The Value of Time in Consumption and Residential Location in an Urban Setting

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Several economists have recently studied the location decisions of different population groups in towns where these groups are often classified according to income. In the context of a partial equilibrium model, for example, Richard Muth has argued that if housing is a superior good, high wage earners will live farther away from urban centers than will low wage earners; and his empirical evidence supports both the assumption and the conclusion.[1] Margaret Reid and John Kain provide results corroborating, respectively, an income elasticity substantially greater than one and the predicted residential distribution of income groups. Using a specific general equilibrium model, Edwin Mills found that the location pattern was consistent with that of Muth, when the income elasticity exceeded one and was indeterminate when it fell short of this figure. Finally, although Martin Beckmann and A. Montesano assume away the income elasticity problem, their findings are not inconsistent with Muth's theory.

However, several recent empirical studies[2] have estimated the income elasticity of housing to average about 0.7, a finding inconsistent with Muth's theory and one which opens up the whole question of relative residential location once again.

It is accordingly the purpose of this paper to amend the Muthian theory reestablishing congruence between the model's predictions and the empirical findings. The fundamental amendment involves treatment of the time constraint in the framework of consumer choice. The value of time as an important cost of commuting and therefore an ingredient in the mechanism of residential choice is generally both recognized and considered in analyses of location decisions. However, the value of time may also affect residential decisions through its role in the cost of consumption activities other than commuting. By neglecting the tradeoff between housing and time in consumption net of commuting, most studies have overemphasized the tradeoff between housing and commuting costs. By considering both tradeoffs, the present paper works both to correct the previous imbalance in the theory's treatment and to indicate that under fairly plausible conditions high wage earners may still choose to reside farther away from urban centers even if housing is an inferior good.

I. Individual Choice and Constraints

Consider a typical individual assumed to maximize a utility function in two normal goods, H and Z, of the form

$$U = U(H, Z) \tag{1}$$

where H is residential land as a proxy for housing (see Alonso, Muth (1969), and Beckmann), and Z is a composite commodity. The household produces Z by combining market goods (excluding land) x, and time in consumption t (see Becker), in

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[1]Further evidence supporting the direct income-distance relation is provided in the Muth (1969) investigation of six cities. The empirical findings indicate that the simple regression coefficients of income on distance are positive and significantly greater than zero (at the 0.1 level) for all six cities.

[2]See, for example, John Campbell and Barton Smith, Geoffrey Carliner, and R.K. Wilkenson.

accordance with a linear homogeneous production function

$$(2) \qquad Z = F(x, t)$$

The respective cost function is given by

$$(3) \qquad C = C(Z; p, w)$$

where p is the price level of market goods and w is the wage rate (the price of time). The shadow price of the commodity Z is given by

$$(4) \qquad \pi = \frac{\partial C}{\partial Z}(Z; p, w)$$

In all that follows, p is assumed to be fixed. Hence, by the linear homogeneity of (2), π is a monotonically increasing function in w

$$(5) \qquad \pi = \pi(w) \qquad \partial\pi/\partial w \geq 0$$

Moreover, since $\partial C/\partial Z = C/Z$

$$(6) \qquad \pi \cdot Z = C(Z; p, w)$$

With the further standard simplifying assumption (see Muth, 1969, Beckmann, and Mills) that the only cost factor in transportation is commuting time, the budget constraint is given by

$$(7) \qquad RH + C(Z; p, w) = w(\mathrm{T} - D) + V$$

where R is rent per unit of land, T is total time available to the household, V is nonearned income, and D is time spent in commuting. Normalizing on T (T = 1), and substituting in (6), (7) can be rewritten

$$(7') \qquad RH + \pi Z = w(1 - D) + V$$

The term D stands, therefore, for the proportion of time spent in commuting and may also be interpreted as a measure of the distance between the residential location and the Central Business District (CBD).

II. Equilibrium in the Residential Ring

Consider the environment as a system of cities in equilibrium with free and costless flow of population between cities. Consider also two groups of population, $i = 1, 2$, with the same utility function of type (1) above, but with different wage rates and nonlabor incomes. Thus, the overall equilibrium utility levels in the system will be

$$(8) \qquad U(H_i, Z_i) = u_i \qquad i = 1, 2$$

where u_i, the utility level of group i, is a parameter for all members in each population group at equilibrium.

