JOURNAL OF URBAN ECONOMICS 29, 2–13 (1991)

Wasteful Commuting: A Re-examination[1]

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Received December 4, 1987; revised March 16, 1988

I. INTRODUCTION

In a provocative article, Hamilton [1] demonstrates that the simple monocentric model of urban location, modified to allow for decentralized employment, does a poor job of predicting actual commuting distances in major U.S. cities. According to the monocentric model, households locate to maximize the utility received from housing and all other goods (= income − commuting costs − housing costs). If households are otherwise indifferent among housing locations, and if there is one worker per household, utility-maximizing location choices minimize aggregate commuting distances, given the location of houses and jobs. The fact that average actual commutes are about 8 times the average minimum commute casts doubt on the validity of the monocentric model.

Hamilton's findings suggest that one should modify the monocentric model to incorporate other determinants of location choice. In the discrete housing-choice literature, for example, households receive utility from neighborhood amenities, as well as from the commuting distances of *all* workers in the household. When utility is defined in this way, utility-maximizing location choices need not minimize aggregate commuting distances; thus, the more general location-choice model may explain the divergence between average-actual and average-minimum commutes.

In this paper we examine by how much a broader definition of utility of residential location raises the average required commute. Specifically, we (1) estimate a utility function defined over housing and neighborhood attributes as well as the commuting distances of all workers in the

[1]The computer time for the research was generously provided by the University of Maryland Computer Science Center. We are grateful to Bruce Hamilton, Molly Macauley, Wally Oates, Bob Schwab, and an anonymous referee for helpful comments.

0094-1190/91 $3.00

household, and (2) reallocate households to houses to minimize the sum of commuting distances subject to the constraint that no household's utility is lowered when households are reassigned to houses. The resulting average commute, termed the average required commute, is then compared to the average distance-minimizing commute.

When this is done in Baltimore, Maryland, the average required commute is 5.04 miles for home owners and 4.17 miles for renters, considerably more than Hamilton's required commute of 0.68 mile. About 85% of the difference in required commutes is explained by differences between the distance-minimizing commute computed using microdata on the location of houses and jobs and actual road distances and that computed by Hamilton under the simplifying assumptions of the monocentric model. Acknowledging the utility received from neighborhood amenities accounts for only 15% of the difference between the two required commutes. Since the average-actual commute in Baltimore is approximately 10 miles, our research supports Hamilton's contention that some wasteful commuting occurs, but suggests that people commute only about twice as far as they need to.

II. A NEW DEFINITION OF THE AVERAGE REQUIRED COMMUTE

The purpose of our paper is to see how a broader definition of the utility a household receives from its residential location alters the average required commute in an urban area.[2] Following the discrete location-choice literature [3, 4, 7], we assume that utility is a function of housing and neighborhood attributes, the commuting distances of all workers in the household, and all other goods. Formally, the utility received by household h from house j is given by

$$U_{hj} = \alpha \ln(Y_h - P_j) + Z'_{hj}\beta + \gamma_1 D^1_{hj} + \gamma_2 D^2_{hj}, \tag{1}$$

where Y_h is household income, P_j is the annual cost of house j, Z_{hj} is a vector of housing and neighborhood attributes associated with the house, and D^1_{hj} and D^2_{hj} are the distances that the primary and secondary earners in household h must travel from house j to their jobs.[3] Throughout, we treat housing and job locations as fixed. We assume that households

[2] We follow Hamilton in referring to the average-minimum commute consistent with utility maximization as the "average required commute."

[3] In some formulations of (1) commuting costs are subtracted from income or commuting time is used in place of commuting distance. We have avoided the use of commuting costs, since their computation requires making arbitrary assumptions about the value of time and transportation-mode choice. Because the correlation between commuting distance and commuting time in our sample is high (0.96), it is a matter of indifference which is used.

choose residential locations to maximize utility, and denote by U_h^0 household h's present utility.

