Confirmations and Contradictions

Urban Commuting Journeys Are Not "Wasteful"

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Do urban workers commute too much? Bruce Hamilton (1982) was the first to raise the question whether urban workers' commuting journeys are too long or, in his terms, "wasteful." He argued that the monocentric urban model predicts that workers' commuting journeys will be minimized. To test the model, he calculated the minimum commuting journey length for the average worker in a group of U.S. cities and compared the results to the actual average commuting journey length for those workers. He assumed that any difference between the two figures was "wasteful commuting." He found that the average minimum commuting distance was only 1.1 miles, but the average distance actually commuted by workers in those cities was 8.7 miles, or nearly eight times as great. Hamilton therefore concluded that the monocentric urban model has little predictive value concerning commuting behavior and that actual commuting behavior could be predicted just as well using an assumption that commuting is random.

Commuting behavior is a central feature of any model that purports to explain urban residential and job location choice. Hamilton's assertion that the monocentric urban model has little predictive value concerning commuting behavior therefore strikes at the heart of

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modern urban economics. But Hamilton made such strong and inclusive assumptions concerning the definition of wasteful commuting that no city whose residents determine their locations by the postulates of economic rationality would be expected to satisfy them. In this paper I calculate new estimates of the average minimum commuting journey length in a sample of U.S. cities, using a more reasonable interpretation of what urban models would predict concerning location behavior by workers and firms. Comparing the resulting estimates of minimum commuting with data on the actual commuting journey length by workers in the same cities results in new estimates of the amount of wasteful commuting. For a sample of cities that overlaps Hamilton's, I find that only around 11 percent of the actual amount of commuting in urban areas is wasteful. Thus waste in fact appears to be only a minor factor in explaining the commuting behavior of U.S. urban workers.

Section I of the paper discusses the predictions of the monocentric urban models theory concerning commuting decisions by workers. Section II presents the assignment model approach used here to calculate new estimates of the minimum commuting journey predicted by the monocentric urban model.

I. Predictions of the Monocentric Urban Model Concerning Commuting

In the simplest monocentric urban model, all households have identical tastes and have one worker, all workers have identical jobs and earnings, and all jobs are at the central business district (CBD). Households choose their residential locations by maximizing utility functions subject to budget and time constraints. Commuting is assumed both to take time and to cost money. Residential locations are characterized by distance from the CBD, with the city assumed to be identical in all directions. Workers are willing to choose residential locations that involve longer commutes because housing prices fall with greater distance from the CBD. All commuting is on radial roads that are assumed to be ubiquitous. The average one-way commuting journey length therefore equals the average residential distance from the CBD. In the centralized employment model, which worker takes which job is irrelevant.[1]

Now introduce partial employment decentralization into the model but hold other assumptions unchanged.[2] Following Hamilton, I as-

[1] See Mills (1967) and Muth (1969) for development of the monocentric urban model.

[2] Urban models that explore suburbanized employment include White (1976, 1988), Ogawa and Fujita (1980), and Straszheim (1984).

sume that the spatial patterns of employment location and housing location are both fixed. When any jobs move out of the CBD, the pairing of individual workers' residential and job locations becomes important. The minimum possible average commuting journey length for workers in a city occurs if the following properties hold for all workers employed at suburban jobs: (1) workers' jobs are on the same ray from the CBD as their houses and (2) their jobs are closer to the CBD than their houses. If these two conditions are satisfied for all workers, then all commuting in the urban area will be in-commuting, that is, toward the CBD along a single ray during the home-to-work journey. There will be no out-commuting and no circumferential commuting, that is, no commutes that are away from the CBD during the home-to-work journey or that start on one ray from the CBD and end on another. Further, if all workers in the city commute inward, then the average commuting journey length of workers in the city will be minimized.

Hamilton assumes that these two conditions are both satisfied for all workers in all cities when he calculates his estimates of the average minimum commuting distance in a city. He therefore assumes that all commuting in excess of the distance required for workers to commute inward to their jobs is wasteful.[3] However, in actuality, when firms move out of the CBD, they usually choose suburban locations that are concentrated at particular suburban subcenters. This causes suburban jobs to have a distribution around the CBD different from the distribution of workers' residences. As a result, not all workers can commute inward to their jobs. Under what circumstances will workers choose to commute outward or circumferentially to suburban jobs, and what effect does this have on the average length of commuting journeys in the urban area?

