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Urban Studies, Vol 30, No 9, 1993 1485–1500

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[Paper first received, May 1992, in final form, January 1993]

Summary. Basic to several key issues in current urban economic theory and public policy is a presumption that local imbalances between employment and residential sites strongly influence people's commuting patterns. We examine this presumption by finding the commuting pattern for the Los Angeles region in 1980 which would minimise average commuting time or distance, given the actual spatial distributions of job and housing locations. We find that the amount of commuting required by these distributions is far less than actual commuting, and that variations in required commuting across job locations only weakly explain variations in actual commuting. We conclude that other factors must be more important to location decisions than commuting cost, and that policies aimed at changing the jobs–housing balance will have only a minor effect on commuting.

Introduction

The length of the urban work trip and how it is influenced by land-use patterns have become critical issues for urban economic theory and public policy Many economic models and policy analyses hinge on the belief that land-use patterns strongly affect commuting, yet the empirical evidence for this belief is weak In this paper, we use disaggregate data for a very large urban region to examine this key relationship

The standard model of urban economics (e g Mills, 1972) relies on a basic assumption about household behaviour choice among residential locations is determined primarily by a tradeoff between commuting cost and land cost This assumption, which we term 'cost minimisation', has come under increasing criticism Evidence is accumulating that in modern cities the effects of commuting cost are swamped by variations in household characteristics, preferences and locational amenities (Wheaton 1979, Lowry, 1988, Giuliano, 1989) Furthermore, direct comparisons of actual commuting distances or times with those implied by some version of the standard model reveal a huge discrepancy People live much further from their place of work than the standard model would predict even when controlling for the actual distribution of jobs and for people's preferences for amenities These studies are reviewed in the next section

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Public policy also has begun to focus on the relationship between commuting distance and the locational patterns of job sites and housing units Increased congestion, particularly in suburban areas, has been linked to numerical imbalances and mismatches between jobs and housing (Cervero, 1989a, Downs, 1989) Imbalances occur when the number of workers who can be housed in an area differs substantially from the number of jobs there Mismatches occur when prices or other characteristics make housing in the area unsuitable for the workers who hold jobs there Both make inter-area commutes necessary Proposed remedies include far-reaching policies to promote *jobs–housing balance* by redirecting new employment and housing at a metropolitan-wide scale (e g Southern California Association of Governments, 1988)

These theoretical and policy issues are conveniently linked by the concept of the *required commute*—i e the minimum average commute required by the actual spatial patterns of housing units and job sites *Excess commuting* is simply the difference between the average actual commute and the required commute These concepts, devised mainly to test the standard theoretical model, also provide both an objective measure of jobs–housing imbalance and a rigorous framework for defining mismatches

We examine excess commuting using disaggregate data in a larger and more dispersed region than has been analysed before the urbanised portion of the five-county Los Angeles region Our data include 1980 journey-to-work information for 1146 zones We first demonstrate the existence of substantial excess commuting for the overall region We then examine excess commuting at the level of sub-areas and at the level of individual employment centres Finally, we examine whether this excess commuting is caused by mismatches between the locations of jobs for specific occupational groups and the locations of houses suitable for members of those groups

The results suggest that commuting distance and time are not very sensitive to variations in urban structure, and are far in excess of what can be explained by jobs–housing imbalances, even when occupational mismatches are accounted for We conclude that the behavioural assumption of cost minimisation in the standard model is inadequate to explain commuting, and that large-scale changes in urban structure designed to promote jobs–housing balance would have only small effects on commuting

Prior Research

The literature on jobs–housing balance and on excess commuting provides two apparently quite different approaches to the question of how urban structure affects commuting We review each in turn

Jobs–Housing Balance

Most discussions of jobs–housing balance have been anecdotal, documenting cases where housing is inadequate or expensive near regions of high employment, so that workers are drawn from a wide area Giuliano (1991) reviews much of this evidence, finding it less than fully persuasive She demonstrates that most municipalities are balanced, that sub-regional imbalances caused by rapid growth tend to disappear over time, and that commuting trips seem only tenuously related to such imbalances when they occur Furthermore, the definition of affordable housing used in this literature has often been oversimplified by assuming just one worker per household and one household per housing unit

Nowlan and Stewart (1991) examine the effects of reducing jobs–housing imbalance where it is greatest the central city core They find that although substantial new office construction occurred in central Toronto between 1975 and 1988, much of its impact on peak-hour work trips entering the area was offset by accelerated housing construction The implication is that a large portion of newly constructed central housing was occupied by people working there, a fact borne out by a separate survey which they report (p 174) How large an effect this had on the average commute distance for the region is not known

Cervero (1989a, 1989b) attempts to provide more systematic evidence that serious jobs-housing imbalances exist in suburban areas and cause long commutes He relies especially on two cross-sectional studies, one of census tracts in the San Francisco Bay Area in 1980, the other of 18–26 suburban employment centres from all over the United States