We define the average required commute as that which minimizes total commuting distance subject to the constraint that, in rearranging households to reduce commutes, no household's utility falls below U_h^0. Formally, this is equivalent to finding a matrix $[X_{hj}]$, with the property that $X_{hj} = 1$ if household h occupies house j and $X_{hj} = 0$ otherwise, that minimizes

$$\sum_h \sum_j X_{hj}\left(D_{hj}^1 + D_{hj}^2\right) \qquad \text{subject to} \tag{2}$$

$$\sum_h X_{hj} = 1, \qquad \text{all } j, \tag{3}$$

$$\sum_j X_{hj} = 1, \qquad \text{all } h, \tag{4}$$

$$X_{hj} \geq 0, \qquad \text{all } h, j \tag{5}$$

and

$$U_{hj} \geq U_{hj}^0 \qquad \text{if} \qquad X_{hj} = 1. \tag{6}$$

This is a variation of a standard assignment problem and can be solved using a network programming algorithm [2].

To compute the average required commute for Baltimore we have estimated the parameters of (1) and solved the assignment problem (2)–(6) using the Baltimore Travel Demand Dataset [8]. The Baltimore Travel Demand Dataset, a survey of 967 households living in the Baltimore metropolitan area in 1977, describes the transit zone in which each person in the household worked at the time of the survey, as well as his or her race, occupation, and education level. We also know the transit zone and census block in which the household lived, as well as housing tenure and household income. Distances between transit zones were computed using actual road networks.[4]

A. Estimation of the Location-Choice Model

The parameters of the utility function were estimated using a multinomial logit model of location choice. Let the unobserved attributes of house (location) j be summarized by an error term ϵ_{hj}, where ϵ_{hj} is assumed independently and identically distributed for all h and j with a Type I extreme value distribution. The probability of household h selecting house

[4]The geographic area covered by the survey (the set of all Regional Planning Districts that existed in 1977) is approximately equal to that used by Hamilton to compute average-minimum and average-random commutes, a circle of 20-mile radius extending from the center of Baltimore City. The area contains 498 transit zones.

(location) j then corresponds to a multinomial logit model of residential location choice

$$\pi_{hj} = P(U_{hj} + \epsilon_{hj} > U_{hk} + \epsilon_{hk}, \quad \text{all} \quad k \neq j) = \exp(U_{hj}) \Big/ \sum_k \exp(U_{hk}). \tag{7}$$

A multinomial logit model of choice of census block group was estimated, separately, for renters and owners in the Baltimore Travel Demand Dataset. The universal choice set for each respondent was assumed to consist of census block groups for which annual housing expenditure was no more than 60% of the respondent's income. For blacks, census block groups that were more than 90% white were excluded from the choice set. Since the average choice set contained over 1000 alternatives (there are 1348 census block groups in the Baltimore SMSA), a sampling rule was used to generate the choice set used in estimation of the logit model [4]. Each household's choice set consisted of the chosen alternative plus a 10% sample selected at random from the remaining alternatives in the universal choice set.

Table 1 presents two models of residential location choice, one for home owners and one for renters.[5] Except for commuting distance, distance to the CBD, and expenditure on all other goods, all variables that enter the utility function describe the housing stock or population of the census block group. Occasionally these variables interact with household characteristics, obtained from the Baltimore Travel Demand Dataset. Since our purpose is to control for as many determinants of location choice as possible, more than 20 housing/neighborhood variables are included in the utility function. It is, therefore, not surprising that only about half of these variables are significant at the 0.10 level or better. In the owner model, neighborhood variables generally perform well and have correct signs. Fewer neighborhood variables have significant coefficients in the equation for renters, possibly because renters are less concerned about neighborhood amenities or because of smaller sample sizes. For both renters and owners, variables that describe the housing stock often have the wrong signs.

[5]These models assume that the choice to rent or own is made before selecting a residential location, and imply that tenure choice should be treated as given when computing the average required commute. We have also estimated a nested logit model in which each household chooses tenure as well as census block group (see Appendix). If this utility function is used in (6), tenure status may change when households are reassigned to block groups to minimize commuting distance. How this alters the minimum required commute is noted below.