As an example, suppose that an arbitrary large firm (or group of firms) called firm A moves from the CBD to a suburban location one mile east of the CBD. All jobs in the urban area are now located either at the CBD or at firm A. Figure 1 shows the CBD of the urban area at the origin of a graph and firm A at (1, 0). The outer boundary of the city is the curve *ced*. Given firm A's location, only workers that live more than one mile from the CBD and along the x-axis can commute inward to it. Workers are willing to commute inward to a suburban firm if it pays a wage equal to the wage at the CBD minus workers' savings in commuting costs from working at the suburban firm. Assume that the wage per day at the CBD is w^* and that commuting

[3] These assumptions are somewhat hidden by Hamilton's use of negative exponential density gradients to represent the spatial patterns of jobs and housing. They require that the density patterns of jobs and housing be identical along all rays from the CBD.

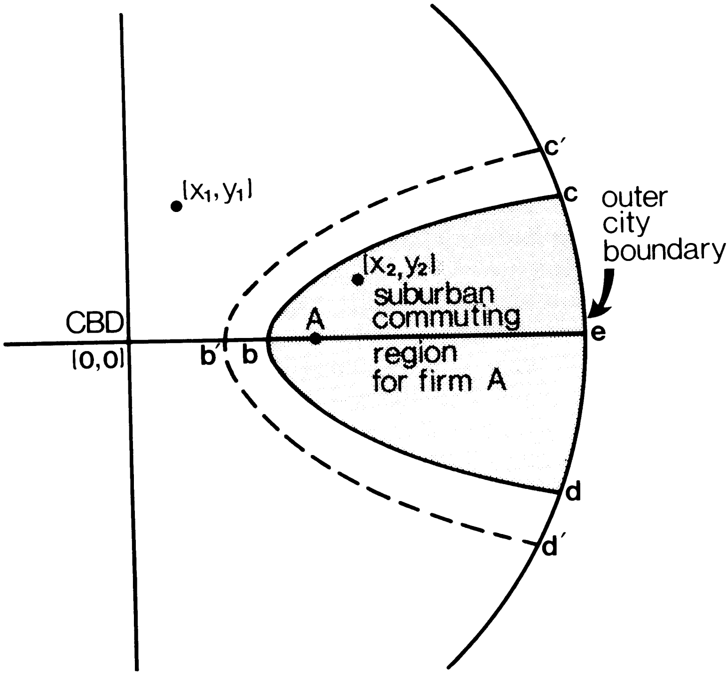

FIG. 1

costs are γ per mile round trip. Then firm A's in-commuting wage is $w^* - \gamma$. At this wage, *only* workers that can commute inward to firm A will be willing to work there. Therefore, firm A's in-commuting region consists solely of workers living along the line segment *Ae*.

However, if firm A is large, then it may demand more workers than those who live along the line segment *Ae*. Then to induce some workers to commute outward or commute circumferentially to the firm, it must raise its wage above $w^* - \gamma$. Suppose that firm A offers a wage of w', which is above the in-commuting wage but below the CBD wage, or $w^* - \gamma < w' < w^*$. Also suppose that the urban area has straight-line roads connecting all residences to all workplaces. Finally, assume that all households in the urban area consume the same amount of housing.[4]

The rise in wages paid by firm A increases the size of the commuting region from which workers are willing to commute to firm A. Workers are indifferent between commuting to two different job locations when the wages at both job locations minus commuting costs are equal. Therefore, the equation defining the boundary of firm A's

[4] Urban models typically assume that the amount of housing consumed rises with distance from the CBD. Making this assumption would not change the general results obtained here.

commuting region is

$$w^* - \gamma(x^2 + y^2)^{1/2} = w' - \gamma[(x - 1)^2 + y^2]^{1/2}, \qquad (1)$$

where x and y are the coordinates of a worker's residential location on the graph of the urban area, $(x^2 + y^2)^{1/2}$ is the distance between point (x, y) and the CBD, and $[(x - 1)^2 + y^2]^{1/2}$ is the distance between point (x, y) and point A.