Thus, the utility function reduces to a single indifference curve for each type of population. Note that equal utility levels between cities does not necessarily imply equal wage rates. Without restrictions on the generality, further assume that

$$(9) \qquad u_1 > u_2$$

Consider now a city in this system containing both types of population, and assumed as is standard, to be circular with a CBD of given radius ϵ where the labor market is located.

Each population group has its own bid-rent function, that is, the maximum rent an individual from that group is ready to pay in each location. Competitive equilibrium implies that the group residing in a given location is the one with the higher bid rent (see Alonso and Mills).

Let $R_i(D)$ be the bid-rent function for population group i. For every D, $R_i(D)$ is determined by the solution to the problem

$$(10) \qquad R_i(D) = \max_{Z, H} R_i \qquad i = 1, 2$$

subject to (7′) and (8). The first-order condition necessary for that maximization is

$$(11) \qquad R_i = \frac{U_H}{U_Z}\pi_i \qquad i = 1, 2$$

The properties of the bid-rent functions can be worked out as follows. Differentiating the budget constraint (7′) with respect to distance D results in

$$(12) \qquad H_i R_i' + R_i H_i' + \pi_i Z_i' = -w_i \qquad i = 1, 2$$

where a prime above a letter denotes a partial derivative with respect to distance D. After differentiating totally (8) and then substituting in (11), the result is

$$(13) \qquad R_i H_i' + \pi_i Z_i' = 0 \qquad i = 1, 2$$

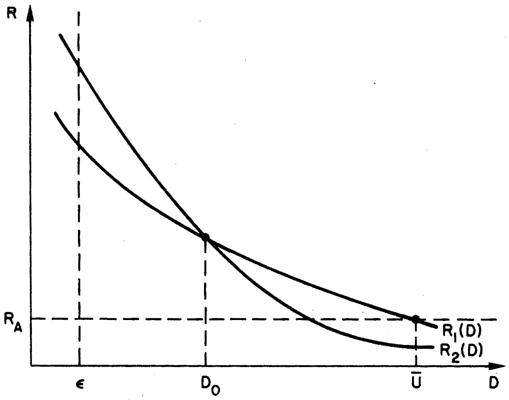

FIGURE 1

Solving from (12) and (13) for R_i',

$$R_i' = -w_i/H_i < 0 \qquad i = 1,2 \tag{14}$$

reflecting the well-known spatial equilibrium condition $R_i'H_i + W_i = 0$.[3] This condition indicates that a household is in equilibrium when moving one unit of distance away from the *CBD* increases commuting cost by exactly the same amount it reduces housing cost. By further differentiating (14), noting that $H' > 0$,

$$R_i'' = \frac{w_i}{H_i} H_i' > 0 \qquad i = 1,2 \tag{15}$$

Equations (14) and (15) indicate that the bid-rent curves must be concave and decreasing. Two typical bid-rent curves obeying these properties are shown in Figure 1.

III. Relative Location Due to Difference in Nonearned Income

Investigation of relative residential location due to differences in nonearned income can now proceed. Consider two population groups with different levels of nonearned income, but equal in all other respects. Thus

$$w_1 = w_2 = w \qquad \text{but} \qquad V_1 > V_2 \tag{16}$$

The presence of two population groups at equilibrium in the same city implies the existence of at least one intersection point between the two respective bid-rent functions. Consider then, such an intersection point D_0 (see Figure 1), where $R_1(D_0) = R_2(D_0)$. By (5) and (16) $\pi_1 = \pi_2$ and since H is a normal good $H_1 > H_2$. Hence, substitution of these relations into (14) obtains

$$|R_1'| = w/H_1 < w/H_2 = |R_2'| \tag{17}$$

Namely, the bid-rent function of the poorer group is steeper in the neighborhood of the given intersection point. Since this particular intersection point was arbitrarily chosen, this result must obtain in the neighborhood of any intersection point. Two outcomes follow: first, the bid-rent curves of the two population groups have one and only one intersection point; second, $R_1 < R_2$ for $\epsilon \leq D < D_0$, but $R_1 > R_2$ for $D_0 < D \leq \bar{U}$, where D_0 and $\bar{U}$ are the intersection point and the boundary of the town, respectively (see Figure 1).

