are more marked in smaller SMSAs (i.e., those with less than 500,000 people) that are less likely to be candidates for gentrification. However, in the larger SMSAs (one million plus) economizing on commuting by the higher income groups is more visible for central city than for suburban households.

CARPOOLING

The influence of carpooling upon commuting patterns in the United States is muted because of the small numbers of commuters who participate in carpools. Nevertheless, the incidence of carpooling and mean travel times can be expected to be positively related. First, carpools result in longer collection and delivery times because several passengers have more origin–destination diversity than has one passenger. Second, in cities where work trips are longer carpooling may be a response to higher commuting costs. However, this latter effect may be modest because the increase in monetary commuting costs resulting from longer work trip distances is offset by the higher time costs resulting from carpooling.

PUBLIC TRANSIT

The role of public transit in metropolitan commuting in U.S. cities remains modest, increasingly so; the proportion of commuting trips by car rose from 69.5% in 1960 to 86% in 1980. Nevertheless, it is interesting to speculate whether the determinants of public transit commuting behavior, especially the land use influences, are the same as, or different from, the determinants of automobile commuting. Because of the dominance of buses in public transit rather than a much more restricted suburban rail or subway network, the major route networks for buses and automobiles are probably similar, with secondary road access by car playing an analogous role to walking to the bus stop. This suggests that similar influences may operate on both. However, public transit is more viable when both residential and employment densities are high; thus, the density variables might be more powerful. The income effect might be weaker for public transit time if public transit commuters have, on the average, lower incomes than automobile commuters and if the value of travel time increases with income. To test these ideas, similar regressions were run with public transit mean travel times as the dependent variable with the obvious difference that the carpooling variable was excluded.

RESULTS

Regressions were run with mean commuting time[3] by automobile and public transit as dependent variables using the density, economic structure, urban size, policentricity, and income measures as independent variables, plus the addition of carpooling in the automobile commuting equations. The results for 2SLS equations showed negligible differences from the OLS results, so only the latter are reported in this paper (see Tables 2a, 2b).

Focusing on automobile commuting times first, the equation has good explanatory power (with an adjusted $\bar{R}^2$ of 0.87). Several variables are

[3] It would be useful to separate out the two components of travel time, the length of the trip and the speed of travel (reflecting the degree of congestion). The Census data are for commuting times only. An anonymous referee suggested merging the LANDSAT data file with the Annual Housing Survey data which cover both mean distance and time. Unfortunately, the degree of overlap between the two samples of cities was too small (only 15 cities were common to both samples) to permit this. However, we have undertaken some separate research on the determinants of trip lengths using the AHS data. A representative equation is

$$\begin{aligned}\text{TRIPLENGTH} = {} & \underset{(-2.55)}{-0.673} + \underset{(11.54)}{0.326}\ \text{URBAREA} + \underset{(1.88)}{0.296}\ \text{POPRAT} \\ & \underset{(-6.06)}{-0.591}\ \text{POPGRO} \underset{(-4.22)}{-0.165}\ \text{CBDRA} + \underset{(3.66)}{0.256}\ \text{JOBMIX} \\ & \underset{(6.63)}{+0.232}\ \text{DOWNER}\end{aligned}$$

$$\bar{R}^2 = 0.825,$$

where URBAREA = log(urbanized area, 1980), POPRAT = log(noncentral city share of SMSA population divided by noncentral city share of SMSA area), POPGRO = log(ratio of 1960 to 1980 SMSA population), CBDRA = log(CBD jobs/SMSA jobs), JOBMIX = log(manufacturing/total SMSA jobs), DOWNER = dummy variable for owners as opposed to renters. Some of these results, especially the URBAREA and POPRAT findings, are consistent with those reported later in this paper with travel time as the dependent variable. Others, such as the results that owners have longer commuting trips than renters and that commuting distances tend to be longer in fast-growing cities (though here the relationship is not quite statistically significant), deal with variables not used elsewhere in this paper. The negative association between CBDRA and TRIPLENGTH means very little, because travel time or some other measure of congestion would be the more relevant dependent variable in cases where relatively more jobs were centralized. The one result that conflicts with the main findings of this paper is the positive sign on JOBMIX.

TABLE 2a
List of Variables

T_{AUTO} = Mean travel time by private automobile
T_{PUBLIC} = Mean travel time by public transport
RESDEN = Residential density (total population/residential land)
COMMDEN = Commercial density (commercial workers/commercial land)
INDDEN = Industrial density (manufacturing workers/industrial land)
ULAND = Total urban land
CITYEMP = Proportion of employment in largest city of SMSA (= 1.00 in monocentric SMSA)
INCOME = Median family earnings of SMSA workers
INDEMP = Proportion of workers in industrial employment
COMMEMP = Proportion of workers in commercial employment
AUTODR = Proportion of workers driving alone

Note. Sources: With the exception of the land use data which are from the U.S. Geological Survey, all the other variables are from the 1980 "Census of Population."