Firm A's commuting region is shown in figure 1 by the shaded area enclosed by the line *cbde*. The inner boundary of the region is at point *b*, where a worker living along the x-axis is indifferent between commuting inward and outward. Increases in w' relative to w^* cause firm A's commuting region to increase in size, while decreases in w' relative to $w^* - \gamma$ cause firm A's commuting region to decrease in size and to collapse eventually to the line segment *Ae*. The larger area in figure 1 enclosed by the dashed line shows firm A's commuting region if its wage rose but remained below the CBD wage.[5]

Thus the sizes of commuting regions for firms at different locations are determined by workers choosing job locations to maximize their wages net of commuting costs. But when workers choose jobs by this criterion, the total amount of commuting by workers in the urban area (and the average commuting journey length) is minimized given the fixed spatial pattern of jobs and housing. This is the link that emerges in the urban models literature between individual workers' optimizing behavior and minimization of the total amount of commuting in an urban area.[6] But workers are assumed to choose job

[5] The outer boundary of firm A's commuting region actually will bulge out slightly beyond the circle of radius 0*e*. Note that the shape of firm A's commuting region would be similar if the more realistic assumption were made that housing consumption rose with greater distance from the CBD. In that case, the boundary of firm A's commuting region would be determined by the condition that households living along the boundary must achieve the same level of utility if their workers commuted to the CBD vs. to firm A.

[6] In the example in fig. 1, this implies that the average commuting journey length by all workers in the city is minimized when workers living in the shaded area choose jobs at A and all other workers choose jobs at the CBD. To show this, suppose that a worker lives at an arbitrary point (x_1, y_1), which is not in the shaded region in fig. 1, and commutes to the CBD. Another worker lives at (x_2, y_2), which is in the shaded region, and commutes to firm A. If total commuting is minimized by workers in the shaded region commuting to firm A and workers not living in the shaded region commuting to the CBD, then commuting by the two workers together must increase if they switched jobs. This implies that $(x_1^2 + y_1^2)^{1/2} + [(x_2 - 1)^2 + y_2^2]^{1/2} < (x_2^2 + y_2^2)^{1/2} + [(x_1 - 1)^2 + y_1^2]^{1/2}$. Each worker decides where to work by choosing the job location where wages net of commuting costs are highest. For the worker at (x_1, y_1) to choose a job at the CBD, the wage net of commuting costs must be higher there than at firm A, or $w^* - \gamma(x_1^2 + y_1^2)^{1/2} > w' - \gamma[(x_1 - 1)^2 + y_1^2]^{1/2}$. Similarly, for the worker at (x_2, y_2) to choose a job at firm A, it must be the case that $w' - \gamma[(x_2 - 1)^2 + y_2^2]^{1/2} > w^* - \gamma(x_2^2 + y_2^2)^{1/2}$. But if the two inequalities defining workers' job location choices are added together, the resulting expression is the condition that the two workers minimize the sum of their commuting distances. The same argument can be made for any pair of workers in the city.

locations taking the spatial pattern of workplaces as fixed. If the pattern of commuting that results when workers choose job locations to maximize net earnings includes out-commuting or circumferential commuting, then there must be more commuting in total and on average in the urban area than there would be if the spatial pattern of job locations could be rearranged so that all workers could commute inward to their jobs.

Thus when predictions concerning commuting behavior are developed using the monocentric urban models approach, the assumption that workers maximize earnings net of commuting costs is enough to assure that the total amount of commuting and the average commuting journey length in the urban area will be minimized. But workers make their decisions subject to the fixed spatial pattern of job locations in the urban area. They therefore may end up commuting outward or circumferentially to a suburban subcenter. Further, workers make their decisions subject to the constraint that they travel via the existing transportation network in the city. These two factors cause the minimum amount of commuting by all workers in the city and the minimum average commuting journey in the city to be higher than they would be if all workers could commute inward or if all commuting trips could take place along ubiquitous, straight-line roads. But the postulates of rational behavior by urban workers cannot go so far as to require that workers do the impossible: commute only inward when the spatial pattern of job locations requires some outcommuting or commute along only straight-line routes when the actual road network is a grid pattern or a series of former cow paths. The urban monocentric model should not be interpreted to require that workers do more than choose rationally with respect to the existing spatial pattern of jobs and the existing transportation network. Only commuting that exceeds this amount should be counted as "wasteful."

