Chapter 4: Spatial Structure and Travel

Trends in Commuting and Non-Commuting Travel in US Metropolitan Areas

Peter Gordon

University of Southern California

Bumsoo Lee

University of Illinois, Urbana-Champaign

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I. Introduction

The economist Robert Lucas famously noted that, once you start thinking about economic growth, it's hard to think about anything else. Those who think about cities also think about economic growth, to the point that describing cities as the "engines of growth" is almost a cliché. Paul Romer, perhaps the father of modern economic growth theory, has launched his Charter Cities project which recognizes that the most promising option for lagging economies is successful cities. He seeks to foster well run big cities as "opportunity zones especially for the working poor."[i]

Human capital, entrepreneurship and creativity, Julian Simon's (1995) "ultimate resource,"[ii] are most potent when ideas can be exchanged. But some analysts simply tout the advantages of proximity to a "knowledge base" found in cities. This is misleading. Knowledge is highly fragmented, specialized, and dispersed. Various locators seek the peculiar benefits of interactions with highly specialized sources of ideas. Urban districts and clusters of specialized firms and outlets are well known. Matt Ridley (2010) has famously discussed human progress this way: "I believe that at some point in human history, ideas began to meet and mate, to have sex with each other." This was surely not casual or random sex. It refers to specific interactions involving specific proximities. But this denotes complex spatial organization.

Tyler Cowen and Alex Tabarrok (2010) have summarized much of what we know about growth economics in one schematic (Figure 1). Whereas they cited the importance of "organization" at the center of his chart, they did not cite *spatial* organization. Our analysis in this chapter addresses spatial organization which many commentators seemingly over-simplify when they apply generic urban form types such as "urban sprawl" or "compact development". But even these are not easily defined.[iii]

Does city size or the city's spatial organization matter with respect to productivity, competitiveness and growth? Both matter and you cannot have one without the other. When activities are concentrated in space, there is an opportunity for economizing with respect to transactions costs *and* at the same time with respect to many *realized* positive and negative externalities.[iv] But both types of interactions are vis a vis many activities spread over many locations. In fact, cities exist and survive because they manage to find the spatial organization whereby the positive advantages, including those transacted as well as those not (the positive externalities), dominate. Whereas analysts contrast and compare Marshallian specialization externalities (between firms in the same industry) with Jacobsian diversification externalities (between firms not necessarily in the same industry) (Glaeser et al., 1992), both of them occur and land markets sort out which ones are best *realized* in which situations.

Within the U.S., the near stability at the top of city-size rankings suggests that the big metropolitan areas manage to get even bigger. Table 1 compares population rankings from seven decennial cross-sections of U.S. urbanized areas. There is a strong link between size and ability to maintain rank. Among the top five areas there are thirty possible rank changes, but only five occurred. Among the next five, there are also thirty possible, but twenty-two occurred. How is it that the biggest places manage to get even bigger? It is well known that they grow outward. But they must do so in ways that are not costly to the point of undermining the metropolitan area's economic advantage. Size and scale economies are achieved via the proper spatial organization.

Data on urban travel have been widely used to address some of these questions. There are many urbanization benefits and costs beyond travel costs, but trip patterns denote spatial organization and we are trying to identify modes of spatial organization that are selected in a context of competition between metropolitan areas. Labor and capital are quite mobile within most modern economies and can be expected to be economic in their selection of locations.

II. Literature: Urban Spatial Structure and Travel

The relationships between urban form (or land use) and transportation have been among the most debated topics among planning researchers in recent years. Extensive research has been done in this area and various surveys of the literature (Badoe & Miller, 2000; Crane, 2000; Ewing & Cervero, 2001; Handy, 2005) have been published. An up-to-date and comprehensive meta-analysis of the literature concludes that travel behaviors such as vehicle miles traveled (VMT) and travel mode choices are generally inelastic with respect to changes in individual urban form variables (Ewing & Cervero, 2010). But, this report also shows that the combined effects of simultaneous changes in various urban form measures can be substantial. The travel impacts of neighborhood characteristics are found to be significant in many studies even after controlling for the influence of residential self-selection. It still remains to be clarified whether the autonomous effects of neighborhood scale built environments are large enough to justify land use policies designed to change people's travel behavior (Cao et al., 2009).

Much less is known about the links between metropolitan level spatial structure and transportation because most research to date has focused on the (especially residential) neighborhood-scale built environment. We are particularly interested in metropolitan level studies because spatial structure at the metropolitan scale has profound implications for the efficiency of urban agglomerations. Moreover, neighborhood-scale travel impacts may be contingent on metropolitan spatial contexts. Cervero and Gorham (1995) showed that distinct transit ridership rates between auto-oriented and transit-oriented neighborhoods observed in the San Francisco metropolitan area were not found in the Los Angeles area.

This chapter will focus on the question whether metropolitan level spatial restructuring towards more polycentric and dispersed forms is linked to reduced or increased (especially commute) travel times. Urban economists and planners generally hold contrasting views on the commuting impacts of metropolitan level spatial changes. Most urban economists view the spatial transformation from monocentric to polycentric structures as an adjustment process that mitigates some of the negative externalities that may accompany urban growth, including congestion, whereas many urban planners blame excessive decentralization and sprawl for more congestion and longer commuting distances and durations.