TABLE 1
Coefficients of the Baltimore Urban Area Residential Location Model

	Owners	Renters
1. Log (income − housing expenditure)	8.360	9.278
	(5.62)	(3.04)
2. Length of primary commute (one-way)	−0.157	−0.281
	(7.76)	(5.98)
3. Length of secondary commute (one-way)	−0.094	−0.515
	(1.18)	(1.64)
4. Mean bathrooms[a]	1.356	0.026
	(2.88)	(0.03)
5. Mean bedrooms[a]	−0.944	−1.297
	(1.29)	(2.30)
6. % Units detached[a]	−0.007	−0.0004
	(1.92)	(0.04)
7. Family size × mean bedrooms[a]	0.225	0.490
	(1.32)	(3.91)
8. % Units built before 1940[a]	0.007	−0.002
	(1.93)	(0.34)
9. % Units with central air	−0.012	−0.020
	(2.35)	(2.41)
10. % Population white	−0.090	−0.025
	(3.35)	(3.34)
11. Whether white × % white	0.110	0.054
	(4.03)	(4.77)
12. % Pop. on public assistance	−0.068	−0.055
	(4.18)	(3.37)
13. Median age population	0.039	0.035
	(2.08)	(1.67)
14. % Households with kids < 19	0.020	0.001
	(1.45)	(0.03)
15. Whether kids × % households w/kids	0.014	0.004
	(1.06)	(0.24)
16. % Owners moved in before 1960	−0.008	0.001
	(1.38)	(0.21)
17. % Owner-occupied housing	−0.013	−0.001
	(2.29)	(0.14)
18. % Professional/managerial	−0.023	−0.020
	(1.50)	(1.16)
19. Head professional × % professional	0.043	0.027
	(2.86)	(1.34)
20. % Over 25 < HS degree	−0.016	−0.002
	(1.27)	(0.13)
21. Head w/HS degree × % Pop. < HS	−0.015	−0.011
	(1.27)	(0.78)
22. % Owners moved in 1975–1980	−0.012	0.009
	(1.45)	(1.13)
23. Population per acre	−0.013	−0.007
	(1.99)	(0.85)
24. City dummy	−0.178	0.271
	(0.62)	(0.55)

TABLE 1—*Continued*

	Owners	Renters
25. Whether female × secondary commute	−0.087	−0.074
	(1.08)	(0.27)
26. Whether kids × secondary commute	−0.077	0.180
	(1.06)	(0.69)
27. Distance to CBD	0.087	−0.012
	(2.30)	(0.15)
28. Log (housing units)[a]	1.325	0.987
	(7.09)	(4.14)
$L(0)$	−888.3	−402.6
$L(\beta)$	−649.6	−288.2
−2 Log likelihood ratio	−477.4	−228.8
% Correct	11.6	20.2
Degrees of freedom	28	28
No. households	189	89
No. alternatives	21,495	8651
ρ^2	0.27	0.28
$\bar{\rho}^2$	0.25	0.25

Note. Asymptotic value of *t*-statistics in parentheses.
[a]Variable is measured by tenure.

The natural logarithm of the number of housing units (renter or owner-occupied, respectively) is included in each model to test the appropriateness of the multinomial logit specification. As noted by Lerman [3] and McFadden [4], the coefficient of this variable should not be significantly different from 1 if the multinomial logit specification is correct. This null hypothesis cannot be rejected at the 95% confidence level for either model in Table 1.

B. Implications of the Location-Choice Model

The location-choice models in Table 1 have two implications for wasteful commuting. One is that, contrary to Hamilton's claim, distance to work clearly matters to households in their location decisions. For owners, the marginal value of moving 1 mile closer to work is $386 per year for the primary earner and $634 for the secondary worker, assuming that the secondary worker is female and that children are present. For renters the corresponding values are $428 and $623.[6] These figures are consistent with

[6]The primary earner is considered to be the head of household if the head is in the labor force. If he or she is not, the primary earner is the highest income-earning person in the household. In general, the secondary earner is the person with the second-highest earnings in the household; however, if the head of household's spouse is working, he or she is always considered the secondary earner.

the literature on husband–wife commuting patterns [6, 9], which suggests that families place a higher value on the wife working close to home than on the husband working close to home.

The other implication of the location-choice model is that the average required commute, for persons in the Baltimore Travel Demand Dataset, is 5.04 miles for owners and 4.17 miles for renters. These figures were obtained by solving the assignment problem of (2)–(6) separately for renters and owners, with U_h^0 equal to the utility received by the household at its actual location. Both figures are considerably higher than the 0.68 mile reported by Hamilton.[7]

III. EXPLANATION OF THE AVERAGE REQUIRED COMMUTE

There are two possible explanations for the difference between our average required commute and Hamilton's minimum distance commute. One is that the minimum distance commute computed using data on the actual locations of houses and jobs and actual road distances is greater than the minimum distance commute computed using the monocentric model. The other is that broadening the definition of utility to include neighborhood amenities and the commute of all workers in the household raises the required commute above the minimum distance commute.