One further issue is whether it is reasonable to assume that firms actually locate in spatially concentrated suburban subcenters (such as point *A* in fig. 1) or whether profit-maximizing firms would actually choose locations that are spread out uniformly around the CBD so as to allow workers to commute inward. Clearly there is an incentive for firms to spread out uniformly around the CBD since by doing so they can save the extra wage payments necessary to induce workers to commute outward or circumferentially. In general, firms choose locations within a metropolitan area by a process of cost minimization. By moving to the suburbs, they save on the cost of land (since the price of land falls with greater distance from the CBD), they also may save on the costs of transporting inputs and outputs by avoiding CBD congestion, and they save on workers' wages, with the amount of savings depending on the extent to which their workers must commute outward or circumferentially. The costs of production also may be lower in the suburbs for some firms, such as manufacturing firms that realize cost savings from having large sites to accommodate horizontal assembly lines. Thus we expect that at least some firms will choose suburban locations even though they are large and need work forces that must commute outward or circumferentially. In general, firms making location decisions minimize a broader set of costs than just workers' commuting costs.[7]

II. New Estimates of the Amount of Waste in Urban Commuting

We have shown that Hamilton's measure of wasteful commuting actually includes three separate factors leading to extra commuting. These are (1) differences between the spatial distributions of jobs and residences around the CBD, which are caused by concentrations of employment at suburban subcenters; (2) the fact that the actual road network is not ubiquitous, so that commuting journeys do not proceed along straight-line routes; and (3) the existence of commuting trips that could be shortened if workers trade jobs or residences, thereby reducing the total amount of commuting in the metropolitan area. (This latter will be referred to as "cross-commuting.") Of these three sources of extra commuting, only the third should be counted in determining the amount of wasteful commuting because only cross-commuting can be eliminated if workers trade jobs or houses given the fixed spatial pattern of workplaces and residences. But Hamilton's own method includes all three.

A new method of calculating the average minimum commuting journey length using an assignment model enables us to separate out the amount of extra commuting actually due to cross-commuting from that due to the first and second factors of the three listed above. The 1980 *Census of Population* (subject report, *Journey to Work: Characteristics of Workers in Metropolitan Areas* [sec. 1]) divides metropolitan areas into political jurisdictions including the legal central city, suburban towns having populations of 25,000 or more, the remaining parts of suburban counties, and sometimes entire suburban counties. For each jurisdiction, data are given on how many workers live in that jurisdiction and commute to workplaces in each of the other jurisdic-

[7] For the 49 largest U.S. metropolitan areas, only 8 percent of jobs are located in the CBDs and 48 percent of jobs are located in the legal central cities. This suggests that even some large firms must have found it profitable to choose suburban locations, although they must pay their workers extra to commute outward.

tions within the same metropolitan area. Also, the average time spent commuting is given for workers who live in each jurisdiction and commute to workplaces in each of the other jurisdictions. For purposes of the workplace breakdown, the legal central city is divided between jobs in the CBD and jobs in the rest of the central city.[8]

Suppose that a metropolitan area has residential jurisdictions, denoted i, that include the legal central city and its suburban jurisdictions. The same metropolitan area has separate workplace jurisdictions, denoted j, that include the CBD, the remainder of the central city, and the same set of suburban jurisdictions. There are I separate residential jurisdictions and J separate workplace jurisdictions, where $J = I + 1$.[9] The number of workers who live in jurisdiction i and commute to workplaces in jurisdiction j is denoted n_{ij}. A matrix having dimensions I by J and elements n_{ij} is constructed of the number of workers who commute from any residential location to any workplace location.

The total number of workers living in the ith jurisdiction is denoted N_i, where $N_i = \Sigma_j n_{ij}$. The total number of workers living anywhere in the metropolitan area is denoted N, where $N = \Sigma_i N_i$. The total number of workplaces in the jth jurisdiction is denoted M_j, where $M_j = \Sigma_i n_{ij}$. The total number of workplaces anywhere in the metropolitan area is denoted M, where $M = \Sigma_j M_j$. Workers who live in the standard metropolitan statistical area but work outside it and workers who live outside the area but work in it are excluded from the analysis. Therefore, the total number of workers must equal the total number of jobs in the metropolitan area, or $N = M$.[10]

A matrix of actual commuting times having dimensions I by J is also constructed. Its elements are denoted t_{ij}. Average actual commuting time for workers in the metropolitan area, denoted $\bar{t}$, is the weighted sum of the matrix of commuting times, with weights equal to the proportion of workers in the metropolitan area commuting from jurisdiction i to j. Thus $\bar{t} = \Sigma_i \Sigma_j t_{ij} n_{ij}/N$.