Worker's behavior to economize on commuting trips is an important foundation in many theoretical urban models. Spatial adjustments in cities occur in such a way as to mitigate congestion and shorten workers' commute time as a city grows, according to these urban economic models. One of the most studied spatial evolutions is the transformation from monocentric to polycentric structure (Fujita & Ogawa, 1982). McMillen and Smith (2003) demonstrated empirically that the number of urban employment subcenters increases with population and commuting costs. Wheaton's (2004) urban model which includes land use mix implied that jobs dispersal also leads to lower commuting costs and distances.

Gordon and Richardson and their colleagues published a series of empirical studies in the 1980s that show polycentric or dispersed spatial structure was associated with shorter commute times (Gordon & Wong, 1985; Gordon et al., 1989). The seeming paradox, constant average commute time in spite of increased congestion and commuting distance, led them to suggest that many individual households and firms "co-locate" to reduce commute time and that this spatial adjustment can be more easily made in dispersed metropolitan space with many alternative employment centers and residential location choices (Gordon et al., 1991; Levinson & Kumar, 1994). A more recent empirical study using panel data also found that jobs decentralization in the context of suburbanized population contributes to shorter average commutes (Crane & Chatman, 2003).

Kim's (2008) recent empirical study of location choices and commuting behavior in the Seattle metropolitan area highlights the co-location mechanism by using a unique panel data set. He shows that relocators choose their residence and workplace locations in commuting zones (in terms of commute time and distance) similar to the one before their relocation. As a result, the average commute time and distance in the region remain stable despite rapid regional growth and high residential and workplace mobility.

An interesting computable general equilibrium (CGE) simulation study of the Chicago metropolitan area by Anas (2011) also demonstrates that average commute time and personal travel time per day would remain remarkably stable over long periods, in this case between 2000 and 2030. In this model, workers and firms make economizing adjustments in their location choices and mode choice (increased public transit ridership) in response to population growth and the rise of congestion and gasoline price.

In spite of these findings, it appears that most urban planners believe that the dispersion of jobs and population, or sprawl type development, causes more frequent and longer travels, more auto uses, and hence more congestion (Sarzynski et al., 2006). Cervero and Landis (1992) argued that the co-location process may not work properly produce short commutes due to the growing number two-earner households, location barriers and restricted residential and job mobility, and increased auto dependency. Cervero and Wu (1998) showed that both commute time and distance increased with employment subcentering and decentralization in the San Francisco Bay Area in the 1980s. But, a case study of this kind has limitations in properly controlling for the effects of other relevant factors such as increased wealth.

More recent studies have employed cross section regression analysis utilizing various urban structure and land use measures. A study of the links between four sprawl indicators and transportation outcomes in 83 U.S. metropolitan areas (Ewing et al., 2003) found that higher residential density and more centering were associated with higher transit and walk shares of commute trips, but not with greater average commute time. Rather, denser and finer street layouts were associated with longer commute times and more congestion delays. It was land use mix that contributed to reducing commute durations in their analysis.

Sarzynski et al. (2006) significantly advanced cross-sectional research on commuting by using more elaborate urban form variables (sprawl indices) and addressing potential endogeneity and time-lag effects between urban structure and congestion. Their regression analysis with a sample of 50 largest urban areas provides mixed results. Controlling for the 1990 congestion level and other demographic and transportation supply changes, density/contiguity and housing centrality were associated with more congestion while housing-job proximity were related with less congestion in 2000.

In sum, there was some support for the co-location hypothesis in the literature. Polycentric spatial structure seems to be more accommodating of urban growth while mitigating commute time growth. On the other hand, more centralized structures with higher density appear to encourage more public transportation use and lower VMT (Bento et al., 2005). Therefore, spatial evolution may have different implications for efficiency and the area's future prospects.

III. Work Trips

1. Urban structure and commute time

Descriptive Analysis

This section presents results from an empirical analysis of the determinants of average commute time after briefly reviewing descriptive statistics on average commute time by different intra-urban locations in U.S. metropolitan areas. Lee (2006) examined the 79 largest U.S. metro areas and compared commute times by drive-alone mode with job location in each area. Figure 2 shows how average commuting times rise with metropolitan area size. There are metropolitan area advantages associated with polycentric structures and jobs dispersion; they accommodate continued growth in the largest metropolitan areas. Lee placed all commuters as either working in the traditional center, the various subcenters or outside of either, namely dispersed. The proportions for the largest (3 million or more population) metropolitan areas were 18, 14 and 68 percent, respectively. The first panel shows a linear relationship between average commuting time and the natural log of metropolitan population size. The other three panels show the same relationship for downtown (CBD) commuters, subcenter and dispersed commuters. The steepest slope describes the CBD commuters while the least steep slope describes the dispersed workplace commuters.

These relationships hold up when control variables are added to the analysis. In multivariate analysis, Lee found that a doubling metro of area population size results in average commute time increases of approximately 2.2 minutes. However, the commute time penalty of metropolitan population size is much larger for CBD workers (6.1 minutes) and smaller for workers in subcenters (2.9 minutes) and dispersed locations (2.0 minutes). These differential effects of city size by different types of locations demonstrate that polycentric and dispersed employment distributions have an edge in mitigating congestion in large metropolitan areas.