To see how important the first factor is, we have computed the average distance-minimizing commute for persons in the Baltimore Travel Demand Dataset by solving the assignment problem of (2)–(5). The average distance-minimizing commute is 4.39 miles for home owners and 3.65 miles for renters. The fact that the monocentric model understates the minimum distance commute thus accounts for most of the difference between our average required commute and Hamilton's. Broadening the definition of utility obtained from residential location increases the required commute above the minimum distance commute, but only by 0.65 mile for owners and 0.52 mile for renters.[8]

Hamilton notes three reasons why the monocentric model may understate the minimum distance commute. One is that it assumes a radial network of roads that is everywhere dense, whereas actual roads follow a rectangular grid. The second is that the model assumes that the locations of houses and jobs are approximated fairly well by a negative exponential density function. The negative exponential distribution may, however,

[7] When tenure choice is endogenous, the average required commute falls to 4.57 miles, slightly lower than the average of the required commutes for renters and owners (4.83 miles).

[8] When tenure choice is endogenous, the average distance-minimizing commute is 3.89 miles. In this case, broadening the definition of utility increases the required commute by 0.68 mile.

overstate the degree of employment decentralization. A third reason the minimum distance commute may be understated is that the monocentric model ignores the existence of secondary earners. Secondary earners may raise the minimum distance commute since workers in the same household are constrained to move together when the assignment problem is solved.

Of the three factors cited by Hamilton, the second does not seem to be significant in the case of Baltimore. Hamilton's employment density gradient, estimated by Macauley [5], implies that jobs are an average distance of 6.07 miles from the CBD. Disaggregated data on job locations, obtained from the Baltimore Regional Planning Council, imply that jobs in Baltimore are located an average of 6.61 miles from the CBD.

A more important reason for the difference between our minimum distance commute and Hamilton's lies in his assumption of symmetrically distributed jobs and houses. If jobs and houses are distributed symmetrically about the CBD then, as demonstrated by Hamilton, the minimum distance commute calls for workers to live on the same ray from the CBD as their jobs, but on the suburban side of the job location. If, in the real world, there are more jobs than houses along some rays from the CBD, then such a commuting pattern is impossible, and the minimum aggregate commute necessitates some circumferential commuting [10]. In Baltimore there are two suburban employment centers located in sparsely populated areas, one to the west of the city (along route 70) and one to the north (in Towson). It is either the case that some circumferential commuting must occur to these areas or that workers must commute outward from the CBD, thus violating the rule used to calculate Hamilton's minimum distance commute.

The fact that our broader definition of utility raises the required commute by less than 1 mile may be due to two factors. One is that we have failed to capture important neighborhood amenities, such as school quality and crime, whose qualities vary throughout the Baltimore SMSA. The other is that we have captured (via proxies) the most relevant neighborhood attributes; however, development has taken place so that neighborhoods that appeal to highly educated, professional workers are located close to professional jobs.

IV. CONCLUSIONS

The main point made by Hamilton is his study of urban commuting is that the average-actual commute in most U.S. cities is many times greater than the average required commute—the shortest commute compatible with utility maximization—if the latter is computed using the monocentric model of urban location. In Baltimore, for example, the average-actual commute [1] is 10.2 miles, 15 times Hamilton's required commute of 0.68 mile.

TABLE 2
Coefficients of Stage 1 of the Nested Logit Model

1. Log (income − housing expenditure)	7.960 (6.52)
2. Length of primary commute (one-way)	−0.181 (9.89)
3. Length of secondary commute (one-way)	−0.127 (1.63)
4. Mean bathrooms[a]	1.115 (2.92)
5. Mean bedrooms[a]	−1.271 (3.06)
6. % Units detached[a]	−0.002 (0.57)
7. Family size × mean bedrooms[a]	0.421 (4.46)
8. % Units built before 1940[a]	0.002 (0.81)
9. % Units with central air	−0.011 (2.80)
10. % Population white	−0.039 (5.92)
11. Whether white × % white	0.061 (8.23)
12. % Pop. on public assistance	−0.053 (4.76)
13. Median age population	0.037 (2.76)
14. % Households with kids < 19	0.009 (0.84)
15. Whether kids × % households w/kids	0.012 (1.10)
16. % Owners moved in before 1960	−0.004 (1.07)
17. % Owner-occupied housing	−0.003 (0.82)
18. % Professional/managerial	−0.020 (1.83)
19. Head professional × % professional	0.037 (3.16)
20. % Over 25 < HS degree	−0.007 (0.73)
21. Head w/HS degree × % Pop. < HS	−0.015 (1.70)
22. % Owners moved in 1975–1980	−0.002 (0.36)
23. Population per acre	−0.009 (1.71)
24. City dummy	−0.028 (0.12)
25. Whether female × secondary commute	−0.062 (0.80)