[8] Commuting time is used here rather than commuting distance to measure work-place-residence separation for convenience reasons, since the census does not give distance data, and because time spent commuting is a better measure than distance of the cost of commuting, since it is workers' time that is scarce and is economized on. Also, independent evidence suggests that workers who commute further tend to travel at considerably higher average speeds. Cherlow and Morgan (1976) found that a group of workers who commuted less than 6 miles had an average speed of 13 mph, while a group of workers who traveled 11 miles or more had an average speed of 34 mph. The average distance traveled of the former group was 2.6 miles and that of the latter group was 21.2 miles. Thus an eightfold increase in distance was associated with only a threefold increase in commuting time.

[9] Occasionally, a metropolitan area has two CBDs. Then $J = I + 2$.

[10] Workers who are unemployed or who do not report a fixed place of work are also excluded.

We wish to construct a figure for the average minimum commuting time in the metropolitan area that corrects for cross-commuting but not for extra commuting due to the differing spatial patterns of jobs and housing or due to the actual road network. Assume that the actual spatial patterns of jobs and housing are represented by the numbers of jobs and residences located in each jurisdiction, or by the vectors N_i and M_j, which are assumed to be fixed. Also assume that the actual road network is represented by the matrix of actual average commuting times between jurisdictions, whose elements are t_{ij}. These values are also assumed to be fixed. Then we can determine the average minimum commuting time figure by solving for the assignment of workers to jobs that minimizes the total time spent commuting by all workers in the metropolitan area.

The optimization problem thus solves for a new matrix of worker-to-job assignments that minimizes the total time spent commuting by all workers in the metropolitan area. Suppose that the elements of this matrix are denoted n^*_{ij}. The optimization problem is then[11]

$$\min Z = \sum_i \sum_j t_{ij} n^*_{ij} \tag{2}$$

subject to the constraints $\Sigma_i\, n^*_{ij} = M_j$, $\Sigma_j\, n^*_{ij} = N_i$, and $n^*_{ij} \geq 0$. The solution matrix is then used to solve for the minimum average commuting time in the metropolitan area, which is denoted $\bar{\tau}$. It is $\bar{\tau} = \Sigma_i \Sigma_j\, t_{ij} n^*_{ij}/N$.

The difference between the average actual time spent commuting, $\bar{t}$, and the average minimum time spent commuting, $\bar{\tau}$, is cross-commuting, which could be eliminated if workers trade residences or jobs. This corresponds exactly to Hamilton's definition of wasteful commuting, except that our procedure has eliminated the actual road network and the differing spatial patterns of jobs and housing as additional contributors to the measured amount of wasteful commuting. The proportion of commuting that is wasteful in these calculations is expected to be smaller than that found by Hamilton because it eliminates these two additional sources of extra commuting.

In choosing cities, I included all the cities studied by Hamilton, for purposes of comparison with his study, plus several cities chosen because they contain large numbers of separate jurisdictions. The results are given in table 1. Columns 1 and 2 give the actual average and minimum average commuting times for workers in each metropolitan area. Column 3 gives the proportion of commuting that is wasteful, equal to $(\bar{t} - \bar{\tau})/\bar{t}$.

The results are quite striking. They suggest that there is little waste

[11] The algorithm used here is taken from Syslo, Deo, and Kowalik (1983).