Using the Bay Area data, Cervero estimates a gravity-type model to explain interzonal commute flows He finds that a census tract with high employment draws more workers from outside its boundaries if (1) it has little land zoned for residential use, and (2) it has a high housing cost The first finding should be no surprise if housing has been excluded from an employment area, the workers obviously must be commuting from somewhere else The second finding is misleading because high housing cost is endogenous the scarcity of housing in jobs-rich areas will itself drive up housing prices, which therefore are not demonstrated to be an independent cause of long commutes In any case, census tracts are small areas, so we learn little from this about why commuting distances average more than a few miles

Cervero's nationwide cross-section is based on data from selected suburban employment sites covering a wide range of sizes and types Using stepwise regression, he finds that a high ratio of jobs to on-site housing units lowers the percentage of work trips made by walking and cycling, and raises the level of congestion on nearby expressways However, a more appropriate jobs-housing ratio would be for the area surrounding the employment centre, not just the centre itself Furthermore, stepwise regression can produce spurious findings by excluding pertinent variables Finally, the estimated coefficients are barely significant at a conventional significance level, and would almost surely become insignificant if the estimated standard errors were adjusted for the 'data mining' inherent in stepwise regression (as suggested, for example, by Lovell, 1983)

With the exception of central Toronto, then, the case for jobs–housing balance having an important influence on commuting distances or times has not been made, and nowhere has it been made on a metropolitan-wide basis

Excess ('Wasteful') Commuting

Hamilton (1982) investigates how well our knowledge of urban structure alone can predict average commuting distance He does so in the context of the standard monocentric model of urban economics Hamilton measures exponentially declining density functions for employment and population, and uses them to calculate the average distance from home to work of commuters who follow the behavioural dictates of the model Using data from 14 US metropolitan areas, he finds this distance to be 1 12 miles, compared to an average actual commuting distance of 8 7 miles Hence 87 per cent of actual commuting is excess ('wasteful' in Hamilton s terminology) in the sense of being unexplained by the standard monocentric model For 27 Japanese cities, the explained distance is 1 83 miles compared to an actual distance of between 6 and 8 miles

Hamilton's method does not determine whether this excess commuting contradicts monocentricity or cost minimisation The latter is the more fundamental assumption to urban economics, and it can be tested independently To see how, observe that in the standard urban model, freely adjustable capital and housing prices guarantee that individual households, each minimising its housing plus commuting cost, will achieve an equilibrium with no cross-commuting i e one which minimises aggregate commuting cost given the distributions of housing and job locations [1] White (1988) tests this implication in isolation by applying a linear programme to the existing distribution of housing and job locations, reassigning workers to housing locations so as to minimise average commuting cost. That is, the assignment algorithm minimises the quantity

$$Z = \sum_i \sum_j c_{ij} X_{ij} \quad (1)$$

subject to the constraints

$$\sum_i X_{ij} = D_j, \sum_j X_{ij} = O_i, X_{ij} \geq 0, \text{ for every } i,j, \quad (2)$$

where X_{ij} is the number of workers commuting from zone i to zone j, c_{ij} is the corresponding travel cost (either time or distance), D_j is the employment in zone j, and O_i is the number of workers residing in zone i.

We can approximate c_{ij} by the average time or distance for observed commutes between the two zones, or within one zone in the case of c_{ii}. The minimised value of Z, divided by the number of workers, is the required commute.

Using 25 US metropolitan areas and measuring commuting cost by travel time, White (1988) finds the average required commute to be 20.0 minutes, compared to the average actual commute of 22.5 minutes, for an excess commute of only 11 per cent. Hamilton (1989), using the same technique except based on distance, finds an excess commute of 47 per cent for Boston. However, Small and Song (1992) show that the level of aggregation in White's and Hamilton's data greatly bias these calculations against finding excess commuting. They find an excess commute of 66 per cent using time and 69 per cent using distance, based on disaggregate data for Los Angeles County. (They also verify Hamilton's (1982) finding of an even larger excess commute relative to a monocentric model.)

Cropper and Gordon (1991) extend White's approach to account for mismatches between households and housing characteristics. They do this by estimating a hedonic utility function as part of a logit model of location choice, using a sample of households from the Baltimore area. The required commute is then calculated by applying the above procedure to the housing and job locations represented in this sample, but for two cases: one with just constraint (2), the other with the additional constraint that no household's predicted utility may be decreased through reassignment. Home-owners and renters are treated as separate populations. The matching constraint makes a difference of less than 1 mile in the required commute, so it does not appear that mismatches between the characteristics of households and those of available houses add much to jobs–housing imbalance. Even with the matching constraint applied, excess commuting is more than 50 per cent.