Recent work by Lee and Gordon (2007) looks for the urban growth effects of spatial structure via its impact on commuting; growth is the most easily accessible proxy for productivity. The finding is that urban forms evolve to accommodate growth; spatial patterns emerge that accommodate and limit the road and highway congestion that comes with greater urban scale. This view places a premium on flexible land markets and the open-ended evolution of urban structure. Dispersion and jobs sprawl is more likely to be the traffic solution than the traffic problem in large metropolitan areas with massive population already suburbanized. In fact, problems are intensified when downtowns and central locations gain in size. This makes sense in light of our understanding of how land markets work. It is standard practice to model traffic flows to reflect adjustments to temporary disequilibria; but land markets are similarly a dynamic process energized by various disequilibria. This view also undermines the conventional wisdom that links more development to more traffic.

Tables 2 and 3 show some of Lee's results -- the various travel times and the workplace locations of the corresponding groups Looking at the drive-alone travel times, the two tables indicate that the more concentrated the workplaces, the longer the commutes; CBD workers have the longest trips while those working in dispersed locations enjoy the shortest trips. These data are consistent with three plausible ideas: (1) where there are the most agglomeration economies, there are likely to be the highest wages which compensate commuters for the longer trips; (2) the co-location of workers and employers ("dispersed" column) favors the greatest number of workers; (3) the idea that the latter is a chaotic and wasteful "sprawl" does not stand up.

Multivariate Analysis

In this section, we report the results of multivariate analyses that examine the impacts of urban spatial structure on average commute time in 79 largest metropolitan areas in the U.S. As Sarzynski et al. (2006) correctly pointed out, the relationship between commute time and urban spatial structure can be simultaneous. On the one hand, congestion or longer commute time facilitates jobs decentralization and dispersion given population size and other conditions. On the other hand, more spatial adjustment may contribute to mitigating congestion all else being equal. Thus, we used two stage least square (2 SLS) regression models as well as ordinary least square (OLS) regressions.

Our regression model is specified as in the equation below and descriptions of variables are shown in Table 4. The dependent variable for all the regression models is the natural log of mean one-way commute time by drive-alone mode from 2000 Census data. On the right-hand side, we include population size, spatial structure variables, population distribution and other covariates. For population distribution, we have population density and a decentralization factor score derived from three different decentralization indices via a principal components analysis. Other covariates include transit use, highway facility, income, an indicator of the presence of a bay, housing supply and other demographic variables.

Log (Mean commute time) = f (P, Spatial structure, R, X)

, where P denotes log population size; R vector of variables indicating population distribution (density and decentralization); X vector of covariates.

We define two dimensions of spatial structure, decentralization and dispersion, and used two alternative measures for each spatial dimension. The first measure of decentralization is the percent share of metropolitan employment located outside the CBD and the second is a factor score which is derived from the first measure and the other three decentralization indices: a modified Wheaton index, an area-based centralization index and weighted average distance from the CBD.[v] In a similar fashion, dispersion is represented by two measures, employment share outside all centers and a factor score extracted from the dispersed job shares and three concentration indices, Spatial Gini, Theil index and Delta index. See Lee (2007) for detailed explanations of these indices and how we defined CBD and employment subcenters.

Because spatial variables are endogenous to the model, we used instrument variables in 2SLS regressions. The instrument variables include median housing age, four factor scores presenting industrial structure, Census Region dummies, the percent share of metro population in the core central city, the number of cities and a dummy variable indicating the presence of rail transit. In the first stage regression models, we also included population size and distribution, and a presence of a nearby bay as well as instrument variables.

Tables 5 and 6 present OLS and 2SLS regression results, respectively. The most consistently significant control variable was the presence of a bay; median household income was significant in some of OLS models. Both variables were positively associated with average commute time when they were significant. The presence of a bay in such areas as San Francisco and Seattle was associated with about a 5 percent longer average commute time (about 1.2 minute in an average metropolitan area). The percent transit commuting variable was significant only in the decentralization models indicating that more transit use may shorten drivers' commute time by mitigating congestion to some extent. However, freeway density was not significant in most of the estimations, perhaps may be due to measurement issues. This variable was measured for core urbanized areas while all the other variables were for metropolitan areas.

Turning to the population variables, population size was highly significant in all the estimated models: average commute time increases by about 10 percent with doubling metropolitan population size. This is the same result as reported by Anas (2012). Population decentralization was significant and associated with longer commute times in both the OLS and 2 SLS results except for only one specification. Because our decentralization variable is a factor score, the variable unit is a standard deviation. Commuting time effects of one standard deviation change in the extent of population decentralization were smaller than 6 percent in OLS results and 13 percent in the 2 SLS results. Population decentralization and other variables being controlled, population density was not significant in most specifications except for only two 2SLS models with employment dispersion.

Spatial structure variables presenting employment decentralization and dispersion were significant in all but one model. Given the population size and suburbanization, more decentralized and dispersed employment distribution was associated with shorter average commute time. In Models 2 and 4 of Tables 5 and 6, the two dimensions of spatial structure were measured by factor scores. Thus, the estimated coefficients are comparable to the coefficients of population decentralization. The coefficients of employment distribution variables were slightly larger than those of population decentralization in 2 SLS models while the size of coefficients was similar to the OLS results.