The first outcome indicates that a well-defined and unique dividing line between an inner residential ring and an outer residential ring has been established in the framework of the given assumptions. The second outcome indicates that the bid rents of the wealthy dominate that market in the outer ring. Hence, this result follows:[4]

COROLLARY 1: *Two local groups of population with different levels of nonearned income, but equal in all other respects, would tend to locate in the following order: the poorer group closer to the CBD, the wealthier farther away.*

IV. Relative Location Due to Wage Differentials

Consider now two local groups of pure wage earners (with no other income aside from earnings) facing different wage rates, but equal in all other respects. In particular,

$$w_1 > w_2 \qquad \text{but} \qquad V_1 = V_2 = 0 \tag{18}$$

Substitution into (7') of $V_i = 0$, followed by division by H_i and substitution for w/π

[3]See, for example, Muth (1969) and Mills.

[4]This result is consistent with earlier findings of Becker and Muth (1969).

from (14), results in

$$(19)\quad R_i + \pi_i \frac{Z_i}{H_i} = -R_i'(1-D) \quad i = 1,2$$

Since $R_i' < 0$, $-R_i' = |R_i'|$. Hence, by subtracting (19) for $i = 2$ from (19) for $i = 1$,

$$(20)\quad (|R_1'| - |R_2'|)(1-D) = (R_1 - R_2) + \left(\frac{\pi_1 Z_1}{H_1} - \frac{\pi_2 Z_2}{H_2}\right)$$

At an intersection point D_0, at which $R_1(D_0) = R_2(D_0) = R$, equation (20) can be expressed in a slightly different form:

$$(21)\quad (|R_1'| - |R_2'|)(1-D) = R(1/S_{H_1} - 1/S_{H_2})$$

where S_{H_i} is the share of housing in total expenditure on consumption, that is,

$$(22)\quad S_{H_i} = \frac{R_i H_i}{R_i H_i + \pi_i Z_i} = \frac{R_i H_i}{w_i(1-D)} \quad i = 1,2$$

From (21), it is clear that

$$(23)\quad |R_1'| \gtreqless |R_2'| \quad \text{as} \quad S_{H_1} \lesseqgtr S_{H_2}$$

If $S_{H_1} > S_{H_2}$ everywhere, then for $\epsilon \leq D < D_0$ (i.e., everywhere in the inner ring), $R_1 < R_2$, and for $D_0 < D \leq \bar{U}$ (i.e., everywhere in the outer ring), $R_1 > R_2$. If $S_{H_1} < S_{H_2}$, these inequalities are reversed. If $S_{H_1} = S_{H_2}$ everywhere, the two bid-rent curves coincide and $R_1 = R_2$ everywhere. Note also that as long as $S_{H_1} \neq S_{H_2}$ everywhere, D_0 must be the only intersection point.

A preliminary conclusion with respect to the residential distribution of wage earners then follows:

COROLLARY 2: *Two local groups of pure wage earners with different wage rates, but equal in all other respects, would tend to locate in the following order: the group with the lower share of housing at each given level of rent will locate closer to the CBD; the group with the higher share will locate farther away. Equal housing shares, on the other hand, imply a mixed residential distribution of the two groups.*

Note that this is a refutable hypothesis for which direct data might actually exist. Indeed, the whole issue boils down to the question of which group tends to consume a larger share of housing, and the following analysis attempts to characterize the above result in more familiar terms.