A different way of accounting for mismatches is used by Hamburg *et al.* (1965), who apply this same assignment algorithm to the Buffalo metropolitan area, constraining the reassignments to be within population segments based on household income, race and auto availability. They find that the actual commute is two to three times the required commute, and conclude that job location has only a limited influence on housing-location choice.

These prior studies on excess commuting, covering a wide variety of methods, types of metropolitan area, and times, are summarised in Table 1. It seems clear that commuting is vastly longer than predicted by the monocentric model with dispersed employment. Even taking the actual urban structure as given, commuting is two to three times as large as can be accounted for by the behavioural assumption of cost minimisation. This is true whether commuting cost is measured by time or distance, and whether or not a constraint is placed on the assignment process to represent housing preferences, type of ownership, race or income.

Empirical Results for the Los Angeles Region

Our study area contains most of the urbanised portion of the US's second-largest Consolidated Metropolitan Statistical Area.[2] The region, containing 10.6 million people and 4.6 million jobs in 1980, is well known

Table 1. Summary of prior studies of excess commuting

Author	Date	Data	Results: Required commute	Results: Actual commute	Results: Percentage excess
A Calculations assuming monocentricity					
Hamilton (1982)	14 US metro areas		1 12 miles	8 7 miles	87 1
Hamilton (1982)	27 Japanese cities		1 83 minutes	6–8 minutes	70–77
Small and Song (1992)	Los Angeles–Long Beach metro area	Minimum distance	2 16 miles	10 03 miles	78 5
		Minimum time	3 59 minutes	22 06 minutes	83 7
B Calculations using actual urban structure and highway network					
Hamburg *et al* (1965)	Buffalo metro area	Low income	3 8 minutes	11 7 minutes	67 5
		Medium income	5 0 minutes	14 0 minutes	64 3
		High income	6 9 minutes	15 8 minutes	56 3
White (1988)	25 US metro areas		20 0 minutes	22 5 minutes	11 1
Hamilton (1989)	Boston metro area		4 82 miles	9 11 miles	47 1
Cropper and Gordon (1991)	Baltimore metro area	*Unconstrained*			
		Owners	4 39 miles		
		Renters	3 65 miles	Approximately 10 20 miles	
		Constrained			Approximately 50–64
		Owners	5 04 miles		
		Renters	4 17 miles		
Small and Song (1992)	Los Angeles–Long Beach metro area	Minimum distance	3 10 miles	10 03 miles	69 1
		Minimum time	7 59 minutes	22 06 minutes	65 6

for its sprawl and its pattern of suburban sub-centres (Frieden, 1961, Gordon *et al*, 1986, Heikkila *et al*, 1989, Giuliano and Small, 1991) These traits, along with very high housing prices near many job centres, create the potential for long required commutes Hence if large-scale jobs–housing imbalances are important anywhere, it should be here

We use 1980 journey-to-work data coded to geographical units known as transportation analysis zones, as defined by the Southern California Association of Governments (SCAG) Our data set includes 1146 zones,[3] and is extracted from the data created for the Urban Transportation Planning Package (UTPP) The data include aggregate zone-to-zone commute flows and some aggregate characteristics of workers by zone of employment These data are supplemented by estimates of inter- and intra-zonal distances and peak-period travel times on the highway network, provided by SCAG and generated by its transportation network model, these are the sources of our c_{ij} Note that just as with White's data, our intra-zonal costs c_{ii} do not necessarily reflect an optimised situation, but since our zones are small, it does not matter very much

Our data portray a region with a wide variety of urban environments and many employment sub-centres, described more fully in Giuliano and Small (1991) Despite the region's sprawl, its central area retains a dominant influence This is indicated by the sheer size of the employment centres at and near downtown Los Angeles, and by the steep decline in employment and population densities as one moves away from downtown The central area is very densely developed, with employment concentrated along a corridor extending westward from the Los Angeles central business district some 20 miles to the Pacific Ocean. Adjacent to it are suburban areas with much lower densities but still a great deal of employment the San Fernando valley to the north-west, the older communities of Los Angeles County to the south and east, and Orange County further to the south-east The more remote and less developed counties of Riverside, San Bernardino and Ventura are lower still in density and were not closely integrated into the region in 1980

Figure 1 shows four sub-areas in Los Angeles County, whose boundaries we have chosen for the present study to maximise roughly the proportion of commuting that takes place within sub-areas Together with the other four counties, this gives us a total of eight sub-areas across which to examine variations in jobs–housing balance and commuting patterns We also examine variations across the 32 major employment centres identified by Giuliano and Small (1991) For this purpose, an employment centre is defined as the largest set of contiguous zones, each with gross employment density of at least 10 per acre, that contains at least 10 000 employees (7000 in the three outer counties) These centres, shown by size and rank in Figure 1, contain almost one-third of the region's employment