2. Stability of commute time in the 2000s

ACS commuting data are available for the years 2000, and 2005-2009. Table 7 (minutes, one-way, all modes) shows that for the U.S. as a whole, the average trip times barely moved, although they were greater than in 1990. Our previous paper (2009) did show that there was a post-1995 effect on commuting times resulting from slow rates of road construction and growing affluence which prompted more non-work travel. For the years since 2005, the data are available by metropolitan as well as micropolitan areas as well their principal cities[vi]. Each row of the Table shows remarkable intertemporal stability. And, corroborating the other two studies citied, the shortest commutes are by people living in the principal cities of micropolitan areas, the "edge cities."

The other principal source of commuting data for the U.S. is the Nationwide Household Travel Survey (NHTS). The latest two iterations of this survey were for 2001 and 2009. These two are distinctive because they include slightly greater spatial detail than the previous surveys. NHTS now aggregates data for three types of metropolitan location, "urban", "suburban" and "second city." Table 8 shows the two surveys' mean travel times for these places for the two years mentioned. Once again, changes over the time span were very minor; the metropolitan average had increased by just one minute, from 24 minutes in 2001 to 25 minutes in 2009, even though the relevant population had increased by 12 percent. Looking at the three sub-area types, the changes were also minor with no change for "suburban" and only one-minute increases for the other two area types. And here too, the "suburban" and "second-city" averages were lower than the urban averages.

Most of these results corroborate the idea that employers and employees have chosen locations that favor mutual accessibility. Location choice involves numerous trade-offs, but important among these is continued mutual accessibility.

IV. Nonwork travel

In our recent paper on non-work travel we compared data from the 1990 and 2001 NHTS surveys.[vii] We found that whereas the U.S. population had grown by 16 percent in these years, and number of workers had grown by 20 percent, the volume of non-work travel (person-trips) grew by 30 percent (while worktrips grew by 23 percent). We also found that in the Monday-Thursday AM-peak 62 percent of all person-trips were for non-work purposes. In the Monday-Thursday PM-peak it was 76 percent. We speculated that the absence of peak-period pricing explained some of this.

Having suggested that there is some seeming rationality in U.S. urban land market outcomes, as corroborated by the 2001 and 2009 data on commuting, what about other travel? Most of the literature on urban travel focuses on commuting. But most urban travel is not for work. The 2009 NHTS shows that 79 percent of all person-trips, 61 percent of all person-miles and 70 percent of all person-minutes (population of age five and up) were for nonwork purposes. To be sure, while most travel is for other purposes, most work trips occur during peak periods and are the most regular.

Table 9 shows NHTS travel times for nonwork trip types presented in the same format as the commuting data in Table 8. Remarkably, there was little change between the two surveys, again even though there had been significant population growth. And suburban as well as second-city nonwork trips were slightly less time consuming than urban trips in all three categories.

The International Council of Shopping Centers reports that in 2010 there were 106,752 shopping centers of all types in the U.S., and that these accounted for one-half of all the retail space in the country.[viii] Many of these centers were more than simply places to shop because they also included places to socialize and be otherwise entertained. Some include medical, legal, insurance and other outlets. In other words, these places account for many of the nonwork trips. Our analysis shows that no matter where people reside, their accessibility to these many destinations is remarkably similar. As in the case of workplaces, buyers and sellers have found ways to locate that enables them to keep doing business with each other. Once again, as with our discussion of worktrips, we ascribe these benign results to flexible and accommodative land markets.

V. Conclusions

Whether we consider commuting or nonwork travel, the data and findings we described reveal that, in spite of the continued spreading out of cities, the effect on traffic conditions (measured by average travel times) is remarkably benign. Transportation economists often point to the absence of peak-load pricing on most urban roads and the non-price rationing (crowding) that results. Indeed, traffic congestion is cited as a major complaint by many Americans. But in spite of all this, it is interesting that aggregate travel time measures show no significant deterioration as the population grows and as cities spread. These results are perhaps counter-intuitive unless we consider the possibility that land markets are able to accommodate the co-locations of many origins and destinations so that reasonable travel times remain available to most people. In a world of second-best (many “market failures” and many “policy failures”), these results will comfort some and surprise others.

Tables and Figures

TABLE 1. Rankings of top-ten U.S. urbanized areas, six Census years, 1950-2010

Rank	1950	1960	1970	1980	1990	2000	2010	Changes
1	New York	New York	New York	New York	New York	New York	New York	0
2	Chicago	Los Angeles	Los Angeles	Los Angeles	Los Angeles	Los Angeles	Los Angeles	1
3	Los Angeles	Chicago	Chicago	Chicago	Chicago	Chicago	Chicago	1
4	Philadelphia	Philadelphia	Philadelphia	Philadelphia	Philadelphia	Philadelphia	Miami	1
5	Detroit	Detroit	Detroit	Detroit	Detroit	Miami	Philadelphia	2
6	Boston	San Francisco	San Francisco	San Francisco	San Francisco	Dallas	Dallas	2
7	San Francisco	Boston	Boston	Wash D.C.	Wash D.C.	Boston	Houston	4
8	Pittsburg	Wash D.C.	Wash D.C.	Boston	Dallas	Wash D.C.	Wash D.C.	4
9	Knoxville	Pittsburgh	Cleveland	Dallas	Houston	Detroit	Atlanta	6
10	St. Louis	Cleveland	St. Louis	Houston	Boston	Houston	Boston	6