The second term on the right-hand side of (21) can be rewritten as follows:

$$(24)\quad 1/S_{H_1} - 1/S_{H}2 = \left[1/S_{H_1} - (1/S_H)_{\substack{\pi=\pi_1\\U=u_2}}\right] + \left[(1/S_H)_{\substack{\pi=\pi_1\\U=u_2}} - 1/S_{H_2}\right]$$

Defining the bracketed terms on the right-hand side of equation (24) as ΔI (the income effect), and Δs (the substitution effect), respectively, allows equation (21) to be rewritten:

$$(25)\quad (|R_1'| - |R_2'|)(1-D) = R(\Delta I + \Delta s)$$

The sign of ΔI is determined by the standard definition of the income elasticity as follows:

$$(26)\quad \Delta I \lesseqgtr 0 \quad \text{as} \quad \eta \gtreqless 1$$

where η is the income elasticity of H. Similarly, when $\pi_1 > \pi_2$, the sign of Δs is determined as follows:

$$(27)\quad \Delta s \lesseqgtr 0 \quad \text{as} \quad \left.\frac{\partial S_H}{\partial \pi}\right|_{\substack{dU=0\\dR=0}} \gtreqless 0$$

When $\pi_1 = \pi_2$, $\Delta s = 0$.

Let σ stand for the Allen-Hicks elasticity of substitution of U, that is,

$$(28)\quad \sigma = \left.\frac{d\log Z/H}{d\log R/\pi}\right|_{dU=0} = 1 + \left.\frac{d\log S_Z/S_H}{d\log R/\pi}\right|_{dU=0}$$

Since $S_H + S_Z = 1$, solving for S_H in terms of S_Z/S_H obtains

$$(29) \qquad S_H = \frac{1}{S_Z/S_H + 1}$$

Differentiating both sides of (29) with respect to π results in[5]

$$(30) \qquad \left.\frac{\partial S_H}{\partial \pi}\right|_{\substack{dU=0\\dR=0}} = \frac{S_H S_Z}{\pi}(\sigma - 1)$$

Since all the variables on the right-hand side of equation (30) are positive, the sign of the expression depends on whether $\sigma \gtreqless 1$. Hence by (27) and (30)

$$(31) \qquad \Delta s \begin{cases} = 0 & \text{iff} \quad \sigma = 1 \quad \text{or} \quad \pi_1 = \pi_2 \\ > 0 & \text{iff} \quad \sigma < 1 \\ < 0 & \text{iff} \quad \sigma > 1 \end{cases}$$

Table 1 sums up the results derived from equation (26). Corollary 3 follows immediately.

COROLLARY 3: *Two groups of pure wage earners residing in the same city, differing in their wage rates but equal in all other respects, would tend to locate in the following way:*

a. *High (low) wage earners will reside farther away from (closer to) the CBD than the low (high) wage earners if both the income elasticity of housing is greater than one* ($\eta > 1$) *and the elasticity of substitution between housing and all other goods is greater than one* ($\sigma > 1$).

b. *High (low) wage earners will reside closer to (farther away from) the center of town than low (high) wage earners if both* $\eta < 1$ *and* $\sigma < 1$.

c. *If* $\eta = 1$ *and either* $\sigma = 1$ *or* $\pi_1 = \pi_2$, *a mixed residential distribution of the two groups will result.*

[5]The following steps are involved in the derivation of the right-hand side of (30):

$$\frac{d}{d\pi}\frac{1}{S_Z/S_H + 1} = -\frac{d(S_Z/S_H)}{d\pi}(S_Z/S_H + 1)^{-2} = S_H^2 \frac{d(S_Z/S_H)}{d(R/\pi)}\frac{d(R/\pi)}{d\pi} = \frac{S_H S_Z}{\pi}\frac{d \log (S_Z/S_H)}{d \log (R/\pi)}$$

By substituting in the above equation $(\sigma - 1)$ from equation (28), we get (30).