Table 2 presents some summary statistics for the eight sub-areas[4] Job sites are substantially more concentrated in Central Los Angeles County than are workers' residences, implying a general in-commuting pattern All the other sub-areas have some excess of resident workers over jobs, with the less developed sub-areas generally showing the greatest excess

Required and Actual Commutes
Region-wide Optimisation

The results of applying the assignment algorithm developed by Hamburg *et al* (1965) and White (1988), described in the previous section, are shown in Table 3 Taking peak-period travel time on the UTPP highway network as representing commuting cost, the region-wide optimisation yields a required region-wide average commute of just 8 4 minutes, leaving unexplained nearly two-thirds of the actual commute of 23 0 minutes (last row of the table) This verifies the findings of most other such studies a large fraction of commuting cannot be explained by the sheer geographical imbal-

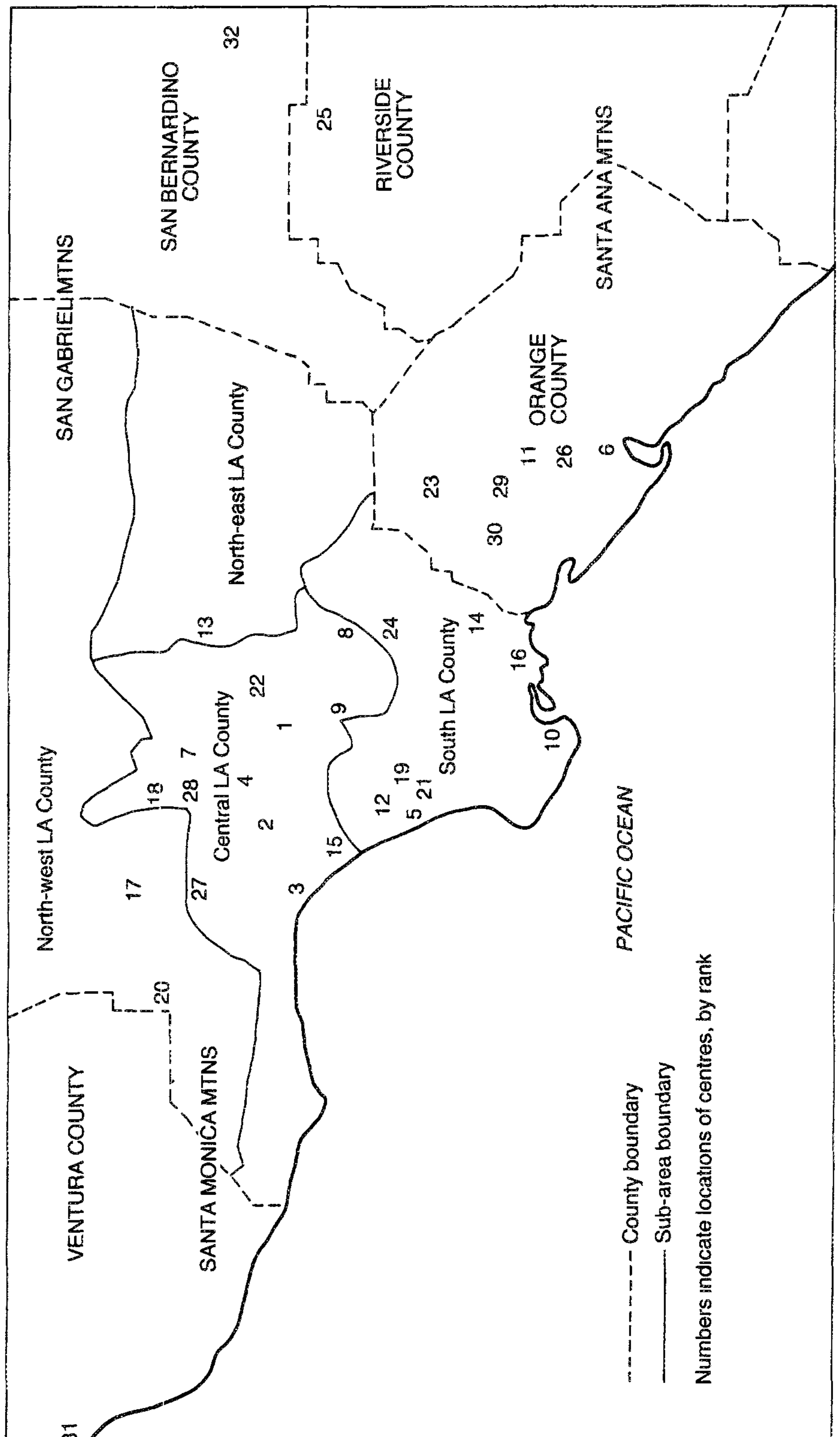

Figure 1. The Los Angeles region

Table 2. Summary statistics Los Angeles Region, 1980

Sub-area	Jobs (1000s)	Population (1000s)	Resident workers per job[a]
Central LA County	1603	2862	0 78
South LA County	890	2013	1 01
North-west LA County	356	905	1 16
North-east LA County	466	1402	1 27
LA County total	3315	7183	0 95
Orange County	872	1902	1 08
Riverside County	103	321	1 14
San Bernardino County	194	648	1 23
Ventura County	102	509	1 31
Region total	4587	10 563	1 00