Source: Author calculations; data from demographia.com

TABLE 2. Mean commute time by workplace type in largest metropolitan areas

MSA Name	Population	All modes				Drive alone mode			
		Metro	CBD	Subcenters	Dispersed	Metro	CBD	Subcenters	Dispersed
New York	21,199,865	34.3	51.1	38.6	31.6	28.5	55.6	30.2	27.8
Los Angeles	16,369,949	29.0	39.0	30.0	28.1	27.8	36.6	28.9	27.0
Chicago	9,157,540	31.3	46.4	33.3	29.7	28.9	41.8	32.1	28.0
Washington	7,608,070	32.1	42.0	32.2	31.2	30.3	40.2	30.2	29.8
San Francisco	7,039,362	30.4	40.9	30.7	29.4	28.4	39.3	29.3	27.8
Philadelphia	6,188,463	27.7	38.8	26.4	26.6	26.1	36.6	26.1	25.7
Boston	5,828,672	28.3	42.3	26.5	27.2	27.1	41.6	25.9	26.7
Detroit	5,456,428	26.6	32.0	27.7	25.9	26.2	31.0	27.7	25.4
Dallas	5,221,801	28.1	33.3	28.5	27.6	27.4	31.5	28.0	27.1
Houston	4,669,571	29.2	35.8	30.0	28.2	28.1	32.9	28.9	27.3
Atlanta	4,112,198	31.9	37.8	32.4	31.3	30.9	36.0	31.4	30.3
Miami	3,876,380	28.9	35.8	29.6	28.0	27.9	33.8	28.9	27.1
Seattle	3,554,760	27.9	35.1	27.5	27.1	26.2	30.7	26.3	25.8
Phoenix	3,251,876	26.2	32.2	25.6	25.7	25.4	31.1	24.7	25.0
3 million and plus		29.4	38.8	29.9	28.4	27.8	37.1	28.5	27.2
1 to 3 millions		24.8	28.0	23.9	24.4	24.1	26.9	23.4	23.8
half to 1 million		22.9	23.8	22.2	22.8	22.3	23.3	21.7	22.2

TABLE 3. Employment shares by location type in 2000

MSA Name	Employment	No. of Sub-centers	Employment			Share of employment (%)			
			CBD	Sub-centers	Dis-Dispersed	All centers	CBD	Sub-centers	Dis-perse
			A	B	C				
New York	9,418,124	33	937,055	1,057,297	7,423,772	21.2	9.9	11.2	78.8
Los Angeles	6,716,766	53	190,100	1,931,988	4,594,678	31.6	2.8	28.8	68.4
Chicago	4,248,475	17	297,755	504,732	3,445,988	18.9	7.0	11.9	81.1
Washington	3,815,240	16	283,341	449,488	3,082,411	19.2	7.4	11.8	80.8
San Francisco	3,512,570	22	205,553	849,021	2,457,996	30.0	5.9	24.2	70.0
Philadelphia	2,780,802	6	239,735	125,190	2,415,877	13.1	8.6	4.5	86.9
Boston	2,974,428	12	238,092	239,257	2,497,079	16.0	8.0	8.0	84.0
Detroit	2,508,594	22	129,845	557,776	1,820,973	27.4	5.2	22.2	72.6
Dallas	2,565,884	10	126,010	404,365	2,035,509	20.7	4.9	15.8	79.3
Houston	2,076,285	14	165,525	432,101	1,478,659	28.8	8.0	20.8	71.2
Atlanta	2,088,215	6	166,946	223,168	1,698,101	18.7	8.0	10.7	81.3
Miami	1,623,892	6	121,045	243,970	1,258,877	22.5	7.5	150.	77.5
Seattle	1,745,407	7	163,051	207,542	1,374,814	21.2	9.3	11.9	78.8
Phoenix	1,463,581	9	104,417	189,071	1,170,093	20.1	7.1	12.9	79.9
3 million and plus		17.0				22.1	7.1	15.0	77.9
1 to 3 million		2.6				17.8	10.8	7.0	82.2
half to 1 million		0.9				17.4	12.2	5.2	82.6

TABLE 4. Variables used in regression models

Variables	Descriptions
Dependent	
Commute time	Log mean commute time by drive alone mode (min)
Spatial structure variables[1)]	
Decentralization	1) Share of metropolitan employment outside CBD (%) 2) Factor score from three decentralization indices (modified Wheaton index, area based centralization index and weighted average distance from the CBD) and employment share outside CBD
Dispersion	3) Share of metropolitan employment outside all centers (%) 4) Factor score from three concentration indices (Gini coefficient, Theil index and Delta index) and employment share outside all centers
Instrument variables for spatial structure	
Metropolitan age	Median housing age
Industrial structure	Four factor scores (principal component analysis) from employment shares by two digit industrial sectors
Region dummy	Three dummy variables indicating Census Region
Central city incorporation	Percentage population in the core central city
Number of municipality	Number of cities with 10,000 people and more / 100k population
Rail dummy	Dummy indicating the presence of rail transit
Independent variables	
Population size	Natural log of population
Population density	Population per acre excluding tracts with 0.15 persons/acre
Population decentralization	Factor score from three population decentralization indices
Percentage transit use	Percentage workers who commute by public transportation
Highway	Highway lane miles / 1000 population
Income	Median household income ($10k)
Bay dummy	Dummy indicating the presence of bay
Housing market flexibility	Housing permits in the 90s / 1990 stock - population growth
Household with children	Percentage households with children
Multi worker family	Percentage multi worker family
Female workers	Percentage female share of workers