TABLE 1

Sign of $(\lvert R_1' \rvert - \lvert R_2' \rvert)$	$\eta < 1$	$\eta = 1$	$\eta > 1$
$\sigma < 1$	+	+	?
$\sigma = 1$	+	0	−
$\sigma > 1$	?	−	−

d. *If either* $\eta > 1 > \sigma$ *or* $\eta < 1 < \sigma$, *then the final outcome is indeterminant on the basis of qualitative information alone. However for every* $\sigma_0 < 1$, *there exists a* $\eta(\sigma_0) > 1$; $\partial\eta(\sigma_0)/\partial\sigma_0 < 0$ *so that if* $\eta \geq \eta(\sigma_0)$, *the high wage earners will live farther away from the center than low wage earners. In the same way for every* $\eta_0 < 1$, *there exists a* $\sigma(\eta_0) > 1$; $\partial\sigma(\eta_0)/\partial\nu_0 < 0$, *so that* $\sigma > \sigma(\eta_0)$, *then again high wage earners will reside farther away than low wage earners.*

V. Conditions under which the Substitution and Income Effects Hold

Recent literature dealing with the relative location of different income groups has taken into account only the income effect. Muth and Mills, for instance, by not including time in consumption have implicitly assumed $\pi_1 = \pi_2$. Their results, reflecting situations for which the income elasticity η is the only determining factor, are consistent therefore with the three entries along the second row in Table 1. Beckmann and Montesano have assumed in addition a utility function with $\eta = 1$, and thus their results are equivalent to the special indifference case as stated in part c of Corollary 3 above (or the zero entry in Table 1).

We may consider the wage effect to be a measure of the market productivity of the worker. If when market productivity increases, home productivity increases as well, then π, the cost of the consumption commodity, may not change with w. In this case, since $\partial\pi/\partial w = 0$, the substitution effect vanishes and the income effect is the sole determinant of residential location. This result is consistent with the traditional approach as argued by Muth and by Mills. In this case, high wage earners will locate in the outer ring if the income elasticity of housing η is greater than unity, and will locate in the inner residential ring if η is less than unity.

The relationship between market and home productivity depends upon the causal structure of those differences. According to Robert Michael, a high correlation between the two productivities is expected if the difference in wage rates reflects personal ability or general training and schooling. Market-specific training, discrimination, or random variation of wages, however, would lower the correlation and bring about strong substitution effects.

VI. Adjustments in Response to Further Household Characteristics

The formulation of the model is now extended to cover differences in household size and composition. The budget constraint (7′) is generalized as follows:

$$(32) \quad RH + \pi Z = n(1 - D)w + mw' + cw'' + v$$

where n is the number of family members in the labor force; w their wage rate; m is adult members not in the labor force; w' is the unit value of their time valued as a shadow price; and c, the number of children present in the household with w'' the unit value of their time. The variables n, m, c, w, w', w'', may be viewed as vectors if further breakdowns are desired.

To see the modification implied by this generalization in our main results, substitute (32) for (7′) and proceed with the same analysis, and calculations as in the simple model (Section III). Instead of (14), the generalized version of this equilibrium condition becomes

$$(33) \quad R' = -nw/H$$

By substituting (33) into (32) and rearranging,

$$(34) \quad -R' = R/(\alpha - D)S_H$$

where

$$(35) \quad \alpha = 1 + mw'/nw + cw''/nw + V/nw$$

Comparing the bid-rent functions of two population groups ($i = 1, 2$) at the intersection point ($R_1 = R_2 = R$ and $D_1 = D_2 = D$),

$$(36) \quad |R_1'| - |R_2'| = R\left[\frac{1}{(\alpha_1 - D)S_{H_1}} - \frac{1}{(\alpha_2 - D)S_{H_2}}\right]$$

Equation (36) is a generalization of (21) allowing for differences in family composition and labor force participation of its members. Without such differences, $\alpha_1 = \alpha_2 = 1$ and all the results obtained in Corollaries 2 and 3 follow straightforwardly. If differences in family characteristics do exist, $\alpha_1 \neq \alpha_2$, and further implications arise.

For example, let us consider the effect of a larger number of earners in the household on its relative location. Consider a typical case of two groups ($i = 1, 2$) of husband-wife families assumed to be identical in all respects except that in group one ($i = 1$), two members are employed in the CBD, whereas in the second group ($i = 2$) only one is in the labor force.