[a]Resident workers means employed persons by place of residence

ances in current locations of housing and jobs Using distance to represent cost yields a similar result (last column)

The other rows of the table compare required to actual commute for employees working in each of the sub-areas These are simply the disaggregated components of the region-wide optimisation results, the optimisation is not repeated for each separate sub-area Hence, the finding of a required average commute of 5 2 minutes for north-east Los Angeles (LA) County means that in the cost-minimising pattern for the entire region, people holding jobs in that sub-area would commute an average of 5 2 minutes one way

As expected, the required commute tends to be higher where the ratio of resident workers to jobs is low Only in central LA County, however, is the jobs–housing imbalance so great as to increase required commuting time above the 5–7 minutes range Orange County has the second-highest required commute, just under 7 minutes

The actual average commute to each of these areas shows a somewhat similar but less precise relationship to the worker–jobs ratio For example, the actual average commute to jobs in central LA County, which is jobs-rich, is high, but it is just as high in north-west LA County, which is jobs-poor Actual commutes to the other counties do tend to be shorter than to Los Angeles County What is most striking, however, is that the average commuting time to each sub-area is at least twice as large as it would be in the cost-minimising pattern, and in most cases more than three times as large

The Effects of Employment Centres

The results for central LA County conform to expectations regarding commutes to employment concentrations Employment centres must draw workers from surrounding areas, thus requiring longer commute trips than would be the case for employment that is distributed in concert with the population The effect of employment concentration is further identified by dividing job sites into those located in employment centres and those located outside employment centres

Table 4 shows what the region-wide optimisation just presented implies for commutes to these two categories of job sites Employment centres clearly require longer commutes, ranging from 9 to 20 minutes, than do zones outside centres, where required commutes are only 3–6 minutes Actual commutes, however, are only slightly longer to centres than to non-centres in most sub-areas—in fact, they are shorter in two of the outer counties Overall, required commutes are more than three times longer to centres than elsewhere, whereas actual commutes are just 23 per cent longer to centres than elsewhere

Table 5 lists the required and actual com-

Table 3. Required and actual mean commutes: region-wide unconstrained optimisation

Sub-area	Resident workers per job	Based on commute time			Based on commute distance
		Required (minutes)	Actual (minutes)	Excess (percentage)	Excess (percentage)
Central LA County	0.78	12.63	25.30	50.1	53.3
South LA County	1.01	6.61	23.61	72.0	76.3
North-west LA County	1.16	5.09	25.50	80.0	78.5
North-east LA County	1.27	5.16	20.04	74.3	77.2
LA County total	0.95	9.15	24.13	62.1	65.2
Orange County	1.08	6.95	21.25	67.3	70.6
Riverside County	1.14	5.34	17.89	70.2	75.4
San Bernardino County	1.23	5.75	17.52	67.2	62.8
Ventura County	1.31	5.50	16.07	65.8	69.9
Region total	1.00	8.42	22.98	63.4	66.3

mute to jobs in each individual centre, again using the single region-wide optimisation of equations (1) and (2). Actual commutes are much longer than required commutes in most cases,[5] and show far less variation across the region. The important exception is the downtown Los Angeles employment centre where the actual commute is only 4.0 minutes longer than required by its heavy concentration of jobs (469 000 in a 20-sq-mi area).

It is clear from these results that the polycentric pattern of employment centres, along with the dispersal of many jobs outside centres altogether, creates the potential for shorter commutes than those required of people working in downtown Los Angeles. However, commuters are taking little advantage of this potential, choosing instead to commute only a few minutes less than downtown workers. At the same time, given the size of the region, commutes are clearly much shorter than they would be if workers chose randomly among all available housing locations. One must conclude that commuting costs affect residential location choices somewhat, but are far from the sole consideration.

The Special Role of Central Los Angeles County

These results show that central LA County is quite different from other parts of the region. It has a substantially longer required commute than other sub-areas, and a longer actual commute than all but one of the other sub-areas. These facts appear to be caused primarily by its containing the region's largest employment centre, downtown Los Angeles, which has the longest required commute (though not the longest actual commute) of any employment centre. By way of contrast, the other 11 employment centres in this sub-area, including the second-, third- and fourth-largest in the region, do not stand out as having unusual commuting patterns.