1) See Lee (2007), for detailed explanations for these spatial structure variables.

TABLE 5. Ordinary least square regression results

	Model 1			Model 2			Model 3			Model 4		
	Beta	t		Beta	t		Beta	T		Beta	t	
Intercept	2.206	4.41	***	1.678	3.60	***	2.161	4.16	***	1.896	3.77	***
Spatial structure[1)]	-0.004	-1.93	*	-0.060	-4.08	***	-0.001	-0.72		-0.025	-2.04	**
Log (population)	0.104	5.16	***	0.110	6.16	***	0.089	4.65	***	0.092	4.93	***
Pop density	-0.007	-0.60		-0.009	-0.79		-0.009	-0.69		-0.015	-1.19	
Pop decentralization	0.019	1.95	*	0.059	4.10	***	0.011	1.24		0.026	2.24	**
% transit use	-0.005	-1.37		-0.006	-1.69	*	-0.003	-0.76		-0.002	-0.63	
Freeway lane miles/1k pop	0.043	0.93		-0.003	-0.08		0.063	1.35		0.030	0.62	
Median HH income($10k)	0.048	1.58		0.051	1.87	*	0.048	1.53		0.050	1.67	*
D Bay	0.050	2.02	**	0.042	1.84	*	0.050	1.96	*	0.044	1.75	*
Housing supply	0.000	0.08		0.000	0.59		0.000	-0.11		0.000	0.46	
% HH with children	0.001	0.35		0.000	0.09		0.001	0.32		0.001	0.43	
% Multi worker family	-0.005	-1.44		-0.005	-1.53		-0.005	-1.44		-0.005	-1.53	
% Female workers	-0.002	-0.21		0.001	0.11		-0.002	-0.25		0.001	0.15	
R-square	0.647			0.702			0.630			0.649		
Adj R sq	0.583			0.648			0.563			0.586		

1) Spatial structure variables:
Model 1: Share of metropolitan employment outside CBD (%)
Model 2: Decentralization factor score
Model 3: Share of metropolitan employment outside all centers (%)
Model 4: Dispersion factor score.
2) Dependent variable: Natural log of commute time by drive alone mode.

TABLE 6. Two stage least square regression results

	Model 1			Model 2			Model 3			Model 4		
	Beta	t		Beta	t		Beta	t		Beta	t	
Intercept	2.492	4.26	***	1.127	1.93	*	2.957	3.97	***	1.268	1.85	*
Spatial structure[1)]	-0.014	-2.84	***	-0.142	-4.96	***	-0.012	-2.90	***	-0.110	-3.75	***
Log (population)	0.139	5.04	***	0.138	6.02	***	0.084	3.30	***	0.101	4.11	***
Pop density	-0.010	-0.72		-0.012	-0.92		-0.038	-1.91	*	-0.046	-2.43	**
Pop decentralization	0.041	2.79	***	0.126	4.99	***	0.025	1.97	*	0.082	3.69	***
% transit use	-0.009	-1.96	*	-0.009	-2.11	**	0.003	0.49		0.001	0.31	
Freeway lane miles/1k pop	-0.032	-0.52		-0.110	-1.82	*	-0.055	-0.74		-0.122	-1.59	
Median HH income($10k)	0.032	0.92		0.047	1.42		-0.011	-0.23		0.035	0.88	
D Bay	0.050	1.77	*	0.031	1.10		0.047	1.38		0.022	0.66	
Housing supply	0.000	0.56		0.001	1.33		0.000	0.34		0.002	1.77	*
% HH with children	0.001	0.33		-0.001	-0.23		0.001	0.15		0.002	0.57	
% Multi worker family	-0.003	-0.69		-0.004	-0.88		0.001	0.27		-0.003	-0.66	

% Female workers	0.000	0.02	0.005	0.59	0.002	0.22	0.013	1.23
R-square	0.597		0.643		0.517		0.556	
Adj R sq	0.524		0.579		0.429		0.475	

1) Spatial structure variables:
Model 1: Share of metropolitan employment outside CBD (%)
Model 2: Decentralization factor score
Model 3: Share of metropolitan employment outside all centers (%)
Model 4: Dispersion factor score.
2) Dependent variable: Natural log of commute time by drive alone mode.