TABLE 1

AVERAGE ACTUAL AND MINIMUM COMMUTING JOURNEY LENGTHS AND WASTEFUL COMMUTING

Metropolitan Area	Average Actual Commute (Min.) (1)	Average Minimum Commute (Min.) (2)	Proportion Wasteful (3)	Hamilton's Proportion Wasteful (4)	Number of Jurisdictions (5)	Suburban Jobs/ Houses (6)
Baltimore	21.6	19.5	.097	.93	7	.79
Boston	22.2	18.7	.16	.80	16	.84
Chicago	27.7	23.7	.14	...	22	.93
Cleveland	22.9	20.2	.12	...	10	.65
Columbus, Ohio	19.4	18.2	.062	.87	8	.72
Dallas	22.3	19.5	.12	...	32	.93
Denver	20.9	18.3	.12	.90	11	.63
Detroit	22.7	18.1	.20	...	21	1.06
Houston	26.4	24.7	.065	.85	10	.71
Los Angeles	23.6	19.6	.17	...	30	.91
Memphis	21.5	20.5	.047	...	6	.61
Milwaukee	18.7	16.6	.11	.90	8	.97
Minneapolis/St. Paul	19.4	16.3	.16	...	15	.72
New York	34.9	31.5	.097	...	14	.73
Philadelphia	24.9	21.7	.13	.98	17	.88
Phoenix	21.5	18.2	.15	.90	7	.86
Pittsburgh	22.7	20.8	.084	.86	7	.71
Rochester, N.Y.	18.8	17.4	.074	.76	6	.62
Sacramento	18.9	17.8	.058	.79	5	.80
San Antonio	20.0	19.4	.030	.94	5	.67
San Diego	19.0	17.4	.083	.79	8	.82
San Francisco	24.5	20.9	.15	...	19	.89
St. Louis	22.6	20.3	.10	...	12	.74
Washington	28.0	24.5	.12	...	14	1.06
Wichita	17.5	16.3	.069	...	5	.82
Average	22.5	20.0	.11	.87	12.6	.80

in commuting behavior by urban workers. The average commuting journey length is 22.5 minutes, the average minimum commuting journey is 20.0 minutes, and the average proportion of commuting that is wasteful is .11. The number of minutes added to the average commuting journey by cross-commuting is 2.5.

Column 4 of table 1 gives Hamilton's results for the proportion of commuting that is wasteful, measured in the same way as in column 3, for those cities included in his study.[12] Measured in this way, his average proportion of commuting that is wasteful is .87, or eight times the results obtained here. Since both sets of figures for wasteful commuting include commuting that could be eliminated if workers trade jobs or residences, a comparison of Hamilton's results with mine suggests that the influence of the actual road network and of the differing spatial patterns of jobs and housing, which add to Hamilton's calculations of waste in commuting but not to the results presented here, is much more important than the influence of cross-commuting in explaining Hamilton's results. If these factors are eliminated, then the amount of waste in the urban commuting pattern falls to a small proportion of actual commuting.

In order to explain why my results for the amount of wasteful commuting are so low, it is of interest to examine the characteristics of the actual spatial pattern of jobs and housing more closely. Column 6 of table 1 gives the average ratio of jobs to houses in suburban jurisdictions for each of the metropolitan areas in the sample.[13] The average value for the sample of cities is 0.80. Thus the majority of workers who live in any suburban jurisdiction can take a job in the same jurisdiction if they choose.[14] Further, the characteristics of the road network suggest that the worker has a strong incentive to do so. A general characteristic of the commute time matrix is that the average time required for commuting journeys that begin and end in the same jurisdiction is smaller than for any journey that crosses jurisdiction lines; that is, t_{ij} is minimized for $i = j$. Typically, commuting time is next lowest for journeys to a few nearby jurisdictions and rises steeply for journeys to the CBD and to nonadjacent suburban jurisdictions.[15]

[12] The figure given here is Hamilton's "mean actual commute" minus his "mean optimum commute," divided by the former, or (col. C − col. D)/col. C of his table 1 (1982, p. 1041).

[13] This figure is the simple average of M_j/N_i for all jurisdictions included in the commuting calculations except the legal central city (or cities).

[14] Given the degree of aggregation in the data, this figure is still consistent with substantial differences in the spatial distributions of jobs and housing. However, the figures do suggest that the stereotypical "bedroom suburb" is a disappearing phenomenon.

[15] The average within-jurisdiction commute for each metropolitan area, excluding commutes within the central city, ranges from 11 to 17 minutes in the group of met-

The low wasteful commuting results suggest that the number of workers who commute between nonadjacent suburban jurisdictions (which are the journeys most likely to be wasteful) is small.

Variation in the number of jurisdictions on which the calculations of wasteful commuting for each metropolitan area are based presents a potential source of bias in the calculations. (The number of separate workplace jurisdictions for each metropolitan area is given in table 1, col. 5.) As indicated, normally the length of the average commuting journey within a jurisdiction is shorter than the length of any commuting journey that crosses jurisdiction lines. This means that any commuting journey within a jurisdiction is already efficient and will not be changed by the assignment procedure.[16] In contrast, commuting journeys that cross jurisdiction lines have greater potential to differ in the optimal versus the actual assignment of workers to jobs. But as the number of jurisdictions in a metropolitan area falls, their size increases and the proportion of commuting journeys that are within jurisdictions rises. Therefore, the observed pattern of commuting will be closer to the optimal assignment pattern. This suggests that the proportion of commuting that is wasteful may tend to fall as the number of jurisdictions falls.