TABLE 2b
Determinants of Urban Travel Time
(*t* Values in Parentheses)

Dependent variable:	T_{AUTO}	T_{PUBLIC}
Independent variables		
RESDEN	0.115	0.175
	(4.44)	(2.79)
COMMDEN	0.029	0.062
	(2.03)	(1.79)
INDDEN	−0.019	−0.043
	(−1.96)	(−1.79)
ULAND	0.154	0.205
	(14.93)	(10.02)
CITYEMP	0.224	0.254
	(3.62)	(1.75)
INDEMP	−0.072	−0.314
	(−1.96)	(−3.43)
COMMEMP	−0.177	−0.907
	(−1.39)	(−2.94)
INCOME	−0.200	−0.320
	(−2.56)	(−1.68)
AUTODR	−0.256	—
	(−3.14)	
$\bar{R}^2$	0.87	0.61
N	82	82

highly significant; others are marginally so. Where the theory is clear-cut as in the case of urban size (ULAND), INDEMP, COMMEMP, income, and carpooling (AUTODR), the coefficients have the expected signs. Commuting times are indeed longer in spatially large cities, and the ULAND variable has the most potent effect of any variable. The negative sign of the INDEMP coefficient supports the hypothesis that worker housing is located close to industrial sites because negative externalities make these residential areas unattractive for higher income households. The sign on the commercial employment variable is negative, in line with the argument that the absence of negative externalities around office workplaces implies no offset to the desire for accessibility, but the coefficient is insignificant. Income and commuting time are negatively associated, consistent with the hypothesis that high-income households have a strong incentive to economize on commuting. Finally, the AUTODR variable has a negative sign; mean commuting times tend to be longer where the incidence of carpooling is higher. Moreover, despite the modest extent of carpooling in American cities the variable is statistically significant.

The more interesting results refer to the variables for which there were alternative hypotheses of how they influence commuting times. Residential densities and commuting times are positively associated, and the relationship is statistically significant. This supports the argument that low-density metropolitan areas with their decentralized employment centers facilitate short work trips. It also highlights the limited value of the monocentric city model, because high densities imply shorter trips in a monocentric city unless congestion effects are strong. The congestion factor may play a role here, but it is more likely to be associated with high nonresidential than with residential densities.

The nonresidential density variables (COMMDEN and INDDEN) in the model have opposite effects. The sign on the COMMDEN variable is positive while that of INDDEN is negative, with both variables on the margin of statistical significance. The COMMDEN results are indicative of the congestion that develops around office zones, while the INNDEN results support the hypothesis that manufacturing clustering permits commuting economies.

The coefficient on the CITYEMP variable is positive and highly significant, confirming the hypothesis that monocentricity adds to commuting times. All the results of this analysis are mutually reinforcing in their implication that policentric or dispersed spatial structures reduce rather than lengthen commuting times. Hence, the prediction of the policentric theorists, that commuting cost savings are among the benefits of decentralization, stands up to empirical scrutiny.

This result conflicts with the finding of Hamilton [6, p. 1042] that "decentralization of employment (the movement of jobs closer to people) has paradoxically resulted in no saving in total commuting." However, it is important to understand precisely the basis for Hamilton's argument. It is derived from the observation that the mean commute in a sample of U.S. cities is about equal to the "required" or "optimum" average commute if all jobs were located in the CBD (about 8.7 miles). By measuring commuting in terms of distance this comparison is misleading, because travel times would be much greater in a monocentric city with all jobs centralized as a result of congestion, and these congestion effects would increase with city size. Hamilton goes on to consider the situation when job decentralization occurs, and to define the mean optimum commute in this case as the difference between the mean required distance when all jobs are located in the CBD and that in the decentralized case, citing the argument "that displacement of a job from the CBD can save the worker a commute equal to the distance between the job and the CBD" [6, p. 1040]. The excess of the actual commute over this mean optimum commute implies a command-economy type of allocation where people are directed to houses and jobs independently of their wishes. It makes sense only if economizing commuting distance was the only factor in location decisions. A modest increase in commuting may be acceptable if it permits a household to satisfy its locational needs with respect to neighborhood, fiscal jurisdiction, environmental quality, ethnic preferences, and other externalities, and cannot in consequence be meaningfully described as "wasteful."

We give a very different interpretation to the conclusion that mean actual commuting distance is the same as commuting-minimizing distance in the jobs-centralized model. It suggests that households can save on commuting costs and time and buy the bundle of residential and neighborhood services they desire in the real-world dispersed or policentric city without having to commute a longer distance than in the CBD-oriented city. Moreover, the finding that the actual commuting distance is less than 72% of the hypothetical (and underestimated) random commute suggests that households make strong attempts to economize on commuting, because random commuting is consistent with the hypothesis that there is "extreme homogeneity of *both* jobs and houses" [6, p. 1050] and the complex variety of influences impacting on residential and employment location decisions.