From (35)

$$(37) \quad \alpha_1 = 1 + \frac{c_0 w''}{2w} < 1 + \frac{w'}{w} + \frac{w''}{w}c_0 = \alpha_2$$

Substitution of (37) into (36) results in the following corollary:[6]

[6]Let D be the intersection point of the two bid rents. If both households have exactly the same characteristics, they must be on the same indifference curve. This implies that $w(1 - D) < w' < w$ so that $\pi_1 > \pi_2$. Equation (36) at D can be written as follows:

$$|R_1'| - |R_2'| = R\left[\frac{1}{(\alpha_1 - D)}\left(\frac{1}{S_{H_1}} - \frac{1}{S_{H_2}}\right) + \frac{1}{S_{H_2}}\left(\frac{\alpha_2 - \alpha_1}{(\alpha_1 - D)(\alpha_2 - D)}\right)\right]$$
$$= R\left(\frac{1}{\alpha_1 - D}\Delta s + \delta\right)$$

where $\delta = \dfrac{1}{S_{H_2}}\left(\dfrac{\alpha_2 - \alpha_1}{(\alpha_1 - D)(\alpha_2 - D)}\right) > 0$

Δs depends on the elasticity of substitution σ alone: the income elasticity of housing η has no effect at all. Corollary 4′ can now replace Corollary 4:

COROLLARY 4′: *Let us consider two households iden-*

COROLLARY 4: *Households of working wives will reside closer to the CBD than households of nonworking wives, unless the share of housing consumed by the former is markedly larger than the share consumed by the latter.*

Corollary 5 follows in much the same way.[7]

COROLLARY 5: *Larger families will reside farther away from the center than smaller ones, unless the share of housing consumed by the latter is markedly larger than the share consumed by the former.*

In practice, the male is the provider in most single earner families. Therefore, the implications of Corollary 4 are that if shares are similar, the proportion of women employed will be higher among those residing near the *CBD* than those farther away. Indeed, empirical findings by Kain indicate that higher proportions of female *CBD* workers in Detroit (1953) resided in nearby residential rings than did the proportions of male *CBD* workers. Similarly, the findings by Rees and Shultz indicate that the three predominantly female occupations show the shortest mean distance traveled to work among twelve selected occupations in Chicago (1963).

The empirical findings of both Kain and Muth directly corroborate Corollary 5. A positive correlation exists between family size and the distance of residences from the *CBD*.

The intuitive appeal of the findings in Corollaries 4 and 5 is also apparent. There is a tradeoff between commuting costs and benefits from housing services, and while the costs of added distance from the *CBD* are related basically only to number of wage earners, the benefits from additional housing services if shares are similar, are related to total family size. The existence of sizeable moving costs, however, indicates that households will make their location decisions according to planned family size in some foreseeable future rather than the *actual* number at any given moment.

Equation (35) indicates that a higher imputed price of children time w'' will result in a greater α, so that distance from center and w'' are positively related. Because the value of childrens' time tends to increase with age,[8] the theory also suggests that households with older siblings would live farther away—unless sizeable moving costs again retard or preclude such movement.

Finally, because differences in intergenerational preferences will produce permanent differences in the imputed childrens' value of time w'', families with a higher preference for child quality would tend to reside farther away from the center. In fact, suburbs have better educational services than their inner cities. Traditionally family migration to the suburbs has been explained by the desire for good education for children. The causation suggested by our argument clearly runs in the opposite direction: it ascribes the better educational services to the demand for such services by the typical population that would reside in the suburbs anyway.

tical in all characteristics, except that one has two earners and the other only one. Then there exists a $\sigma_0 > 1$ so that if σ, the elasticity of substitution, is smaller than σ_0, the family with two earners will reside closer to the CBD. If $\sigma > \sigma_0$ this family will reside farther away from the center. If $\sigma = \sigma_0$, both households will be indifferent about their relative locations.

[7]In the cases where there are differences in household size, the conditions for relative locations cannot be described in terms of elasticities, because the household consumption production functions then differ. The difference in the respective prices of Z cannot be determined.

[8]The major use of children's time in modern societies, particularly in urban areas where child employment is very limited, is in producing human capital. The productivity of a person in this activity is believed to be positively correlated at each given point of time with previously accumulated human capital (see Yoram Ben-Porath). In this respect, families would tend to value the time of older children more than that of younger offspring.

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