Therefore, increases in the number of jurisdictions may have a positive effect on the measured amount of wasteful commuting. However, this effect should decrease in importance as the number of jurisdictions rises. One reason for this is that the longest outward or circumferential commuting journeys, such as a journey from a residence near the CBD to a job in the outer suburbs, would tend to be eliminated in the optimal assignment regardless of whether there are many separate jurisdictions or few. In addition, as the number of jurisdictions rises, their average size gets smaller. This means that some commuting journeys that were previously efficient because they were within a jurisdiction become wasteful when the number of jurisdictions rises because they extend between two adjacent jurisdictions and are outward or circumferential. But as the number of jurisdictions rises, the time difference between the length of the average

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ropolitan areas studied, with an average value of 13 minutes for the sample. The average time spent commuting to the CBD of each metropolitan area from all jurisdictions ranges from 24 to 58 minutes in the sample, with an average value of 38 minutes. The longest commuting journey in each commuting time matrix for the group of cities studied ranges from 35 to 99 minutes. The average of the maximum values is 68 minutes.

[16] The solution matrix to the assignment problem typically specifies that workers living in a particular residential jurisdiction commute only to jobs within that jurisdiction or to jobs in one or two other jurisdictions, usually the CBD or an adjacent suburban jurisdiction. All other entries in the solution matrix are zero. Thus long commuting journeys, except those to the CBD, are almost always eliminated.

commuting journey within a jurisdiction and the length of the average commuting journey between adjacent jurisdictions falls.[17] Thus while the assignment problem may rearrange more commuting journeys when there are more—but smaller—jurisdictions, the gain in terms of reduced commuting when workers trade jobs or houses is likely to be smaller. Therefore, holding other factors constant, we expect that as the number of jurisdictions rises, the calculated amount of wasteful commuting may rise, but at a diminishing rate.

This suggests that if wasteful commuting were measured with a data set having more jurisdictions, the proportion of commuting that would be found to be wasteful by the assignment method would probably rise somewhat. However, given the fact that the method used here to measure wasteful commuting corrects for the effects of the differing spatial patterns of jobs and housing and for the actual road network, it seems unlikely that the amount of wasteful commuting would rise by nearly enough to dominate the actual commuting figures, as Hamilton found.[18]

The results presented here suggest that monocentric urban models are in better shape than Hamilton's gloomy diagnosis would imply but that further research is still needed to explain why some urban workers voluntarily choose "wasteful" commuting trips. One factor likely to be important in explaining these choices is the increasing prevalence of two-worker households. Workers in these households must commute to two different workplaces from a single residence. This makes it more likely that one or both workers will choose an outward or circumferential commute. However, the assignment model treats these workers as though they lived in separate households and it assigns them to residences in different jurisdictions if doing so will reduce the average commuting journey length in the urban area. Another such factor is the proportion of black and minority workers in the urban labor force. To the extent that these workers face discrimination in either housing or job markets, they have more restricted choices of housing and job locations than white workers. They

[17] If jurisdictions were square and the commuting journeys between adjacent jurisdictions were always from the center of one to the center of the other, then halving the dimensions of each jurisdiction would imply a fourfold increase in the number of jurisdictions. But the length of commutes between adjacent jurisdictions would drop by only half.

[18] To test whether the relationship between wasteful commuting and number of jurisdictions diminishes with more jurisdictions, I regressed the proportion of commuting that is wasteful on a constant term, the number of jurisdictions, and on a variable equal to the number of jurisdictions minus 10, if this was nonnegative, or else zero. The sample was the 25 cities shown in table 1. Both variables were significant at the 95 percent level. The implied slope of the relationship between the proportion of commuting that is wasteful and the number of jurisdictions was .0115 for 10 or fewer jurisdictions, but only .0023 for more than 10 jurisdictions.

therefore are more likely to end up commuting outward or circumferentially because they cannot shift residential locations to commute inward to suburban jobs or shift job locations to accommodate centrally located residences. Thus cities having more two-worker households or more black and minority workers are likely to have more wasteful commuting. Further research probing the roles of these and other factors in causing some workers to choose wasteful commutes is clearly needed. It is hoped that future urban economists will not have to characterize any commuting behavior as wasteful and instead will be able to explain it.

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