As a further check, we computed an alternative measure of jobs–housing balance by repeating the optimisation of the previous section eight times, once for each sub-area, each time minimising transportation cost only for commutes to jobs in that sub-area. That is, we computed the shortest average commute that could be achieved by people working within that sub-area regardless of the effect on other sub-areas' commutes. We found that this lowered the required com-

Table 4. Required and actual mean commutes region-wide unconstrained optimisation, centres versus non-centres

Sub-area	Percentage of jobs in centres	Average commute time to jobs in centres			Average commute time to jobs not in centres		
		Required (minutes)	Actual (minutes)	Excess (percentage)	Required (minutes)	Actual (minutes)	Excess (percentage)
Central LA County	60.4	18.65	26.76	30.3	3.44	23.08	85.1
South LA County	27.4	11.37	28.32	59.9	4.81	21.83	78.0
North-west LA County	15.7	8.88	26.83	66.9	4.39	25.25	82.6
North-east LA County	7.6	9.02	20.88	56.8	4.84	19.97	75.8
LA County total	39.3	16.61	26.89	38.2	4.32	22.33	80.7
Orange County	15.5	14.02	23.56	40.5	5.65	20.83	72.9
Riverside County	12.9	9.62	16.34	41.1	4.70	18.12	74.1
San Bernardino County	3.6	14.18	17.63	19.6	5.43	17.52	69.0
Ventura County	8.1	19.90	14.72	−35.2[a]	4.24	16.19	73.8
Region total	32.0	16.31	26.38	38.2	4.71	21.38	78.0

[a] A negative excess commute for a given centre can occur because the optimisation is carried out for the entire region. See note 6.

Table 5. Required and actual commute time by job centre

Rank (by employment)	Name	Required commute	Actual commute
Central LA County			
1	Downtown LA	24 99	28 99
2	LA West	16 89	24 51
3	Santa Monica	6 57	22 31
4	Hollywood	10 02	24 32
7	Glendale	8 30	20 49
8	Commerce	15 65	26 24
9	Vernon/Hunting Park	11 46	27 92
15	Marina Del Rey	3 81	27 98
18	Burbank Airport	20 91	27 30
22	LA East	21 62	28 72
27	Sherman Oaks	7 65	24 64
28	Burbank SW	8 72	22 45
South LA County			
5	LA Airport	14 78	30 26
10	San Pedro	20 61	38 61
12	Inglewood	6 91	26 05
14	Long Beach Airport	12 16	25 44
16	Long Beach	6 03	22 81
19	Hawthorne	4 34	24 03
21	Lawndale	5 83	25 40
24	Downey	8 96	26 19
North-west LA County			
17	Van Nuys Airport	11 86	28 11
20	Canoga Pk/Warner Ctr	5 08	26 50
North-east LA County			
13	Pasadena	9 02	20 88
Orange County			
6	Orange County Airport	20 63	26 01
11	Santa Ana	8 25	21 83
23	Fullerton	24 04	21 74
26	Santa Ana So	5 82	21 90
29	Anah/Orange/Gar Grv	6 55	24 23
30	Gar Grv/Stanton	7 39	22 98
Riverside County			
25	Riverside	9 62	16 34
San Bernardino County			
32	San Bernardino	14 18	17 63
Ventura County			
31	Oxnard	19 90	14 72

mutes shown in Table 3 by only a minute or so except for central LA County, where it lowered it by 4 0 minutes This indicates that there are enough residents living in or near central LA County so that its jobs could be filled with an average commute of only 8 6 minutes The average commute to its 12 employment centres (including downtown Los Angeles) falls more than 6 minutes, to 12 3 minutes, using this calculation Hence the long required commutes to these job centres result not only from insufficient nearby housing, but also from the existence of jobs outside the Central LA sub-area that

Table 6. Required travel times region-wide constrained optimisation, by occupation

Occupational category	Percentage of workers	Average required commute time (minutes)
Administrative	25 70	11 69
Technical	3 16	11 88
Sales	10 62	9 72
Clerical	19 41	9 92
Craft	28 23	10 07
Service	11 64	8 16
Farm	1 23	11 38
All occupations	100 00	10 27

absorb many of the workers who live in that housing

Mismatches The Effects of an Occupational Constraint

Our results thus far corroborate those of previous studies showing that the structure of job and residential distributions does not account for the amount of commuting we observe We turn now to the issue of mismatches between worker and housing characteristics Are such mismatches preventing workers from achieving the lower commuting times that our calculations have shown are compatible with the existing urban structure?