TABLE 7. Commuting times from U.S. Census and American Community Surveys, 1990-2009

	Census		**ACS**					% Change		
	1990	2000	2005	2006	2007	2008	2009	'90-'00	'00-'09	'05-'09
US	22.4	25.5	25.1	25.0	25.3	25.5	25.1	13.8%	-1.6%	0.0%
Metropolitan or micropolitan statistical area*			25.2	25.1	25.5	25.6	25.3			0.4%
Metropolitan statistical area		26.1	25.7	25.6	25.9	26	25.7		-1.5%	0.0%
In principal city**		24.8	24.4	24.2	24.6	24.6	24.2		-2.4%	-0.8%
Not in principal city		26.9	26.5	26.4	26.8	26.9	26.7		-0.7%	0.8%
Micropolitan statistical area			21.1	21.1	21.6	21.8	21.5			
In principal city			16.4	16.5	17	17	16.8			
Not in principal city			23.4	23.3	23.8	24.2	23.8			
Not in metropolitan or micropolitan statistical area		22.9	22.8	22.8	22.8	23.2	22.8		-0.4%	0.0%

TABLE 8. Mean commute times (minutes, one-way, all modes), 2001 and 2009

	Urban	Suburban	Second City	Town & Country	All Metro	
2001	**28.1**	**24.3**	**20.8**	**24.0**	**24.2**	
Population (thousands)*	39,757	61,105	43,140	60,757	204,050	253,131
Prop of US Pop	15.7%	24.1%	17.0%	24.0%	80.6%	
2009	**27.9**	**24.2**	**21.9**	**24.8**	**24.7**	
Population (thousands)*	49,563	69,223	45,322	65,532	229,639	283,017
Prop of US Pop	17.5%	24.5%	16.0%	23.2%	81.1%	

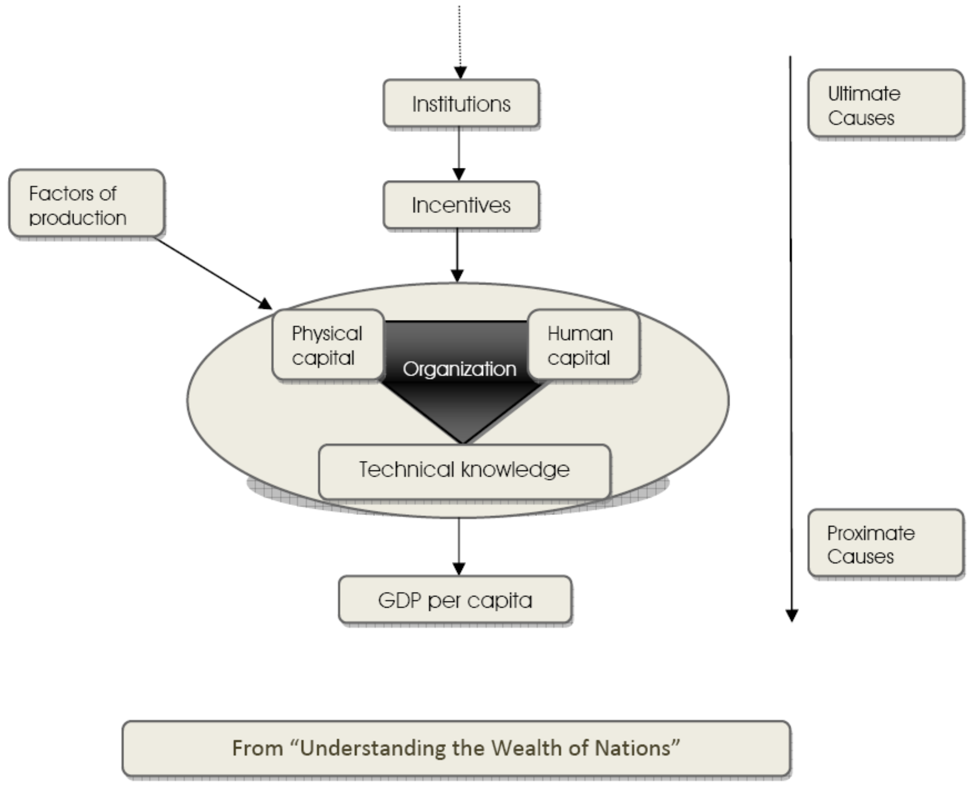
Source: Author calculations from 2001 and 2009 NHTS
Note: NHTS defines an "urban continuum" from "urban" to "suburban" to "second city" to "town and country"
* Excludes ages 0-4.

TABLE 9. Mean non-work travel times (minutes, one-way, all modes), 2001 and 2009

	Urban	Suburban	Second City	Town & Country	All Metro
2001 Non-work	**18.9**	**16.9**	**17.1**	**17.9**	**17.6**
Family/personal	16.8	15.1	15.3	15.9	15.7
School/church	18.6	16.1	15.9	17.6	17.0
Social/recreational	22.7	20.1	20.6	21.6	21.1
2009 Non-work	**19.2**	**16.8**	**17.4**	**18.4**	**17.8**
Family/personal	16.9	14.7	15.4	16.4	15.8
School/church	19.8	16.6	17.1	18.7	17.9
Social/recreational	22.8	20.0	20.8	21.2	21.1