26. Whether kids × secondary commute	−0.072
	(1.04)
27. Distance to CBD	0.042
	(1.26)
28. Log (housing units)[a]	1.060
	(9.76)
$L(0)$	−1291.6
$L(\beta)$	−970.9
−2 Log likelihood ratio	−640.5
% Correct	13.7
Degrees of freedom	28
No. Households	278
No. Alternatives	30,146
ρ^2	0.25
$\bar{\rho}^2$	0.23

Note. Asymptotic value of *t*-statistics in parentheses.
[a]Variable is measured by tenure.

Our computation of the average required commute differs in two respects from Hamilton's. First, we use microdata on the location of houses and jobs and actual road distances rather than relying on the simplifying assumptions of the monocentric model. This raises the average minimum-distance commute (equal to the average required commute in the monocentric model) from 0.68 mile to 4.39 miles for home owners and 3.65 miles for renters. Broadening the definition of utility used in the monocentric model to include neighborhood amenities and the commuting distances of secondary workers further increases the average required commute to 5.04 miles for home owners and 4.17 miles for renters.

Our results thus suggest that the volume of wasteful commuting, at least in Baltimore, is considerably less than that computed by Hamilton. The average wasteful commute in Baltimore is about 5 miles, or about half the average actual commute. This figure, moreover, constitutes an upper bound to the average wasteful commute, to the extent that we have failed to measure all of the determinants of residential location choice, and may thus have understand the average required commute.

APPENDIX

Estimation of Model in Which Tenure Choice Is Endogenous

Treating tenure status as given when computing the minimum required commute imposes a restriction on the assignment problem that may

TABLE 3
Coefficients of Stage 2 of the Nested Logit Model

1. Less than HS degree[a]	−0.638
	(2.02)
2. College degree	−0.563
	(1.28)
3. Age ≤ 25	−0.766
	(1.29)
4. 26 ≤ age ≤ 35	−0.202
	(0.53)
5. 51 ≤ age ≤ 64	1.005
	(2.43)
6. Age ≥ 65	0.794
	(1.30)
7. Household size	−0.259
	(2.89)
8. Household income	0.00004
	(2.72)
9. Female household head	0.270
	(0.62)
10. White household	1.277
	(4.32)
11. Two or more earners	−0.154
	(0.49)
12. Married household head	1.223
	(2.88)
13. Inclusive value	0.738
	(4.74)
$L(0)$	−266.9
$L(\beta)$	−166.2
−2 Log likelihood ratio	−201.3
% Correct	81.0

Note. Asymptotic value of t-statistics in parentheses.
[a]Variable is multiplied by owner dummy.

overstate the minimum required commute. To allow owners and renters to switch locations, however, one must be able to predict how change of tenure alters utility. For this reason we estimated a nested logit model in which households choose tenure as well as residential location. Letting i index tenure choice (rent or own) and j index location (census block group), the probability of a household selecting the tenure-location alternative (i, j) is

$$P_{j|i}P_i,$$

where

$$P_{j|i} = \exp\left(\beta' X_{ij}/(1-\sigma)\right)/\exp(I_i); \quad I_i = \ln\left[\sum_k \exp(\beta' X_{ik}/(1-\sigma))\right]$$

and

$$P_i = \exp\left(\alpha' Y_i + (1-\sigma) I_i\right) \Big/ \sum_j \exp\left(\alpha' Y_j + (1-\sigma) I_j\right).$$

The nested logit model was estimated in two stages. Table 2 presents the coefficients $\beta/(1-\sigma)$ estimated from a model of location choice conditional on tenure. The results of Table 2 were used to compute an inclusive value, I_i, for each tenure option, which was then used to estimate a model of tenure choice. Table 3 contains estimates of α and $1-\sigma$ from the second stage of the nested logit model.

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