We can address this question by placing additional constraints on the cost minimisation of equations (1)–(2) Although the mismatch most commonly cited involves income level, it is very difficult to define accurately the relationship between observed incomes and feasible housing prices Indeed, this is one of the chief weaknesses of the literature on jobs–housing balance We therefore turn to occupation as a proxy for income level, and apply a rather stringent constraint on occupational groups namely, that the only residences feasible for a given worker are those currently occupied by members of the same occupational group There are seven occupational groups identified in our data, so adding this constraint amounts to doing the cost minimisation seven times, once for each group [6]

The results are shown in Table 6 Introducing the occupational constraint raises the average required commute to 10 3 minutes, an increase of 22 per cent Interestingly, this increase is of similar magnitude to that resulting from the quite different constraint applied by Cropper and Gordon (1991) Hence mismatches could lengthen commutes to some extent, but more than half of the average commute time remains unexplained

Differences in the required commute across occupational categories are moderate and do not appear to be related to income or status In particular, these figures provide no support for the belief that lower-paid workers are forced into long commutes by lack of suitable housing near their jobs Such instances may occur, but they do not dominate the regional averages, on the contrary it is the higher-paid administrative and technical workers whose required commutes are slightly longer

Of course, there are many other ways that mismatches could be taken into account However, each of them is to some extent arbitrary, because in reality people have options to alter their consumption patterns rather than accept constraints as absolute This is illustrated by the high proportion of income spent on housing in some coastal areas in California

Explaining Intra-regional Variations in Commuting Time

Our results show that actual commuting times and distances in the Los Angeles

Table 7. Regressions explaining intra-regional variations in commuting time

Regression number	(1)	(2)	(3)	(4)	(5)	(6)
Type of observation	Sub-area	Job centre	Zone	Zone	Zone	Zone
Number of observations	8	29	1113	1113	1113	1113
Regression coefficient						
Constant	38 1**	22 6**	29 99**	22 59**	32 59**	29 62**
	(6 9)	(1 3)	(0 77)	(0 47)	(1 72)	(0 76)
Required commute time		0 25**	0 279**	0 282**	0 281**	0 570**
		(0 10)	(0 022)	(0 024)	(0 022)	(0 052)
Required commute time squared						− 0 0084**
						(0 0014)
Resident workers per job in sub area	− 15 4**		− 9 95**		12 18**	10 35**
	(6 1)		(0 71)		(1 50)	(0 70)
Resident workers per job in RSA				− 2 69**		
				(0 37)		
Dummy for central LA County sub-area					− 1 05	
					(0 62)	
Standard error of regression	2 7	3 3	4 4	4 6	4 4	4 3
Coefficient of determination (R^2)	0 52	0 20	0 27	0 18	0 27	0 29

Notes
**Significant at the 5 per cent level, two-tailed test
t-statistics are in parentheses
RSA = Regional Statistical Area (smaller than a sub-area)

region are far greater than necessary given the intermixing of jobs and houses, either overall or within occupational categories Nevertheless, they may be influenced by this degree of intermixing In this section, we examine this question through simple regressions explaining actual commuting time by various measures of jobs–housing balance We focus on two such measures the required commute to a particular job location (based on the region-wide optimisation presented earlier), and the ratio of resident workers to jobs within an area surrounding that job location

Regression (1) in Table 7 uses the sub-area as the unit of analysis It confirms our earlier observation of a negative relationship between the worker–job ratio and average commuting time However, the size of the coefficient is not very large, indicating that an increase in the ratio by 0 2 (for example, from 0 8 to 1 0) lowers commuting time by only 3 minutes If instead jobs–housing balance is measured by the required commute, it has no discernible effect at the sub-area level (regression not shown)

Regression (2) uses the employment centre as the unit of analysis (excluding the three sub-centres in the outermost counties), it therefore portrays the data of Table 5 In this case the required commute does have a statistically significant relationship with actual commute, but it is weak a 4-minute reduction in required commute cuts just 1 minute from the actual commute If the three outer centres are included, the relationship disappears (not shown)

Regressions (3)–(6) attempt to explain average commuting time to each zone by various measures of jobs–housing imbalance One measure is the required commute to that zone, which automatically takes account of the surrounding area through the workings of the linear programming algorithm Another measure is the worker–jobs ratio, computed alternately for the entire sub-area in which the zone is located and for a smaller area known a Regional Statistical Area (RSA) (SCAG has defined 33 RSAs for our study area)

The results show a clear relationship between both measures of jobs–housing imbalance and commuting time to zones Comparing regressions (3) and (4), we see that the broader measure of worker–jobs ratio, that of the sub-area, has more explanatory power than the narrower measure This may indicate that the relevant region for jobs–housing balance is quite large

To test whether regression (3) is just reflecting the difference between central Los Angeles and the rest of the region, we add in regression (5) a dummy variable for those zones in the Central LA County sub-area The coefficient is insignificant and of unexpected sign, and other coefficients are little affected The same is true if the dummy variable includes just those zones in the downtown LA employment centre (regression not shown)