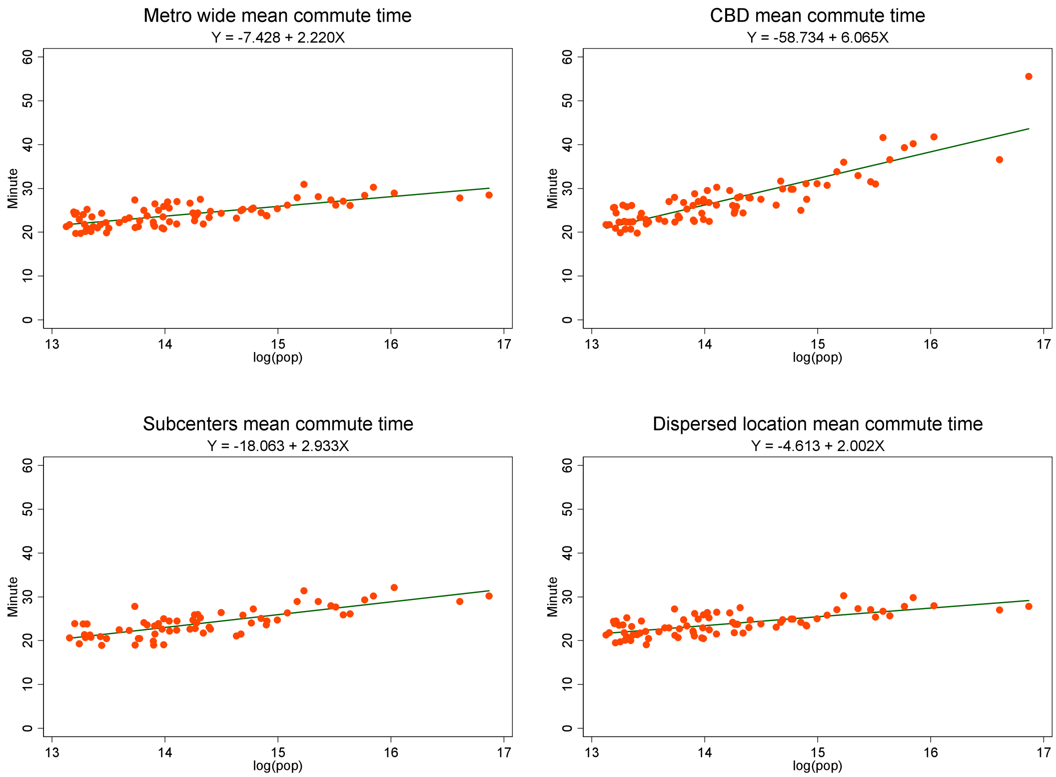
Source: Author calculations from 2001 and 2009 NHTS
Note: NHTS defines an "urban continuum" from "urban" to "suburban" to "second city" to "town and country"
* Excludes ages 0-4.

FIGURE 1. The causes of economic growth



Source: Tyler Cowen and Alex Tabarrok (2010), p. 490.

FIGURE 2. Mean commute time by workplace type vs. metro population size



Source: Lee and Gordon (2011).
Note: Mean commuting time was calculated only for the drive-alone mode.

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[i] http://chartercities.org/blog/212/vox-talk-romesh-vaitilingam-interviews-paul-about-charter-cities

[ii] "[N]atural resources are not finite in any meaningful economic sense, mind-boggling though this assertion may be. The stocks of them are not fixed but rather are expanding through human ingenuity." (see Simon, 1996)

[iii] See, for example, Burchfield, et al. (2006). We prefer the less pejorative and less vague "auto-oriented development", but will use "sprawl" in this discussion with that reservation.

[iv] Many of the trade-offs involved can be specified in terms of discrete programming models, as in Gordon and Moore (1989).

[v] Modified Wheaton index (Wheaton, 2004): $MWI = (\sum_{i=1}^{n} E_{i-1}DCBD_i - \sum_{i=1}^{n} E_i DCBD_{i-1}) \Big/ DCBD*$; Area based centralization index (Massey & Denton, 1988): $ACI = \sum_{i=1}^{n} E_{i-1}A_i - \sum_{i=1}^{n} E_i A_{i-1}$; Weighted average distance from CBD (Galster

et al., 2001): $ADC = \sum_{i=1}^{n} e_i DCBD_i / E$; Gini coefficient (Gordon et al., 1986): $GINI = \sum_{i=1}^{n} E_i A_{i-1} - \sum_{i=1}^{n} E_{i-1} A_i$; Delta index (Massey & Denton, 1988): $DELTA = \frac{1}{2} \sum_{i=1}^{N} \left| \frac{e_i}{E} - \frac{a_i}{A} \right|$. e_i: number of employment at zone i; E_i: cumulative proportion of employment at zone i; E: total metropolitan employment; e_i/E: share of employment at zone i; a_i: land area at zone i; A_i: cumulative proportion of land area at zone i; A: total metropolitan land area; a_i/A: share of land area at zone i; $DCBD_i$: the distance of zone i from CBD; DCBD*: metropolitan radius; n: number of zones.

[vi] Since 2003, the U.S. data have been presented for metropolitan as well as micropolitan areas. Together, they make up the "core-based statistical areas" (CBSAs). The former contain an urban core of at least 50,000 population; the latter have an urban core of at least 10,000.

[vii] Lee, at al (2006)

[viii] http://www.icsc.org/srch/lib/2010%20S-C%20Classification.pdf