These arguments are not intended to undermine the significance of Hamilton's research. We believe that the title of the paper "Wasteful Commuting" and the discussion of mean optimum commutes detracts from the main, and critically important, message that "the monocentric model does an almost unbelievably bad job of predicting commuting behavior in samples of U.S. and Japanese cities" [6, p. 1036]. This is hardly surprising, however, because the pure monocentric model assumes that all jobs are located in the CBD whereas the mean proportion of SMSA jobs in the CBD in Hamilton's sample of 14 cities is 8.2%, and the range is between 3.8% in

San Diego and 11.1% in Columbus [15]. Most jobs in the typical U.S. city are located outside the CBD, and an increasing proportion are in the suburbs rather than in the central city. Any interpretation of commuting behavior that rests upon the assumption of a monocentric city with jobs heavily centralized is bound to be misleading.

The equations for public transit travel time generated results that were qualitatively similar to those for automobiles. The adjusted $\bar{R}^2$ drops to 0.61, and some of the variables that were formerly significant become insignificant, and vice versa. But the signs on the coefficients are identical. The most striking difference between the two types of transportation is that CITYEMP and INCOME become insignificant for public transit while INDEMP and COMMEMP become significant. The weaker income effect is understandable in view of the lower incomes of public transit commuters, while the CITYEMP result may indicate that the speed of travel differential between monocentric and nonmonocentric cities may be narrower for public transit than for automobile commuting. The greater significance of the employment variables may reflect an increase in the frequency of public transit service in cities that are strongly manufacturing-oriented and/or office-oriented. However, the differences between the public transit and automobile results are less notable than their similarities. A surprising finding was the failure of the nonresidential density variables to have more of an impact than in the case of automobile commuting. Both public transit users and automobile commuters appear to adapt to land use variables, metropolitan spatial structures, urban size, and the composition of economic activity in much the same way. The role that commuting cost minimization plays in residential location decisions seems little different for public transit users than for automobile commuters.

CONCLUSION

The cross-sectional results of this paper help to resolve some of the unsettled questions about the effects of metropolitan spatial structure on commuting behavior. Policentric and dispersed metropolitan areas facilitate shorter commuting times as predicted by theory. The density results illustrate the need to discriminate among the types of density. Low residential densities and high industrial densities favor commuting economies, a finding consistent with the idea that the clustering of manufacturing activities, especially "clean" industries at decentralized employment centers, in low-density metropolitan areas implies a spatial structure conducive to residential site choices with shorter commuting times. The positive correlation between commuting times and commercial densities, on the other hand, indicates the persistence of congestion around office zones, often centrally located; the high labor–land ratios associated with office employment create a major traffic burden on surrounding streets. The influence of other variables (city size, economic structure, income, and carpooling) is as expected. The similarity of the results for public transit users suggests that they are as sensitive as automobile commuters to the benefits from commuting economies.

REFERENCES

1. W. Alonso, "Location and Land Use," Harvard Univ. Press, Cambridge, MA (1964).
2. M. J. Beckmann, Equilibrium models of residential location, *Reg. Urban Econom.*, **3**, 361–368 (1973).
3. R. A. Erickson, Multinucleation in metropolitan economies, *Econom. Geography*, **76**, 331–346 (1986).
4. P. Gordon, H. W. Richardson, and H. L. Wong, The distribution of population and employment in a policentric city: The case of Los Angeles, *Environ. Planning A*, **18**, 161–173 (1986).
5. P. Gordon and H. L. Wong, The costs of urban sprawl: Some new evidence, *Environ. Planning A*, **17**, 661–666 (1985).
6. B. W. Hamilton, Wasteful commuting, *J. Polit. Econom.*, **90**, 1035–1053 (1982).
7. J. V. Henderson, "A Framework for International Comparisons of Systems of Cities," World Bank, Urban and Regional Report 80-3, Washington, DC (1980).
8. L. B. Lave, Urban externalities, "Papers from the Urban Economics Conference 1973," Vol. 1, pp. 37–95, Centre for Environmental Studies, Conference Paper 9, London (1974).
9. C. B. Leinberger and C. Lockwood, How business is reshaping America, *Atl. Monthly*, **258**, 43–52 (1986).
10. M. K. Macauley, "Recent Behavior of Urban Population and Employment Density Gradients," Department of Economics, WP 124, Johns Hopkins University, Baltimore (1983).
11. T. Miyao, "The Optimum Number of Business Districts in a Square City," mimeo, Department of Economics, University of Southern California, Los Angeles (1977).
12. D. Pines, On the spatial distribution of households according to income, *Econom. Geography*, **51**, 142–149 (1975).
13. W. C. Wheaton, Income and urban residence: An analysis of consumer demand for location, *Amer. Econom. Rev.*, **67**, 620–631 (1977).
14. W. C. Wheaton and H. Shishido, Urban concentration, agglomeration economies, and the level of economic development, *Econom. Dev. Cultural Change*, **30**, 17–30 (1981).
15. United States Bureau of the Census, "Journey to Work: Metropolitan Commuting Flows," U.S. Government Printing Office, Washington, DC (1984).
16. C. Yim, "Spatial Population Concentration and Sociospatial Inequality Changes in the Development Path: The Case of Korea, 1960–80," Ph.D. dissertation in Urban Planning, Harvard University, Cambridge, MA (1985).