Finally, regression (6) allows for non-linearity in the influence of required commute time Non-linearity is apparent, but explanatory power is little improved This equation suggests that the marginal effect of required commute time t_R on actual commute time t is $\delta t/\delta t_R = 0\ 570 - 0\ 0168 t_R$, which is 0 49, 0 43 and 0 30, respectively, for required commutes typical of non-centres (4 7 minutes), all zones (8 4 minutes), and centres (16 3 minutes) This is a larger influence than that in regressions (2)–(4), but still not large enough to suggest major effects of changes in jobs–housing balance

Regression results explaining commuting distance were similar to the results explaining commute time, but with poorer fit, and thus are not shown here

Conclusion

These results, then, suggest that jobs–housing balance, whether measured by the ratio of resident workers per job in a broad sub-area or by the required commuting time, has a statistically significant but not very large influence on actual commuting times The main exception is that the extreme imbalance of the downtown Los Angeles employment centre does increase commuting times

Consequently, we conclude that attempts to alter the metropolitan-wide structure of urban land use via policy intervention are likely to have disappointing impacts on commuting patterns, even if successful in changing the degree of jobs–housing balance Such policies do not address the main sources of dispersion in location patterns Moreover, the standard economic analysis of urban location, which relies upon the tradeoff between land costs and commuting costs as the primary determinant of residential location, also fails to provide adequate explanation for observed location patterns

Why does the journey to work play only a limited role in residential location choice? We cannot say from our data but we can offer a few hypotheses First, perhaps commuting time is not very onerous for short trips, serving instead as a psychological buffer between home and work activities There is some evidence for this in a modal-choice study by Ben-Akiva and Lerman (1985, pp 174–177) Secondly, rapid job turnover and high moving costs may cause households to seek accessibility to an array of possible future jobs rather than just the current job Thirdly, job heterogeneity may prevent two-worker households from finding jobs close together, making it impossible for both workers to have short commutes Fourthly, the increasing importance of non-work trips (Richardson *et al* , 1992) modifies the tradeoff between land and transportation costs Fifthly urban residents may care about such a variety of housing and neighbourhood characteristics that transportation costs are simply overshadowed in importance by other priorities Sixthly, racial discrimination may limit people's ability to optimise freely their job and residential locations with respect to their own preferences (Hughes and Madden, 1991)

All of these hypotheses are consistent with the view that commuting costs matter in location decisions. It is no accident that urban areas have grown up with a high degree of intermixing of jobs and housing of various types, not that most commutes are shorter than 30 minutes even in an area as large as Los Angeles. At the margin, however, it does not appear that people will respond to land-use or transportation policies as though minimising commuting costs were their dominant consideration.

Notes

1. This is demonstrated by the linear programming formulation of Herbert and Stevens (1960), as amended by Wheaton (1974) and interpreted by Senior and Wilson (1974) (See Los 1979, pp. 1246–1248, or Berechman and Small, 1988, pp. 1292–1294, for a concise summary.) The equilibrium conditions for individual households minimising housing plus commuting cost emerge as the first-order conditions of a linear programme which minimises aggregate commuting cost.
2. The Los Angeles Consolidated Metropolitan Statistical Area consists of four Primary Metropolitan Statistical Areas (PMSAs). The largest PMSA is Los Angeles County, it was formerly classified as the Los Angeles–Long Beach Standard Metropolitan Statistical Area (SMSA) and is the area used in the other studies cited that include Los Angeles (including Small and Song, 1992, who use a sub-set of the data used in this study). The other three PMSAs are Anaheim–Santa Ana–Garden Grove (Orange County), San Bernardino–Riverside (San Bernardino and Riverside Counties), and Oxnard–Ventura (Ventura County).
3. Thirty-three of them have no employment, so are excluded when we report trips by place of employment.
4. These statistics are compiled from the origin–destination matrix in the UTPP data files. There are small discrepancies with the numbers in the resident summary file and the employment summary file, which are used in Giuliano and Small (1991) and in our estimates using an occupational constraint presented in a later section of this paper.
5. Actual commutes to two centres, Oxnard (Ventura County) and Fullerton (Orange County), are *shorter* than what would occur in a region-wide optimisation. This is possible because the optimisation criterion is region-wide, hence need not minimise commuting for just the limited set of workers commuting to any one centre. Detailed analysis of the flows to both Oxnard and Fullerton reveals that in the region wide cost-minimising pattern, the centre draws its workers solely from residential zones on the side away from downtown Los Angeles, whereas in the actual pattern it draws more evenly from all nearby zones. In other words, there is substantial outward commuting that does not occur in the cost-minimising pattern.
6. Thurston and Yezer (1991) also use these seven occupational groups to represent heterogeneity among workers. However, they do so within a monocentric model, so there is nothing analogous to our matching constraint, rather, the different results they get when distinguishing occupations are due solely to differences in the estimated monocentric density functions associated with each occupational group. These in turn reflect differences in estimation errors, not the effects of heterogeneity on jobs–housing imbalances.

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